Health Consultation

ANALYSIS OF ORAL, ESOPHAGEAL AND
STOMACH CANCER INCIDENCE NEAR
CHROMIUM-CONTAMINATED SITES IN JERSEY CITY
(a/k/a Hudson County Chromium Sites)
JERSEY CITY, HUDSON COUNTY, NEW JERSEY

Prepared by:
New Jersey Department of Health and Senior Services
and
New Jersey Department of Environmental Protection

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Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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Prepared By:

New Jersey Department of Health and Senior Services
Environmental and Occupational Health Surveillance Program
and
New Jersey Department of Environmental Protection
Office of Science

Under cooperative agreement with the
U.S. Department of Health and Human Services
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Summary

Introduction

Based on community concerns, the New Jersey Department of Health and Senior Services (NJDHSS) and the New Jersey Department of Environmental Protection (NJDEP) released a Health Consultation in October 2008 that analyzed the relationship between historic exposure to chromium from chromium ore processing residue (COPR) sites and the incidence of lung cancer in Jersey City, Hudson County, NJ. COPR is known to contain hexavalent chromium, a known human lung carcinogen. One of the recommendations in that 2008 Health Consultation was to replicate the analysis for other cancers potentially related to chromium exposure.

In this Health Consultation, the incidence of malignant oral, esophageal and stomach cancers was evaluated in relation to the historic locations of COPR sites in Jersey City. Recent evidence indicates that hexavalent chromium may increase the risk of oral and certain gastrointestinal cancers.

Hudson County was a major center for chromium ore processing and manufacturing. Nearly three million tons of COPR was produced, and much of it was used as fill material in construction of residential and commercial sites in the 1950s and 1960s.

This investigation of the incidence of oral and selected gastro-intestinal cancer cases included those occurring among Jersey City residents in the 28-year period from 1979 through 2006. The New Jersey State Cancer Registry was used to determine the number of cancer cases occurring in the Jersey City population. This analysis includes a total of 739 oral cancer cases, 651 stomach cancer cases and 333 esophageal cancer cases. In addition, 80 small intestinal cancer cases were included in analyses of the incidence of combined cancer groupings.

The NJDEP used historic information on COPR sites to characterize areas of the city as to their potential for residential Cr^{+6} exposure in the past. Cancer incidence in areas of Jersey City with higher potential for past exposure was compared to cancer incidence in areas of Jersey City with no potential for residential exposure.

Conclusions

NJDHSS and ATSDR have reached the following conclusion in this Health Consultation:

Conclusion	*This investigation did not find evidence that residential proximity to historic COPR sites is associated with an increased risk of oral, esophageal or stomach cancers in the population of Jersey City, or of combinations of these cancers with small intestine cancer.*
Basis for Conclusion	Oral and stomach cancer incidence rates were not elevated in Jersey City areas close to the locations of COPR sites. While esophageal cancer incidence rates among males were higher in exposed areas, rates did not seem to increase with increasing potential for exposure, and there was considerable uncertainty about the magnitude of the rate ratio. There were too few cases of small intestine cancer for separate analysis, but analyses of this cancer type in combination with other cancers did not show increased rates.
Next Steps	Since a significant amount of remediation of the chromium slag has occurred, the historic potential exposures noted in this investigation do not represent the current conditions in the city. However, it is recommended that efforts to remediate COPR sites to limit human exposure to hexavalent chromium should continue.
For More Information	Questions about this Health Consultation should be directed to the NJDHSS at (609) 826-4984.

Purpose

In this Health Consultation, the incidence of malignant oral, esophageal and stomach cancers was evaluated in relation to the historic locations of chromium ore processing residue (COPR) in Jersey City, Hudson County, New Jersey. COPR is known to contain hexavalent chromium, a known human lung carcinogen and a possible carcinogen at these other anatomic sites. The three cancer incident types were analyzed for a 28-year period, 1979-2006.

Based on community concerns, the New Jersey Department of Health and Senior Services (NJDHSS) and the New Jersey Department of Environmental Protection (NJDEP) released a Health Consultation in October 2008 that analyzed the relationship between historic exposure to chromium from COPR sites and the incidence of lung cancer in Jersey City (ATSDR 2008a). The investigation found that lung cancer incidence was higher in populations living closer to COPR sites than in other parts of Jersey City. One of the recommendations in that 2008 Health Consultation was to replicate the analysis for other cancers potentially related to chromium exposure.

Background and Statement of Issues

Hudson County was a major center for chromium ore processing and manufacturing through much of the twentieth century; two of the three chromate production facilities in Hudson County were located in Jersey City. Nearly three million tons of COPR were produced by the three facilities and disposed of at numerous places in the County. COPR was sold or given away for use as fill material and used extensively in construction of residential and commercial sites, and was used to backfill demolition sites, road construction, building foundations, and wetlands (Burke et al. 1991).

More than 160 COPR disposal sites have been identified in Hudson County, including 136 sites in Jersey City. Concentrations of total chromium remaining in the disposed COPR ranged as high as 20,000 to 70,000 parts per million (ppm) (Burke et al 1991), with hexavalent chromium (Cr^{+6}) representing a variable proportion of the total chromium in the COPR. Much of the disposal of the COPR took place in the 1950s and 1960s, some of which was deposited in densely populated areas.

Cr^{+6} is known to be a human respiratory carcinogen with substantial epidemiologic evidence of an increased risk of lung cancer among exposed workers, including those engaged in chromate production (NTP 2005, ATSDR 2008b). In 2008, the National Toxicology Program released the final report of a carcinogenesis bioassay of oral exposure to hexavalent chromium in rodents. The study indicated that ingestion of Cr^{+6} in drinking water increased the risk of oral cancer in rats and small intestine cancers in mice (NTP 2008). A recent study of a Chinese population exposed to Cr^{+6} in drinking water provided evidence of an increased risk of stomach cancer (Beaumont et al. 2008).

In the early 1990s, the New Jersey Department of Health and Senior Services (NJDHSS) conducted exposure screening of over 2,000 workers and residents of Jersey City (and nearby cities) who worked or lived near COPR sites. The investigation found evidence of low levels of exposure to chromium among some participants living or working near COPR sites (NJDOH 1994; Fagliano et al. 1997).

It is important to point out that, at present, final or interim remedial measures have been implemented at all of the COPR sites in Jersey City. Final remediation has been completed at 51 sites in Jersey City, resulting in “No Further Action” determinations from NJDEP. Of these, 41 sites were remediated by complete excavation and off-site disposal of COPR. The remaining 10 sites were remediated by on-site containment of COPR with institutional and engineering controls.

Methods

Population

This investigation of cancer incidence in relation to historic chromium exposure included the entire population residing in Jersey City, Hudson County, in the period 1979 through 2006. Population counts for each census block group were determined from 1980, 1990, and 2000 U.S. Census Bureau data (Geolytics 2003). Populations in each of these years were aggregated into U.S. Census Bureau census block group boundaries as of the year 2000. Annual population estimates were calculated by interpolation and extrapolation of the population reported for each of the three census reporting years for each census block group and then summed over the 28-year period to create person-time estimates.

