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Hexavalent chromium in house dust — A comparison between an area with historic contamination from chromate production and background locations

Alan H. Stern^{a,*}, Chang Ho Yu^b, Kathleen Black^b, Lin Lin^b, Paul J. Liroy^b, Michael Gochfeld^b, and Zhi-Hua (Tina) Fan^b

^aOffice of Science, New Jersey Department of Environmental Protection, 428 E. State St., Trenton, NJ 08625, United States

^bDepartment of Environmental and Occupational Medicine, UMDNJ-Robert Wood Johnson Medical School and Environmental and Occupational Health Sciences Institute, 170 Frelinghuysen Road, Piscataway, NJ 08854, United States

Abstract

In contrast to Cr^{+3} , Cr^{+6} is carcinogenic and allergenic. Although Cr^{+6} can occur naturally, it is thought that most soil Cr^{+6} is anthropogenic, however, the extent of Cr^{+6} in the background environment is unknown. Cr^{+6} -containing chromite ore processing residue (COPR) from chromate manufacture was deposited in numerous locations in Jersey City (JC), New Jersey. In the 1990's, significantly elevated concentrations of total Cr ($\text{Cr}^{+6} + \text{Cr}^{+3}$) were found in house dust near COPR sites. We undertook a follow-up study to determine ongoing COPR exposure. We compared Cr^{+6} in house dust in JC to selected background communities with no known sources of Cr^{+6} . Samples were collected from living areas, basements and window wells. Cr^{+6} was detected in dust from all JC and background houses. In the JC homes, the mean ($\pm$ SD) Cr^{+6} concentration for all samples was 3.9 ± 7.0 $\mu\text{g/g}$ (range: non-detect–90.4 $\mu\text{g/g}$), and the mean Cr^{+6} loading was 5.8 ± 15.7 $\mu\text{g/m}^2$ (range: non-detect–196.4 $\mu\text{g/m}^2$). In background homes, the mean Cr^{+6} concentrations of all samples was 4.6 ± 7.8 $\mu\text{g/g}$, (range, 0.05–56.6 $\mu\text{g/g}$). The mean loading was 10.0 ± 27.9 $\mu\text{g/m}^2$ (range, 0.22–169.3 $\mu\text{g/m}^2$). There was no significant difference between Cr^{+6} dust concentrations in Jersey City and background locations. Stratification by sample location within houses and sampling method gave similar results. Samples exceeding 20 $\mu\text{g/g}$ were obtained only from single wood surfaces in different homes. Lower concentrations in window well samples suggests transport from outside is not the major source of indoor Cr^{+6} . Landscaping and groundcover may influence indoor Cr^{+6} . There appears to be a widespread low level background of Cr^{+6} that is not elevated in Jersey City homes despite its historic COPR contamination. It is possible that house dust, in general, is a source of Cr^{+6} exposure with potential implications for persistence of chromium allergic contact dermatitis.

Keywords

Chromium; Hexavalent chromium; Cr^{+6} ; Dust; Dust loading; COPR; Chromate; Exposure assessment; Chromium waste

1. Introduction

Chromium is an unusually challenging element in the context of environmental health assessment. Trivalent chromium (Cr^{+3}) is an essential trace element while hexavalent chromium (Cr^{+6}) is a human respiratory (ATSDR, Agency for Toxic Substances Disease Registry, 2000) and ingestion carcinogen (NTP, National Toxicology Program, 2008) and a contact allergen causing widespread sensitivity (Stern et al., 1993). Thus, it is important to distinguish the two forms in the environment. Depending on redox conditions, there can be interchange between the two states in the environment, in the human body, and in the laboratory (Gochfeld 1991). Most of the naturally occurring Cr is in the trivalent form (Cr^{+3}), and conversion of Cr^{+3} to Cr^{+6} is generally not thermodynamically favorable under natural environmental conditions except under oxidizing conditions such as those provided by high levels of manganese dioxide in the soil. (ATSDR, Agency for Toxic Substances Disease Registry, 2000; Bartlett 1991). In contrast, while Cr^{+6} has been found to occur naturally in isolated environments (Oze et al., 2007), it is generally thought that most of the Cr^{+6} found in soil results from specific anthropogenic sources including the processing of chromite ore to produce chromate, the use of Cr^{+6} in plating, anti-corrosion treatment, and the improper disposal of the waste from these processes. Elevated levels of total Cr were detected in household dust in proximity to Cr^{+6} -containing chromite ore production waste sites (Lioy et al., 1992; Freeman et al., 1997), however, it is not known to what extent Cr^{+6} may occur in the background environment independent of such specific uses and sources. Improved analytic techniques now allow Cr^{+6} to be measured with precision.

One well known specific source of Cr^{+6} in the environment is the slag from chromate production in which trivalent chromite ore is roasted under oxidizing conditions and the resulting Cr^{+6} is extracted. The slag material remaining after the extraction can contain variable amounts of un-extracted Cr^{+6} , and is referred to as chromite ore processing residue (COPR). During the first three quarters of the twentieth century, three major chromate production facilities in Hudson County, New Jersey deposited waste slag material in numerous locations, particularly in Jersey City, New Jersey. Some of this material migrated from its original locations and entered residential and commercial buildings through surface and groundwater seepage (Burke et al., 1991). Studies conducted in Jersey City, during the 1990's found that the concentration of total Cr ($\text{Cr}^{+6} + \text{Cr}^{+3}$) in house dust was significantly elevated in houses within 1 or 2 blocks of known chromate production waste sites (Lioy et al., 1992; Freeman et al., 1997). After the nearby waste sites were remediated, the concentration of total Cr in dust in the adjacent homes rapidly declined to background levels (Freeman et al., 1995; Freeman et al., 2000). Furthermore, prior to remediation of these waste sites, the level of Cr in urine of the residents in Jersey City was significantly associated with the concentration of total Cr in their house dust (Stern et al., 1992; 1998). Chromate production waste contains both Cr^{+3} ore and un-extracted Cr^{+6} (ES&E

(Environmental Science and Engineering Inc.), 1989). Therefore, it is most likely that the observed associations between proximity to known chromate production waste sites and total Cr in house dust reflected the presence of Cr⁺⁶ as well as Cr⁺³.

Despite remediation of most of the known COPR sites in Jersey City in the 1990's and 2000's, residents still expressed concern that incompletely remediated, interim remediated, or, as yet, undiscovered COPR waste sites might still present a continuing source of exposure to Cr⁺⁶. In 2006, in response to these concerns, we undertook a follow up study to determine whether Cr⁺⁶ levels in house dust provided evidence of ongoing exposure from chromate production waste. Given advances in analytical chemistry, it was feasible in this study to directly measure Cr⁺⁶ in house dust (NJDEP, New Jersey Department of Environmental Protection, 2008). We report here on the levels of Cr⁺⁶ measured in house dust in Jersey City neighborhoods and compare those results to selected reference communities outside of Jersey City with no known source of or exposure to COPR that are assumed to represent the background with respect to Cr⁺⁶ in house dust. More specifically, we investigate the null hypothesis that Cr⁺⁶ in house dust occurs at the same levels in Jersey City homes (JC) as in homes in New Jersey locations (background) with no history of COPR waste.

2. Methods

2.1. Site selection

2.1.1. Jersey City locations—Location selection was based on a combination of targeted sites and areas of community concern. Fig. 1 presents a map of Jersey City showing the known COPR waste sites and the sites selected for residential house dust sampling. Droyers Point is a housing development that was built on and around a 28 acre COPR waste site that received a permanent cap. It is also close to a cluster of other sites including the large Roosevelt Drive-In site that, at the time of the sampling, had received only an interim cap and was undergoing remediation to remove waste down to 10–12 feet below the surface. The Garfield Avenue location is adjacent to a large waste site that had received an interim cap, but was not being remediated at the time of sampling. The Garfield Avenue neighborhood also encompasses a tight cluster of previously remediated waste sites. The Lafayette Ave. location is bordered by several previously remediated sites as well as several suspect sites that were undergoing investigation. Two other locations were identified largely on the basis of community concern. Freedom Place borders a single, previously remediated site. Society Hill is a housing development that was constructed in conjunction with Droyers Point and is approximately a half mile from the Roosevelt Drive-In site.

2.1.2. Background locations—Houses in New Brunswick, New Jersey and three surrounding towns were sampled as background locations. Based on the New Jersey Department of Environmental Protection's (NJDEP) Toxic Release Inventory (TRI) database, none of these areas contains or is within a mile of a known source of chromium emission or historic contamination.