Cancer Case Ascertainment

The New Jersey State Cancer Registry (NJSCR) was used to determine the number of specific types of cancer cases occurring in the Jersey City population in the period 1979 through 2006. The first full year of NJSCR data collection was 1979. The NJSCR is a population-based cancer incidence registry covering the entire state of New Jersey. By law, all cases of newly diagnosed cancer are reportable to the registry, except for certain carcinomas of the skin. In addition, the registry has reporting agreements with the states of New York, Pennsylvania, Delaware, Maryland, North Carolina, and Florida. Information on New Jersey residents who are diagnosed with cancer in those states is supplied to the NJSCR.

For this Health Consultation, a "case" was defined as an individual who was diagnosed with a new primary malignant cancer of the following anatomic sites during the investigation time period while residing in Jersey City:

- oral cavity and pharynx cancers (SEER Site Recode 20010-20100);
- esophageal cancer (SEER Site Recode 21010);
- stomach cancer (SEER Site Recode 21020)
- small intestine cancer (SEER Site Recode 21030).

Oral, stomach and small intestine cancers were chosen because of evidence provided by recent animal and human studies (NTP 2008; Beaumont et al. 2008); esophageal cancer was selected because the esophagus is contiguous with the oral and stomach anatomic sites.

NJSCR cases identified only through search of death records or autopsy reports were excluded from this evaluation. Information on important cancer risk factors, such as genetics, personal behaviors (e.g., diet and smoking), or occupational history, is not available from the cancer registry.

Cases for each cancer type were aggregated by U.S. Census Bureau census block groups, based on the case's residence at the time of diagnosis. Block group location was determined for all Jersey City cases using the U.S. Census Bureau's on-line American Factfinder resource (U.S. Census Bureau 2009).

Chromium Exposure Categorization

Chromium exposure categorization methods are identical to those used in the previously released Health Consultation regarding lung cancer incidence in relation to COPR sites (ATSDR 2008a). Using historic information on the location of known COPR sites along with their contaminant levels, the NJDEP characterized the potential for residential Cr^{+6} exposure in Jersey City. The Appendix to this Health Consultation contains a detailed description of the NJDEP's chromium exposure categorization methods, which are briefly described below.

First, COPR sites were classified into categories based on measured or estimated Cr^{+6} concentrations. When site-specific data on Cr^{+6} were available, they were used directly to categorize the site. When only the total chromium contaminant level was known for a specific site, Cr^{+6} concentrations were estimated to be either 3% or 14% of the total chromium value. These percentages represent the average and upper end of the expected proportion of Cr^{+6} to total chromium based on existing data (ES&E 1989). (Note that only the analysis based on the estimate of 14% is presented in this report since the epidemiologic results were very similar.) Sites were characterized as falling into one of three categories: 1) measured or estimated Cr^{+6} concentration of 900 ppm or higher; 2) measured or estimated Cr^{+6} concentration less than 900 ppm; or 3) a known COPR site, but no available total or hexavalent chromium concentration.

A 300 foot buffer was then drawn around each of the COPR site property boundaries, and the proportion of the residential area in each census block group that fell within a 300 foot buffer of each of the Cr^{+6} concentration categories was calculated. The size of the buffer was chosen based on modeling of PM_{10} (particles with a mean diameter of 10 micrometers). The PM_{10} modeling showed that 300 feet was a reasonable buffering distance from site boundaries, representing a distance within which most particulate deposition would occur and ambient PM_{10} concentrations are substantially reduced.

For the epidemiological analysis, census block groups were aggregated into "exposure intensity groups" (none, low, or high) based on the proportion of the residential part of the block group within the 300 foot buffers around COPR sites. Census block groups were categorized as "none" if no residential part of the block group was intersected by a COPR site buffer. Four alternative definitions were considered for the "high" exposure intensity group based on varying proportions of the block group in buffered areas of COPR sites classified by the hexavalent chromium concentration categories. These four alternative high exposure intensity group definitions are:

1. any part of the residential area in a census block group fell within a Cr^{+6} buffer;

2. at least 10% of a residential area in the census block group was within a high ($\geq$900+ ppm) Cr^{+6} buffer, or at least 25% of a residential area was within any Cr^{+6} buffer;

3. at least 25% of a residential area in the census block group was within a high ($\geq$900+ ppm) Cr^{+6} buffer, or at least 50% of a residential area within any Cr^{+6} buffer;

4. at least 50% of a residential area in the census block group was within a high ($\geq$900+ ppm) Cr^{+6} buffer, or at least 75% of a residential area within any Cr^{+6} buffer.

These definitions, going from 1 to 4, are increasingly restrictive in the requirements for considering a census block group to have had historic potential for high Cr^{+6} exposure intensity. As the definitions become more restrictive, the number of census block groups that remain in the high exposure intensity category decreases. The population area defined as having an exposure intensity of "none" is the same across all four alternate definitions. In each definition, populations not classified as "none" or "high" are classified as "low."

Data Analysis

Poisson regression was utilized in the analysis of oral, esophageal, stomach and small intestine cancers and Cr^{+6} exposure in Jersey City. Cancer types were also grouped as 1) esophageal/stomach/small intestinal cancers and as 2) oral/esophageal/stomach/small intestinal cancers. For each cancer type or grouping, the incidence in each exposure intensity group in Jersey City over the entire exposure period (1979-2006) was compared to the incidence in the non-exposed or referent group in Jersey City during the same period.

Cancer type-specific incidence rate ratios (RRs) were computed for each exposure level in comparison to "none," by sex. A RR of 1 indicates that rates are equal; a RR > 1 means the rate is higher in the exposure group, and a RR < 1 means the rate is lower. Rate ratio estimates were computed using the Poisson regression model (Clayton and Hills 1993). Confidence intervals (95%) and p-values were generated for the RR estimates, to indicate whether the observed RR is statistically different from 1. RRs were adjusted for age group and the percent of the population below the poverty level. Epidemiologic analyses were conducted using Stata statistical software, version 9 (Stata 2006).

Results

Exposure Intensity Groupings

Table 1 summarizes the definition of each of the exposure intensity groups for the four alternate analysis methods along with the number of census block groups that fell into each group. Of the 161 block groups, 104 (65%) had no residential area within 300 feet of a COPR site, while 57 (35%) had any part of its residential area within 300 feet of a COPR (exposure grouping method 1). Of the 57 sites classified as having "any" exposure, the three remaining exposure grouping methods (2, 3 and 4) resulted in 29, 15 and 7 of the block groups classified as high exposure, respectively, with the remainder classified as low exposure. Figure 2 shows maps of the block group exposure intensity classifications based on the four alternate exposure categorization methods.

Table 2 provides additional detail regarding the percent of the residential areas of block groups within 300 feet of a COPR site with Cr^{+6} levels $\geq$900+ ppm, <900 ppm, and with unknown Cr^{+6} concentration.