2.1.3. Study recruitment—Although specific areas in Jersey City were targeted, all Jersey City residences were eligible for the study. Participants in Jersey City were recruited

through direct mailing in targeted areas, contacts with neighborhood block associations, and presentations at community meetings organized by local officials. For the background locations, information was distributed to residents in New Brunswick and adjacent areas by posting study flyers in public locations and by word-of-mouth in the University community.

2.1.4. Sample collection—Where possible, samples were collected in three locations in each house with one sample from each of the following household area categories: window well, living area (living room, bedroom, dining room, etc.) and basement. Surfaces were sampled preferentially using the LWW sampler (Liroy et al., 1993) with pre-weighed polyester drain disc filters (GE Water and Process Technologies, Feasterville, PA) and a 150 cm² template. When the LWW sampler could not be used due to insufficient space or an irregular surface texture, samples were collected on the same type of pre-weighed filters using a freehand wipe over a pre-measured area. If a surface contained too much dust to be reliably collected on a filter, the dust was collected using a 1-inch disposable paint brush by sweeping the pre-measured surface area into disposable weighing tray that was then emptied into a pre-weighed Ziploc bag.

Because of the “destructive” nature of dust removal, true duplicate wipe samples could not be collected. Splitting filters would not produce true duplicates due to a non-uniform distribution of dust across the filter. Instead, three side-by-side samples were collected (Freeman et al., 1996). As appropriate, one set of side-by-side samples was used for “duplicate” Cr⁺⁶ analyses and the remaining sample was used for total Cr analysis. Variability in side-by-side samples incorporates the variability of Cr deposition across a given surface as well as variability in the analytical method.

A short questionnaire about the home, including questions about the age of the home, ventilation, and renovations, was administered. Questions were asked about renovations that involved the removal or replacement of drywall as well as renovations such as painting. In Jersey City, if the Cr⁺⁶ concentration in any samples exceeded 20 µg/g, an attempt was made to repeat the sample collection from the same surface and to collect additional samples in the same area in the home. No repeat samples were collected for the background locations.

2.1.5. Sample analysis—Sample processing and analysis procedures for sample filters are presented in detail elsewhere (NJDEP, New Jersey Department of Environmental Protection, 2008). For sweep samples, 0.2–0.4 mg of sample were used for analysis. For the analysis of Cr⁺⁶, samples were sonicated in 5 mL of dilute nitric acid (pH=4 HNO₃). The recovery and stability of Cr⁺⁶ with this method was evaluated by spiking enriched isotope ⁵⁰Cr⁺³ and ⁵³Cr⁺⁶ on blank filters (n=4). The recovery of ⁵⁰Cr⁺³ and ⁵³Cr⁺⁶ were 95±10 % and 90±6 %, respectively. The average conversion rate was <5% in either direction. Spiking of the sample matrices with these isotopes resulted in inconsistent recovery of both isotopes. The reason for this was unclear. Sample extractions were analyzed for Cr⁺⁶ by an ion chromatograph coupled plasma mass spectrometer (IC-ICPMS). A CG5A guard column was used to separate Cr⁺⁶ from other chromium species. An analytical detection limit (ADL) of 0.2 ng was obtained based on 3 times the standard deviation of seven replicate injections of the lowest level Cr⁺⁶ calibration standard (0.5 ng/

mL). A certified Cr^{+6} soil material SQC012 (R.T. Corporation, Laramie, WY) was analyzed as a check on the accuracy and precision of the analytical method.

2.1.6. Data analysis—Statistical analyses were carried out using SAS 9.1 (SAS Institute Inc., Cary, NC). Because the analytical results obtained from the samples diverged significantly from normality, statistical comparisons of Cr concentration and loading were conducted using non-parametric tests, the Wilcoxon–Mann–Whitney U-test (MWU) and Kruskal–Wallis one way analysis of variance, with a Monte Carlo estimate of an exact p-value. Only one sample had a concentration of Cr^{+6} that was less than ADL. A value of one-half of the ADL was assumed for that Cr^{+6} concentration.

3. Results

Table 1 presents the characteristics of the homes sampled in Jersey City and the background locations. In Jersey City, a total of 292 dust samples were collected from 100 homes between 11/15/06 and 4/18/08. Cr^{+6} was detected in samples collected in all of the homes. Fifty side-by-side house dust were compared on the basis of Cr^{+6} concentration. The mean $\pm$ SD percent difference between the side-by-side samples is $36 \pm 33\%$ $\mu\text{g/g}$. The mean ($\pm$ SD) Cr^{+6} concentration in all Jersey City samples was 3.9 ± 7.0 $\mu\text{g/g}$, with a range of non-detect to 90.4 $\mu\text{g/g}$. The mean $\pm$ SD Cr^{+6} loading measured in all Jersey City samples was 5.8 ± 15.7 $\mu\text{g/m}^2$ with a range of non-detect to 196.4 $\mu\text{g/m}^2$. The differences among the six sampling locations in Jersey City were significant for Cr^{+6} concentration and loading (Kruskal–Wallis $p < 0.0001$ for both measures). For the background locations, 60 dust samples were collected from 20 homes between 4/28/08 and 9/20/08. As was the case in Jersey City, Cr^{+6} was detected in all the homes. Sixteen side-by-side house dust samples were analyzed for Cr^{+6} concentration. The mean percent difference, $37 \pm 35\%$ $\mu\text{g/g}$, was remarkably similar to the difference seen with the side-by-side Jersey City samples. The mean ($\pm$ SD) Cr^{+6} concentrations of all samples in the background locations was 4.6 ± 7.8 $\mu\text{g/g}$, with a range of 0.05 to 56.6 $\mu\text{g/g}$. The mean loading was 10.0 ± 27.9 $\mu\text{g/m}^2$ with a range of 0.22 to 169.3 $\mu\text{g/m}^2$. Table 2 summarizes the Cr^{+6} concentration and loading data in Jersey City and background location. For the pooled household dust samples (combining the data from all household area categories, sampling methods and surfaces), there was no significant difference between the Cr^{+6} concentrations from Jersey City and the background locations (MWU $p = 0.11$), and background samples were actually slightly higher Cr^{+6} loadings, however, were significantly elevated in the background locations compared to Jersey City ($p = 0.04$). The differences were similar when we compared the Jersey City and background locations on the basis of samples pooled within a household and then averaged by household. For the arithmetically averaged household dust samples, there was no significant difference (MWU $p = 0.15$) between the Cr^{+6} concentrations from Jersey City ($N = 100$) and the background locations ($N = 20$), however Cr^{+6} loadings were elevated in the background locations compared to Jersey City (MWU $p = 0.02$).

Considering all household location categories (i.e., window wells, living areas and basements) together, collection using the LWW method accounted for most of the samples (73%). Freehand wipes accounted for 25% of the samples and sweep samples accounted for 2%. There was a significant difference in the Cr^{+6} concentration among the samples

collected by each method, with the LWW samples having a median concentration (3.2 $\mu\text{g/g}$) more than 8 times that for the freehand samples (0.37 $\mu\text{g/g}$) and 24 times that of the sweep samples (0.13 $\mu\text{g/g}$). While this may partly reflect the efficiency of dust collection by each of these methods, the comparison is complicated by the fact that the sample method and surface material varied by household area category. The window well samples were predominantly collected from vinyl surfaces using either freehand wipes (58%) or LWW samplers (35%), while living area samples were predominantly collected on wood (63%) and laminate surfaces (26%) using the LWW sampler.

To control for the effects of sample collection method, material, and category, we conducted two additional analyses. First, in order to assess Cr^{+6} concentration and loading among the various locations within and between Jersey City and the background locations on a comparable basis, we compared Cr^{+6} levels in samples taken from wood and laminate surfaces in living areas collected by the LWW sampler. Wood and laminate surfaces were pooled since there was no significant difference in their Cr^{+6} dust concentrations in Jersey City (MWU $p=0.37$). Second, we similarly compared Jersey City and the background locations on the basis of window well samples on vinyl surfaces. Because the mass of dust collected from the window sills by the freehand method was much larger than the mass collected by the LWW method and because no freehand window well samples were collected in the background homes, we further restricted this comparison to window well samples collected using the LWW sampler. These comparisons are presented in Tables 3 and 4. Within Jersey City, there was a significant difference in both concentration (Kruskal–Wallis $p=0.0002$) and loading ($p<0.0001$) among the various areas for the LWW-living area-wood/laminate samples. The maximum difference in mean concentration among the locations on the basis of concentration was less than a factor of three. Likewise, for the window well-vinyl surface-LWW samples, there was no significant difference in concentration (MWU $p=0.19$) and loading (MWU $p=0.32$) among the Jersey City locations. There was an insufficient number of samples to support meaningful comparisons among the background locations stratified in this manner. Comparing Jersey City and the background locations on the basis of LWW-living area samples on wood/laminate surfaces, there was no significant difference in either concentration (MWU $p=0.72$) or loading (MWU $p=0.08$). For the window well-vinyl surface-LWW samples, the concentration was significantly higher (MWU $p=0.0028$) in the background locations, but the loading was not significantly different (MWU $p=0.77$).