Person-Years and Cancer Case Counts, 1979-2006

Table 3 presents the 28-year person-year estimates by each exposure intensity group. The total person-time for males was 3,150,135 years, including 2,027,803 person-years in block groups considered to have no residential exposure (64%), and 1,122,232 person-years with at least some residential exposure (36%). The total person-time for females was 3,372,258 years, including 2,154,773 person-years with no residential exposure (64%) and 1,217,485 person-years with at least some residential exposure (36%).

Over the 28-year evaluation period, there were 739 oral cancer cases (546 males and 193 females), 651 stomach cancer cases (364 males and 287 females), 333 esophageal cancer cases (234 males and 99 females), and 80 small intestinal cancer cases (36 males and 44 females) who were diagnosed in the Jersey City population, and who had sufficient address information to be assigned to the appropriate block group. (About 97% of all cases could be so assigned.)

Tables 4a and 4b presents the number of cases by cancer type for each exposure category. Table 4a includes oral cancer, esophageal cancer and stomach cancer; Table 4b includes case counts for the combined cancer groupings. The number of small intestine cancers was too small for separate analysis, but is included in the selected GI cancers.

Adjusted Rate Ratios

Tables 5 through 9 and Figures 3 through 7 present the rate ratios (RR) analysis for the five cancer types or groups analyzed. RRs are adjusted for age group and the percent of the population below the poverty level.

Oral Cancers

Table 5 and Figure 3 present the RR analysis results for malignant oral cancer. In general, RRs were close to 1.0, and none were found to be statistically significantly high or low. The RR for any exposure was 0.98 for males and 0.98 for females. The highest RR was for females in the high exposure group using the most restrictive exposure grouping method 4 (RR=1.38; 95% CI 0.75, 2.57); the RR for males in the same group was low (RR=0.65; 95% CI 0.37, 1.13).

Esophageal Cancers

Table 6 and Figure 4 present the RR analysis results for malignant esophageal cancer. The RR for males was statistically elevated in the "any" exposure group (RR=1.64; 95% CI 1.27, 2.12), and were elevated in both "low" and "high" exposure groups using each of the exposure grouping methods. For females, none of the RRs were found to be statistically significantly elevated for esophageal cancer. The RR for females in the "any" exposure group was not significantly elevated (RR=1.05, 95% CI 0.70, 1.59); in each of the other exposure grouping methods, the high exposure RRs were higher then the corresponding low exposure RRs, but no RR was significantly elevated.

Stomach Cancers

Table 7 and Figure 5 present the RR analysis results for malignant stomach cancer. RRs were generally close to 1.0, and none were statistically significantly high or low. The RR for any exposure was 1.06 for males and 1.10 for females. The highest RR was for females in the high exposure group using the most restrictive exposure grouping method 4 (RR=1.51; 95% CI 0.92, 2.49); the RR for males in the same group was low (RR=0.93; 95% CI 0.53, 1.62).

Esophageal/Stomach/Small Intestinal Cancers

Table 8 and Figure 4 present the RR analysis results for combined esophageal, stomach, and small intestine cancers. The RR for males was statistically elevated in the "any" exposure group (RR=1.26; 95% CI 1.08, 1.48); RRs were generally higher in the "low" than in the "high" exposure groups in each of the other exposure grouping methods. For females, none of the RRs were found to be statistically significantly elevated for these cancers. The RR for females in the "any" exposure group was 1.08 (95% CI 0.89, 1.32); the highest RR was for females in the high exposure group using the most restrictive exposure grouping method 4 (RR=1.41; 95% CI 0.92, 2.14).

Oral/Esophageal/Stomach/Small Intestinal Cancers

Table 9 and Figure 5 present the RR analysis results for combined oral, esophageal, stomach and small intestinal cancers. RRs for males were elevated in the "any" exposure group (RR=1.12; 95% CI 1.00, 1.27); RRs were generally higher in the "low" than in the "high" exposure groups in each of the other exposure grouping methods. The RR for females in the "any" exposure group was 1.05 (95% CI 0.89, 1.24); the highest RR was for females in the high exposure group using the most restrictive exposure grouping method 4 (RR=1.40; 95% CI 0.99, 1.98), which approached statistical significance.

Discussion

The purpose of this investigation was to evaluate the incidence of oral, esophageal and stomach cancer incidence in the period 1979 through 2006 in the Jersey City population, in relation to residential proximity to areas known to be contaminated with Cr^{+6} in the past. This investigation was conducted to follow up on a recommendation made in a previous health consultation that examined lung cancer incidence in the period 1979 through 2003 (ATSDR 2008a). The methods used in the current investigation were modeled on those used in the lung cancer investigation.

In the period 1979 through 2006, the incidence of oral cancers was similar among areas classified by potential for historic exposure to Cr^{+6}. The incidence of esophageal cancers was elevated in males in areas near COPR sites, but rate ratios were generally higher for the "low" exposure category than for the "high" exposure category, and confidence intervals were wide. Rate ratios for esophageal cancer in females were generally higher with increasing potential for exposure, but confidence intervals were wide. Stomach cancer incidence was not different across exposure categories, except among females using the strictest definition of "high" exposure; this rate ratio was not statistically significant. The findings for combined cancers showed patterns that were similar to esophageal cancer, but were attenuated. In summary, the investigation shows that oral and stomach cancers do not appear to be different across populations of Jersey City grouped by potential for exposure to Cr^{+6} from COPR sites. Esophageal cancer, in particular among males, was higher in the areas categorized as having low and high exposure potential, but there was no indication of a "dose-response," that is, increasing degree of risk with increasing potential for exposure. Observing a dose-response would strengthen a cause-effect interpretation of a finding.

Known risk factors for oral cavity and pharynx cancers include tobacco smoking, use of smokeless tobacco, alcohol consumption, infection with human papillomavirus or Epstein-Barr virus, and sunlight (lip cancer). Other risk factors for oropharyngeal cancers include radiation, and occupational exposure to wood dust, nickel dust or asbestos. Risk factors for esophageal and stomach cancers include tobacco use, a diet low in fruits and vegetables, and infection with the bacterium *Helicobacter pylori*. Alcohol use and gastroesophageal reflux are also risk factors for esophageal cancer (NCI 2010, ACS 2010).

Other than the National Toxicology Program study (NTP 2008), there are very few studies examining the potential for carcinogenicity of ingested hexavalent chromium in experimental animals (Stern 2009), and the evidence of carcinogenicity from human occupational or environmental exposure studies is not strong. This contrasts with the strong evidence of the carcinogenicity of inhaled hexavalent chromium from animal and human studies.

Limitations

Even with the addition of three years of incidence data, the number of cases in this investigation was much lower than for the lung cancer investigation. The total number of combined cases in this investigation was 1,803. In contrast, there were 3,249 cases of lung cancer for the previous analysis. There was therefore a higher degree of uncertainty around the estimated rate ratios in this investigation, particularly for analyses of specific cancer types.

This investigation is a descriptive analysis of cancer incidence, and is not designed to reach cause-effect inferences. A limitation of cancer incidence investigations of this type is the inability to assess actual past exposure levels to individuals in the population. The ability to assess a cause-effect relationship is strengthened when the analysis includes data on actual personal exposure to the contamination and other relevant risk factors over time. That is, who was exposed and who was not exposed, and the magnitude and timing of the exposure that did occur.

Because personal exposure information does not exist, residential proximity to the contaminated areas was used as a surrogate measure for potential past environmental exposure. This was accomplished by aggregating and analyzing populations living in relatively small geographic areas (block groups) within 300 feet of a contaminated site. Although proximity to these areas may be a reasonable surrogate for past environmental potential exposures, it is also unlikely that all of the residents in the designated areas were exposed to hexavalent chromium from the COPR sites. Similarly, those living outside the designated exposed areas may have been exposed to chromium from COPR sites, for example if their workplace was near a site. This would result in misclassifying some of the population as exposed when they are not, and vice versa. In general, the consequence of exposure misclassification would be to bias the results toward not finding an association, even if such an association truly existed (Kelsey et al 1996).

Another limitation is that cancers are chronic diseases that may take many years after exposure to be revealed as a clinical disease. The information supplied by the state cancer registry provides only an address at time of diagnosis for each case. No information is available on length of time an individual may have lived at the address before diagnosis. It is possible that some cases were new, short-term residents with little or no exposure to the contamination. Furthermore, former residents who moved out of the investigation area before diagnosis are not available for analysis. Population mobility cannot be accounted for in this type of analysis. Therefore, some cases would be incorrectly associated with a potential exposure while some cases that should have been associated with a potential exposure would have been missed.

The method used in this investigation is a practical and standard surveillance or screening approach to understanding variation in cancer incidence. Although this approach is well suited for providing a picture of cancer incidence in the specific localities, cause-effect conclusions cannot be drawn from this information alone. Important information on potential risk factors (such as genetics, life style, environmental factors, occupation, etc.) that might explain differences in cancer rates were not available for analysis.

Conclusions and Recommendations

In summary, this investigation does not provide compelling evidence that residential proximity to historic COPR sites is associated with an increased risk of oral, esophageal or stomach cancers in the population of Jersey City.

Oral and stomach cancer incidence rates were not elevated in Jersey City areas close to the locations of COPR sites. While esophageal cancer incidence rates among males were higher in exposed areas, the rates did not seem to increase with increasing potential for exposure, and there was considerable uncertainty about the magnitude of the rate ratio.

It is important to note that, since a significant amount of remediation of the chromium slag has occurred, the historic potential exposures noted in this investigation do not represent the current conditions in the city. However, it is recommended that efforts to remediate COPR sites to limit human exposure to hexavalent chromium should continue.

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Certification

This health consultation was prepared by the New Jersey Department of Health and Senior Services under a cooperative agreement with the Agency for Toxic Substances and Disease Registry. This health consultation is in accordance with approved methodology and procedures existing at the time it was initiated. The cooperative agreement partner has completed an editorial review of this document.

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The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this health consultation and concurs with its findings.

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Tables

Table 1. Exposure Intensity Group Definitions, and Number of Census Block Groups in Jersey City Classified by Four Exposure Grouping Methods.

Exposure Grouping Method	Exposure Groups	Exposure Group Definitions	Number of BGs[1]
1	• None • Any	• 0% of the area of the Residential Block Group (RBGA)[2] within 300 ft of any site • >0% of RBGA within 300 ft of any site	• 104 • 57
2	• None • Low • High	• 0% of RBGA within 300 ft of any site • All other BGs • ≥10% of RBGA within 300 ft of site with ≥900 ppm[3] Cr^{+6} ***or*** ≥25% of RBGA within 300 ft of any site	• 104 • 28 • 29
3	• None • Low • High	• 0% of RBGA within 300 ft of any site • All other BGs • ≥25% of RBGA within 300 ft of site with ≥900 ppm Cr^{+6} ***or*** ≥50% of RBGA within 300 ft of any site	• 104 • 42 • 15
4	• None • Low • High	• 0% of RBGA within 300 ft of any site • All other BGs • ≥50% of RBGA within 300 ft of site with ≥900 ppm Cr^{+6} ***or*** ≥75% of RBGA within 300 ft of any site	• 104 • 50 • 7

Note: [1] BG = Block group (U.S. Census 2000 boundaries)
[2] RBGA = Residential block group area
[3] ppm = parts per million (or milligrams per kilogram)

Table 2. Block Groups (BG) by Cr^{+6} Exposure Potential using Cr^{+6} = 14% of Total Chromium Value.

Percent of Residential Area within 300 feet of a COPR Site with ≥ 900+ ppm Cr^{+6}	Number of BGs
0%	129
>0% to <10%	13
10% to <30%	9
30% to <50%	4
50+%	6
Total	161
Maximum Area	88.8%
Percent of Residential Area within 300 feet of a COPR Site with < 900 ppm Cr^{+6}	**Number BGs**
0%	118
>0% to <10%	23
10% to <30%	11
30% to <50%	5
50+%	4
Total	161
Maximum Area	77.6%
Percent of Residential Area within 300 feet of a COPR Site with Unknown Cr^{+6} Levels	**Number BGs**
0%	158
>0% to <10%	2
10% to <30%	1
Total	161
Maximum Area	24.6%

Table 3. Person-Years by Exposure Intensity Group, Jersey City, 1979-2006.

High Exposure Definition	Exposure Group	Males	Females
	None	2,027,803	2,154,773
1. Any residential area within 300 feet	Any	1,122,232	1,217,485
2. 10%+ ≥900 ppm or 25%+ any	Low	624,573	672,720
	High	497,659	544,765
3. 25%+ ≥900 ppm or 50%+ any	Low	890,729	969,576
	High	231,503	247,909
4. 50%+ ≥900 ppm or 75%+ any	Low	1,015,087	1,095,977
	High	107,145	121,508

Table 4a. Malignant Cancer Incidence by Cancer Type and Exposure Intensity Group. Number of Cases in Jersey City in the Period 1979-2006.

High Exposure Definition	Exposure Group	Oral Cancer		Esophageal Cancer		Stomach Cancer	
		Males	Females	Males	Females	Males	Females
	None	358	125	124	63	234	183
1. Any residential area within 300 feet	Any	188	68	110	36	130	104
2. 10%+ ≥900 ppm or 25%+ any	Low	107	38	62	15	70	57
	High	81	30	48	21	60	47
3. 25%+ ≥900 ppm or 50%+ any	Low	148	53	88	27	101	77
	High	40	15	22	9	29	27
4. 50%+ ≥900 ppm or 75%+ any	Low	174	57	98	31	117	87
	High	14	11	12	5	13	17

Table 4b. Malignant Cancer Incidence by Combined Cancer Groupings and Exposure Intensity Group. Number of Cases in Jersey City in the Period 1979-2006.