3.1. Associations with land use

In an effort to elucidate possible sources of Cr^{+6} in the house dust, we investigated whether characteristics of the land immediately surrounding the houses were associated with Cr^{+6} in house dust. Significant associations were observed in two Jersey City locations, Lafayette, and Other (i.e., the non-location-specific Jersey City category). In the Lafayette area, the mean and maximum Cr^{+6} concentrations were higher in homes without grass in the yard (WMU $p=0.07$ and $p=0.02$, respectively). Mean and maximum loadings, however, were not associated with the absence of grass in the yard ($p>0.1$). A possibly related observation was that homes with an outside dirt area had higher mean and maximum concentrations and loadings than homes with no outside dirt area ($p<0.03$ for both). In contrast, among the

homes in the other locations, having grass in the yard was associated with higher mean and maximum loadings ($p=0.01$ for both). In addition, in the other homes, having a garden was associated with higher mean and maximum concentrations of (MWU $p=0.02$ and $p=0.04$, respectively), as well as higher mean (but not maximum) loadings ($p=0.04$). No associations were observed between Cr^{+6} in house dust and the characteristics of the land immediately adjacent to the house in the background locations.

3.2. Associations with housing characteristics and materials

In Jersey City, the age of the house was significantly correlated with the dust concentration and loading of Cr^{+6} on wood surfaces in living area (Spearman, $r=0.33$, $p=0.002$ and $r=0.39$, $p=0.0002$, respectively). In background locations, a stronger association was observed between house age and loadings on wood surfaces in living area ($r=0.75$; $p=0.01$); however, the association was not significant for concentrations ($r=0.04$; $p=0.92$). Since the majority of samples on wood surfaces were taken in living areas in Jersey City (63%) and background locations (60%), this result may be more informative about the nature of wood surfaces than specifically about the living areas. The possible influence of wood surfaces is further suggested by the observation that all samples (six in Jersey City and one in the background location) exceeding a Cr^{+6} concentration of $20 \mu\text{g/g}$ were collected from wood surfaces. In each case, only a single sample within the home exceeded the $20 \mu\text{g/g}$. Upon repeat sampling of five of these elevated- Cr^{+6} -concentration surfaces in the Jersey City homes (the sixth surface had been discarded before the repeat visit), only the two surfaces with the highest concentrations (37 and $90 \mu\text{g/g}$) were once again found to exceed $20 \mu\text{g/g}$. Both surfaces were stained wood furniture. Within each of these homes, the high concentration was restricted to the single piece of wood furniture. Samples collected from nearby surfaces in the same room were below $20 \mu\text{g/g}$. The association of Cr^{+6} concentration with wood and house age in Jersey City, but not in the background locations may reflect the difference in median house age in Jersey City (25 years) versus the background locations (60 years). Cr^{+6} that may be contained in wood furniture and/or structural materials might be more readily released with the aging and/or wear of the wood over time.

4. Discussion

This is the first study that has specifically measured Cr^{+6} in house dust. The rationale for the study was to evaluate possible indoor contamination from outdoor sources reflecting chromium waste contamination. We found what appears to be a widespread low level background of Cr^{+6} . This background does not appear to be limited to or quantitatively different in Jersey City despite its known history of contamination by chromate production waste. We found comparable levels of Cr^{+6} in house dust in the other urban locations with no history of chromate waste and no known specific sources of Cr^{+6} contamination. This study was not specifically designed to identify sources of Cr^{+6} in house dust. However, several lines of evidence suggest that internal household sources are likely to make a significant contribution to Cr^{+6} in house dust. In Jersey City and the background locations, the highest concentrations of Cr^{+6} were all found on individual wood surfaces in different homes. It has been reported that Cr^{+6} was very commonly used in wood stains especially in the period between 1910 and 1970 and that Cr^{+6} tended to be found in the crystalline residue