High Exposure Definition	Exposure Group	Esophageal, Stomach and Small Intestinal Cancers		Oral, Esophageal, Stomach and Small Intestinal Cancers	
		Males	Females	Males	Females
	None	380	274	738	399
1. Any residential area within 300 feet	Any	254	156	442	224
2. 10%+ ≥900 ppm or 25%+ any	Low	139	81	246	119
	High	115	75	196	105
3. 25%+ ≥900 ppm or 50%+ any	Low	198	117	346	170
	High	56	39	96	54
4. 50%+ ≥900 ppm or 75%+ any	Low	228	132	402	189
	High	26	24	40	35

Table 5. Adjusted Rate Ratios (RR) and 95% Confidence Intervals (CI) for Malignant Oral Cancer in Jersey City, by Sex and Exposure Intensity Group, 1979-2006.

Exposure Group	Block Groups	Males			Females		
		RR	95% CI	p-value	RR	95% CI	p-value
No Exposure	104	**1.0**	-	-	**1.0**	-	-
Any Exposure	57	**0.98**	0.82, 1.17	*0.80*	**0.98**	0.73, 1.32	*0.91*
10%+ ≥900 ppm or 25%+ Any Exposure:							
Low	28	**1.06**	0.85, 1.32	*0.60*	**1.07**	0.74, 1.53	*0.73*
High	29	**0.88**	0.69, 1.13	*0.33*	**0.89**	0.60, 1.33	*0.58*
25%+ ≥900 ppm or 50%+ Any Exposure:							
Low	42	**1.00**	0.82, 1.21	*0.96*	**0.99**	0.72, 1.37	*0.95*
High	15	**0.91**	0.66, 1.27	*0.60*	**0.96**	0.56, 1.64	*0.87*
50%+ ≥900 ppm or 75%+ Any Exposure:							
Low	50	**1.02**	0.85, 1.22	*0.87*	**0.93**	0.68, 1.27	*0.66*
High	7	**0.65**	0.37, 1.13	*0.13*	**1.38**	0.75, 2.57	*0.30*

Table 6. Adjusted Rate Ratios (RR) and 95% Confidence Intervals (CI) for Malignant Esophageal Cancer in Jersey City, by Sex and Exposure Intensity Group, 1979-2006.

Exposure Group	Block Groups	Males			Females		
		RR	95% CI	p-value	RR	95% CI	p-value
No Exposure	104	**1.0**	-	-	**1.0**	-	-
Any Exposure	57	**1.64***	1.27, 2.12	*<0.001*	**1.05**	0.70, 1.59	*0.81*
10%+ ≥900 ppm or 25%+ Any Exposure:							
Low	28	**1.79***	1.32, 2.43	*<0.001*	**0.87**	0.49, 1.53	*0.63*
High	29	**1.48***	1.06, 2.07	*0.02*	**1.24**	0.75, 2.04	*0.40*
25%+ ≥900 ppm or 50%+ Any Exposure:							
Low	42	**1.69***	1.29, 2.23	*<0.001*	**1.03**	0.65, 1.61	*0.91*
High	15	**1.45**	0.92, 2.29	*0.11*	**1.14**	0.57, 2.30	*0.71*
50%+ ≥900 ppm or 75%+ Any Exposure:							
Low	50	**1.64***	1.26, 2.14	*<0.001*	**1.03**	0.67, 1.58	*0.90*
High	7	**1.63**	0.90, 2.96	*0.11*	**1.24**	0.50, 3.09	*0.64*

* RR statistically significantly elevated (CI excludes 1.0).

Table 7. Adjusted Rate Ratios (RR) and 95% Confidence Intervals (CI) for Malignant Stomach Cancer in Jersey City, by Sex and Exposure Intensity Group, 1979-2006.

Exposure Group	Block Groups	Males			Females		
		RR	95% CI	p-value	RR	95% CI	p-value
No Exposure	104	**1.0**	-	-	**1.0**	-	-
Any Exposure	57	**1.06**	0.86, 1.32	*0.59*	**1.10**	0.86, 1.40	*0.46*
10%+ ≥900 ppm or 25%+ Any Exposure:							
Low	28	**1.12**	0.85, 1.46	*0.42*	**1.20**	0.89, 1.62	*0.23*
High	29	**1.00**	0.75, 1.33	*0.99*	**0.99**	0.72, 1.36	*0.94*
25%+ ≥900 ppm or 50%+ Any Exposure:							
Low	42	**1.07**	0.85, 1.36	*0.56*	**1.06**	0.81, 1.38	*0.67*
High	15	**1.02**	0.69, 1.51	*0.91*	**1.21**	0.81, 1.82	*0.35*
50%+ ≥900 ppm or 75%+ Any Exposure:							
Low	50	**1.08**	0.86, 1.35	*0.51*	**1.04**	0.80, 1.35	*0.76*
High	7	**0.93**	0.53, 1.62	*0.79*	**1.51**	0.92, 2.49	*0.11*

Table 8. Adjusted Rate Ratios (RR) and 95% Confidence Intervals (CI) for Combined Esophageal, Stomach and Small Intestinal Cancers) in Jersey City, by Sex and Exposure Intensity Group, 1979-2006.

Exposure Group	Block Groups	Males			Females		
		RR	95% CI	p-value	RR	95% CI	p-value
No Exposure	104	**1.0**	-	-	**1.0**	-	-
Any Exposure	57	**1.26***	1.08, 1.48	*0.004*	**1.08**	0.89, 1.32	*0.45*
10%+ ≥900 ppm or 25%+ Any Exposure:							
Low	28	**1.34***	1.10, 1.63	*0.003*	**1.12**	0.87, 1.43	*0.38*
High	29	**1.18**	0.96, 1.45	*0.13*	**1.04**	0.81, 1.35	*0.76*
25%+ ≥900 ppm or 50%+ Any Exposure:							
Low	42	**1.28***	1.07, 1.52	*0.006*	**1.06**	0.85, 1.31	*0.62*
High	15	**1.22**	0.92, 1.62	*0.17*	**1.16**	0.83, 1.62	*0.40*
50%+ ≥900 ppm or 75%+ Any Exposure:							
Low	50	**1.28***	1.08, 1.51	*0.004*	**1.04**	0.84, 1.28	*0.74*
High	7	**1.16**	0.78, 1.72	*0.48*	**1.41**	0.92, 2.14	*0.11*

* RR statistically significantly elevated (CI excludes 1.0).

Table 9. Adjusted Rate Ratios (RR) and 95% Confidence Intervals (CI) for Combined Oral, Esophageal, Stomach and Small Intestinal Cancers) in Jersey City, by Sex and Exposure Intensity Group, 1979-2006.