that formed on the surface of the stained wood on drying (Ruetze et al., 1994). Although suspended Cr^{+6} -containing particles from outdoor sources could enter through windows, the concentration of window well wipe samples was consistently lower than the concentration found in other household locations. Since window well dust largely reflects material originating outside the house, this observation suggests that airborne particulate transport from the outside environment is not the major source of the Cr^{+6} on the indoor surfaces. Nonetheless the data suggest that some aspects of landscaping and groundcover may influence indoor dust levels of Cr^{+6} . We note that some soil amendments contain biosolids (i.e., processed sewage sludge). It would be worthwhile to investigate such material for the presence of Cr^{+6} resulting from industrial and commercial discharges. There are currently no specific data on atmospheric deposition of Cr^{+6} in the outdoor ambient environment. Measurement of ambient air for Cr^{+6} may need to be considered as part of an overall sampling strategy for determining the sources of indoor Cr^{+6} in indoor dust. It is also possible for Cr^{+6} -containing particles to enter the household by being transported on shoes, clothing and pets.

With respect to Jersey City, we found no significant difference between Cr^{+6} concentrations in Jersey City and those in the urban background locations except for samples taken on vinyl window well surfaces where the concentration in the background locations was significantly elevated above that in Jersey City. While there are no data to suggest a contribution from residual chromate production waste to the Cr^{+6} we observed in the house dust in Jersey City, the current data do not rule out some contribution from chromate production waste.

Results for Cr^{+6} loading were more variable than those for Cr^{+6} concentration. This is not surprising since Cr^{+6} dust loading is a function both of the concentration of Cr^{+6} in the particulates and of the amount of particulate/dust that is present on a given surface (i.e., dustiness). For a given source of Cr^{+6} , Cr^{+6} concentration in the dust is a characteristic of the dust that reflects the extent to which Cr^{+6} is present in the source material of the dust. Dust accumulation on a surface, on the other hand, is related to a number of factors other than the source of the dust such as household cleaning practices, the extent to which windows are open and the presence or absence of outside ground cover and general neighborhood dustiness. Although dust contributions from sources unrelated to the source of the Cr^{+6} can dilute the concentration of the Cr^{+6} in the overall household dust, conditions that result in differences in dust deposition and/or retention at two different locations can result in significant differences in the loading of Cr^{+6} between those locations even if their sources of Cr^{+6} are identical. Therefore, consistent with Lioy et al. (2002), we believe that concentration rather than loading is the more appropriate metric for comparing source-related differences among locations, while loading is more directly related to exposure. Because our primary goal in this study was to determine whether there were ongoing sources of Cr^{+6} exposure in Jersey City compared to the background locations, we focused our comparisons on Cr^{+6} concentration rather than loading. We note, however, that in any given house, the potential for exposure to contaminants in household dust is likely to be more closely related to dust loading rather than concentration.

This study does not provide evidence that the potential for exposure to Cr^{+6} in house dust in Jersey City is different from that in the other urban areas in New Jersey that we investigated.

It does, however, raise the interesting possibility that house dust, in general, could be a source of Cr⁺⁶ exposure. The USEPA classifies Cr⁺⁶ as a known human carcinogen by inhalation (USEPA, United States Environmental Protection Agency, 1998). A recent study by the National Toxicology Program (NTP) concluded that Cr⁺⁶ is carcinogenic to rats and mice by ingestion (Stout et al., 2009). Exposure to the levels of Cr⁺⁶ in house dust encountered in this study could, therefore, contribute to the background burden of environmental cancer risk. However, a more salient environmental health consideration may be the potential of Cr⁺⁶ in house dust to contribute to the incidence of Cr⁺⁶ allergic contact dermatitis (ACD). A meta-analysis of nine separate patch test studies indicated that approximately 10% of subjects with an existing Cr⁺⁶ allergic sensitization are susceptible to eliciting symptoms of Cr⁺⁶ ACD when exposed dermally to 10 ppm Cr⁺⁶ in solution (Stern et al., 1993). Cr⁺⁶ ACD is characterized by its persistence (Stern et al., 1993). This has been attributed to the presence of Cr⁺⁶ in common materials especially cement, some household cleaning products and industrial coatings. However, the current findings suggest the possibility that house dust, in general, may be a contributing factor to this persistence.

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Abbreviations

ACD	allergic contact dermatitis
COPR	chromite ore processing residue
JC	Jersey City, New Jersey
MWU	Mann–Whitney U-test
NJDEP	New Jersey Department of Environmental Protection

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Fig. 1.
Location of known chromate production waste sites in Jersey City (and surrounding area) in relation to recruitment areas for this study.

Table 1

Housing characteristics in Jersey City and “background” locations.

Characteristics	Jersey City	Background locations	
	N (% of total)	N (% of total)	Don't know
House type	N=100	N=20	1
Single family	36 (36)	14 (74)	
Town/row house	57 (57)	2 (10)	
Multi-unit	7 (7)	3 (16)	
Median house age	25 years	60 years	8
Yard material			
Grass	76 (76)	19 (95)	
Dirt	26 (26)	4 (20)	
Mulch	26 (26)	7 (35)	
Have a basement	44 (44)	17 (85)	
Home with inside smoker	10 (10)	2 (10)	
Any renovation within past 6 months	44 (44)	4 (20)	

Concentration and loading of Cr⁺⁶ in house dust in Jersey City and background locations —all samples.

Table 2

Location	Number of samples	Concentration (µg/g)			Loading (µg/m ³)		
		Mean	Std. Dev.	95th percentile	Mean	Std. Dev.	95th percentile
Jersey City							
Drovers point	78	2.1	3.2	6.9	1.5	2.6	4.9
Freedom	24	6.6	9.2	32.1	8.1	7.1	20.6
Garfield	48	3.4	4.4	14.4	6.1	15.2	15.4
Lafayette	38	3.6	4.1	9.7	8.3	18.0	69.4
Society Hill	29	3.5	2.8	9.4	4.0	6.0	13.8
Other	75	5.6	11.1	17.3	8.8	24.3	23.5
All Jersey City samples	292	3.9	7.0	11.7	5.8	15.7	18.2
Background locations	60	4.6	7.8	13.4	10.0	27.9	33.1

Table 3

Concentration and loading of Cr^{+6} in house dust in Jersey City and background locations —LWW samples collected in living areas on wood and laminate surfaces.

Location	Number of samples	Concentration ($\mu\text{g/g}$)			Loading ($\mu\text{g}/\text{m}^3$)		
		Mean	Std. Dev.	95th percentile	Mean	Std. Dev.	95th percentile
Jersey City							
Droyers Point	39	3.4	3.2	13.1	39	1.4	6.1
Freedom	10	8.3	9.2	32.1	10	7.9	20.6
Garfield	23	5.1	4.4	14.4	23	3.8	11.6
Lafayette	14	5.3	4.1	9.7	14	8.8	69.4
Society Hill	21	3.8	2.8	7.5	21	2.8	11.1
Other	34	6.6	11.1	17.3	34	5.6	14.4
All Jersey City samples	141	5.0	7.0	13.1	141	4.2	12.3
Background locations	21	5.5	4.7	15.0	21	12.2	12.4

Table 4

Concentration and loading of Cr^{+6} in house dust in Jersey City and background locations collected in window wells on vinyl surfaces using the LWW sampler only.

Location	Number of samples	Concentration ($\mu\text{g/g}$)			Loading ($\mu\text{g}/\text{m}^3$)		
		Mean	Std. Dev.	95th percentile	Mean	Std. Dev.	95th percentile
Jersey City							
Droyers Point	2	0.1	0.1	0.2	0.5	0.3	0.7
Freedom	2	1.7	0.4	2.0	2.4	0.9	3.0
Garfield	4	1.1	1.2	2.5	2.6	2.9	6.5
Lafayette	6	0.3	0.2	0.7	1.4	1.5	3.8
Society Hill	1	0.2	NA	0.2	0.2	NA	0.2
Other	8	0.6	0.4	1.1	2.3	1.7	5.3
All Jersey City samples	23	0.6	0.7	2.0	1.9	1.8	5.3
Background locations	8	1.8	1.3	4.4	3.2	4.4	13.3