Exposure Group	Block Groups	Males			Females		
		RR	95% CI	p-value	RR	95% CI	p-value
No Exposure	104	**1.0**	-	-	**1.0**	-	-
Any Exposure	57	**1.12**	1.00, 1.27	*0.05*	**1.05**	0.89, 1.24	*0.57*
10%+ ≥900 ppm or 25%+ Any Exposure:							
Low	28	**1.20***	1.04, 1.39	*0.01*	**1.10**	0.90, 1.35	*0.36*
High	29	**1.04**	0.88, 1.22	*0.66*	**0.99**	0.80, 1.23	*0.96*
25%+ ≥900 ppm or 50%+ Any Exposure:							
Low	42	**1.14**	1.00, 1.30	*0.04*	**1.04**	0.86, 1.24	*0.71*
High	15	**1.07**	0.87, 1.33	*0.52*	**1.09**	0.82, 1.45	*0.54*
50%+ ≥900 ppm or 75%+ Any Exposure:							
Low	50	**1.15***	1.02, 1.30	*0.02*	**1.00**	0.84, 1.19	*0.98*
High	7	**0.92**	0.66, 1.27	*0.60*	**1.40**	0.99, 1.98	*0.06*

* RR statistically significantly elevated (CI excludes 1.0).

Figures

Figure 1. Comparison of the number of block groups assigned to “none”, “low” and “high” exposure intensity groups by the four exposure grouping methods.

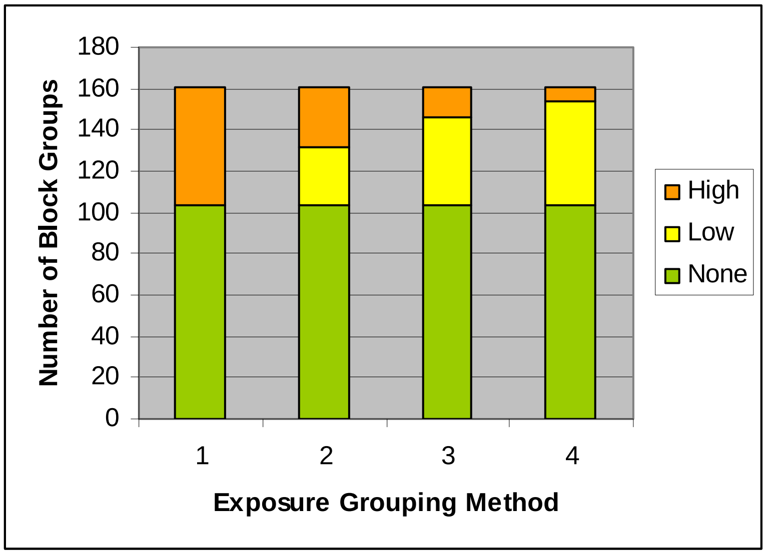
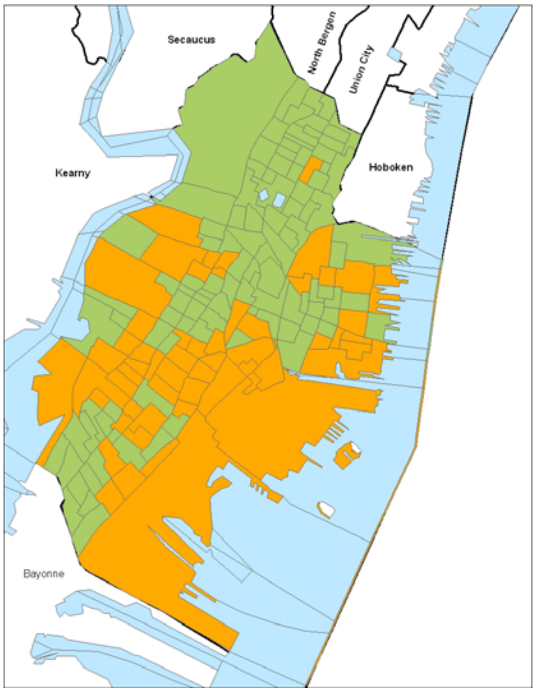
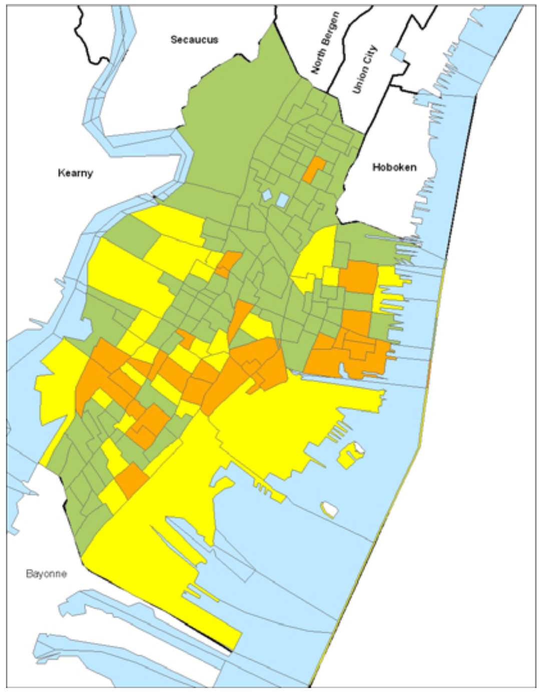


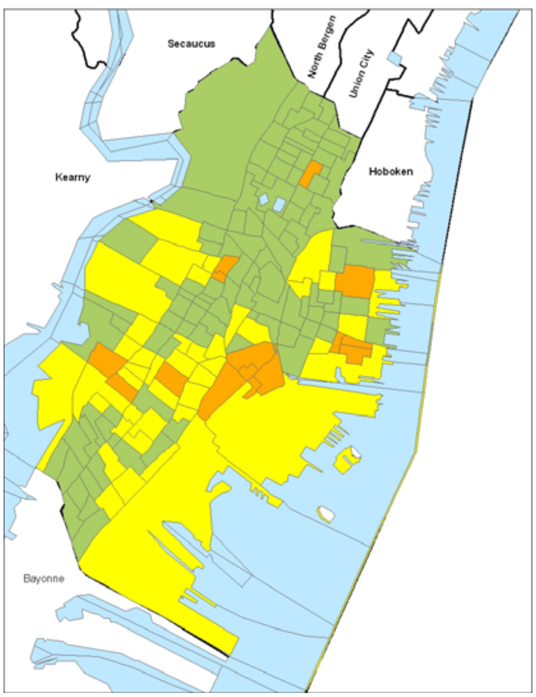
Figure 2. Maps showing exposure intensity group areas by the four exposure grouping methods.



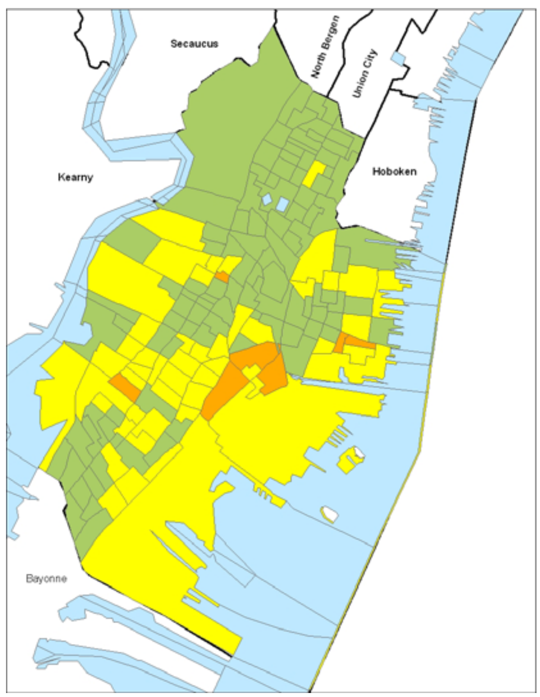
1. High=Any exposure



2. High=10%>900ppm or 25%+Any



3. High=25%>900ppm or 50%+Any

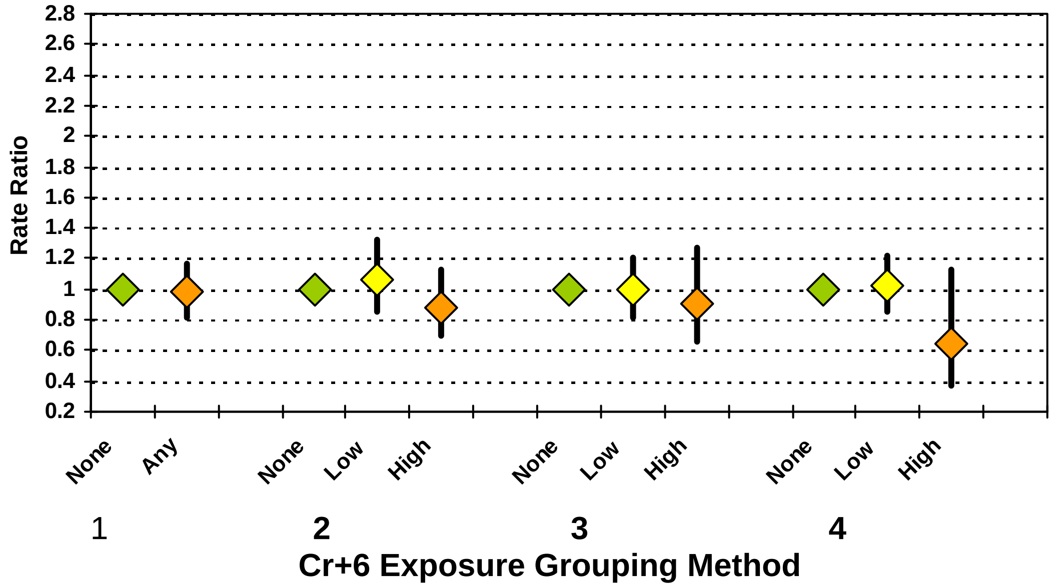


4. High=50%>900ppm or 75%+Any

Exposure Category: Green = None
Yellow=Low
Orange=High

Figure 3. Adjusted Rate Ratios (RR) for Malignant Oral Cancer in Jersey City, by Sex and Exposure Intensity Group, 1979-2006. Vertical bars represent the 95% Confidence Interval.

Males



Females

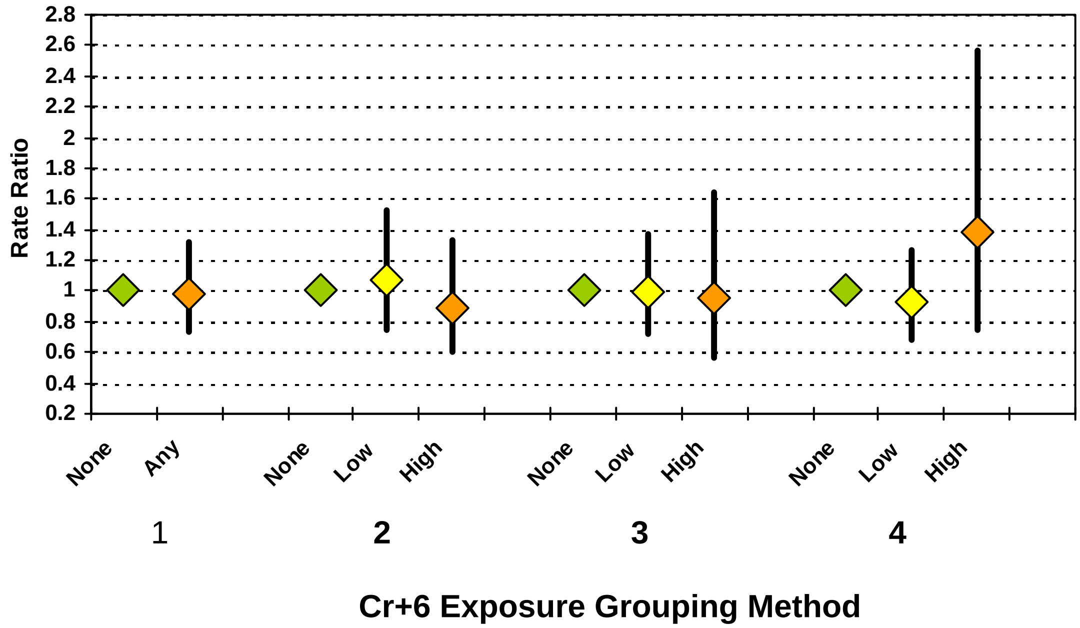
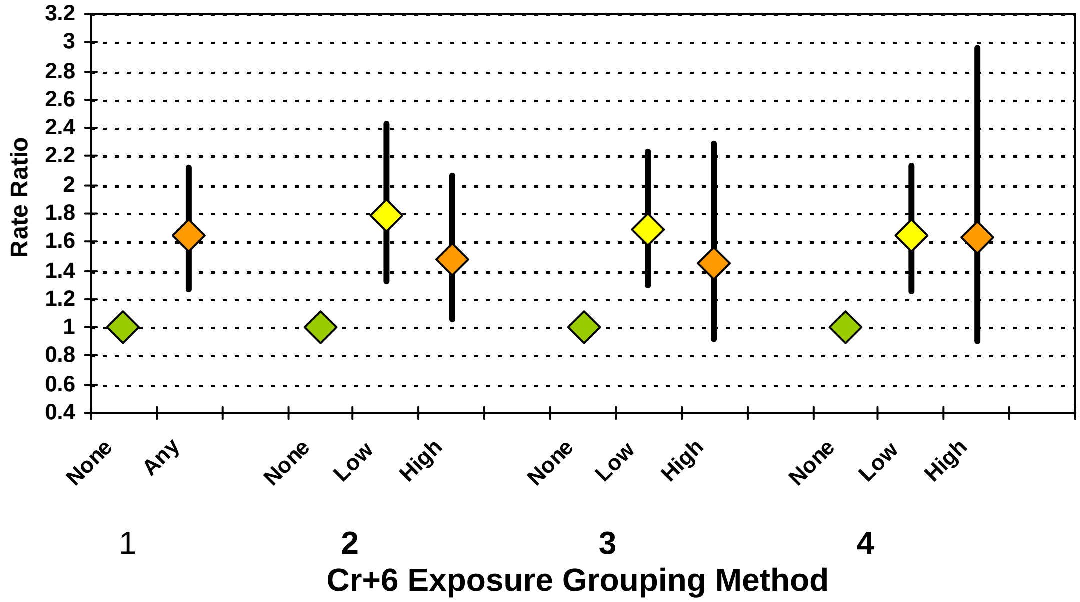


Figure 4. Adjusted Rate Ratios (RR) for Malignant Esophageal Cancer in Jersey City, by Sex and Exposure Intensity Group, 1979-2006. Vertical bars represent the 95% Confidence Interval.

Males



Females

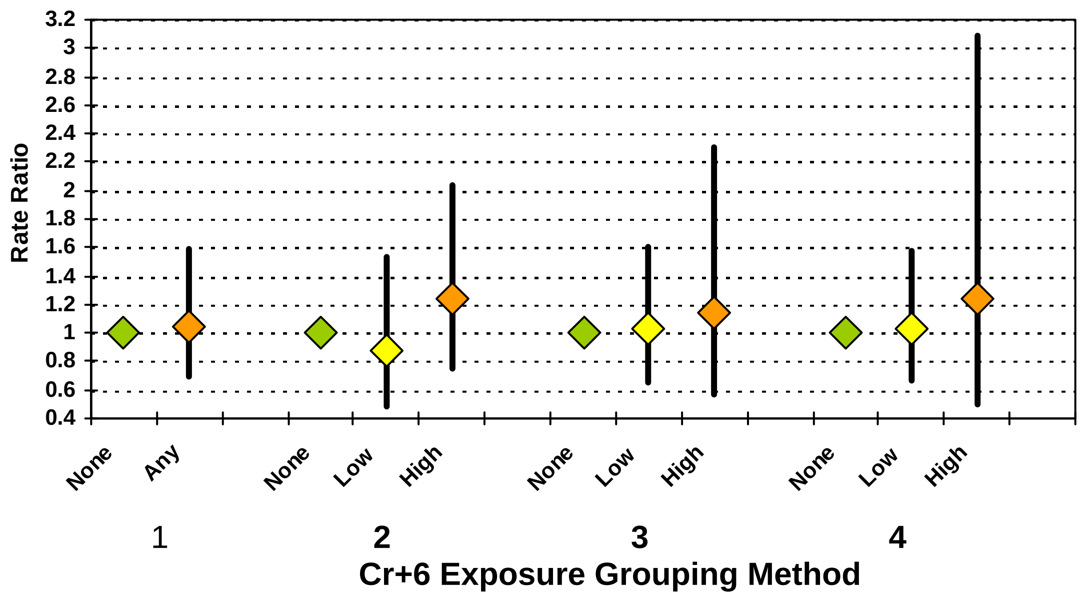
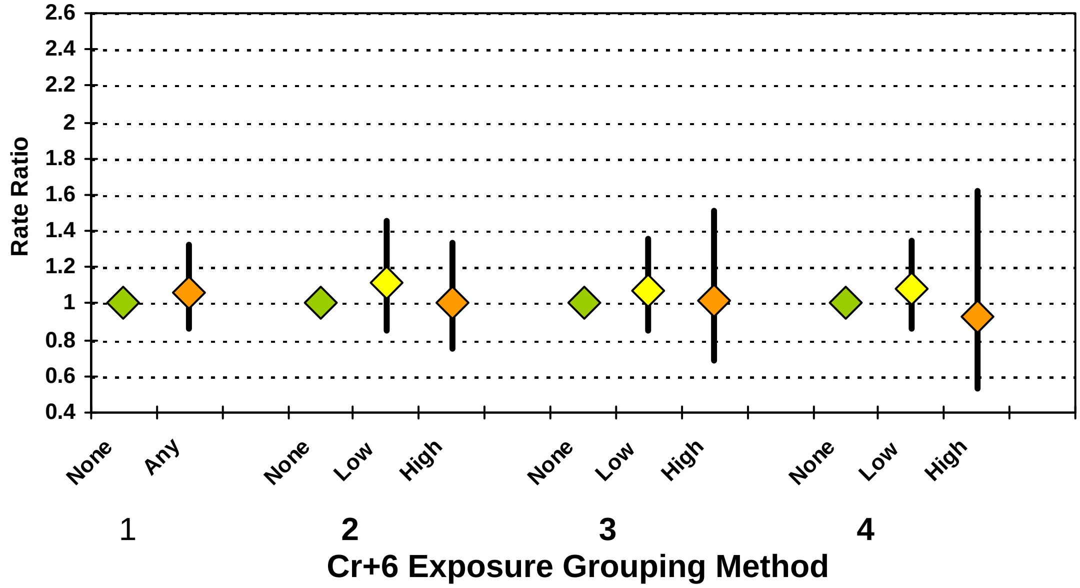


Figure 5. Adjusted Rate Ratios (RR) for Malignant <u>Stomach Cancer</u> in Jersey City, by Sex and Exposure Intensity Group, 1979-2006. Vertical bars represent the 95% Confidence Interval.

Males



Females

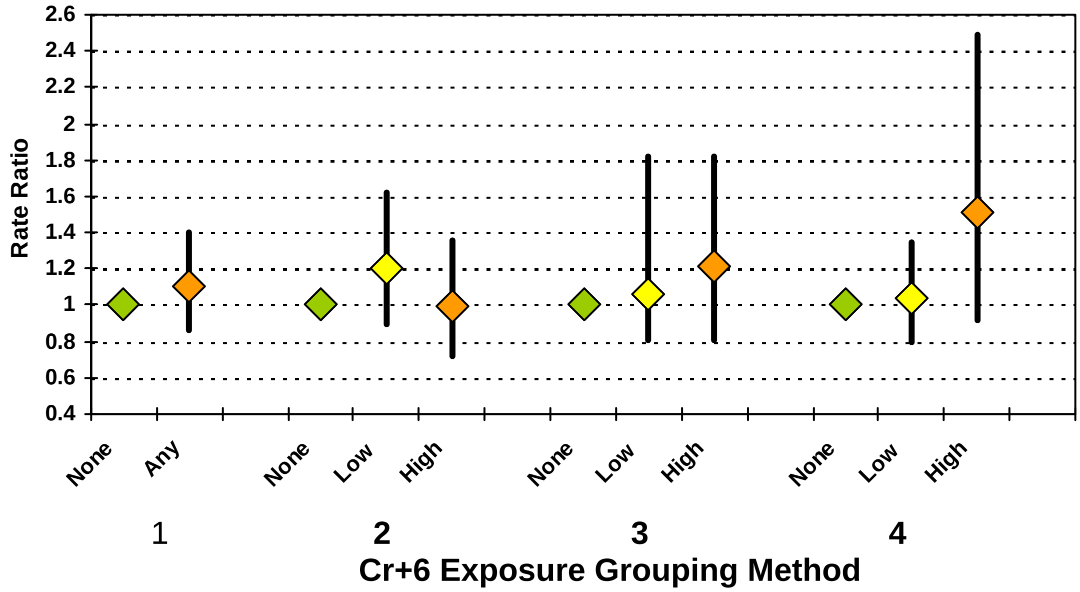
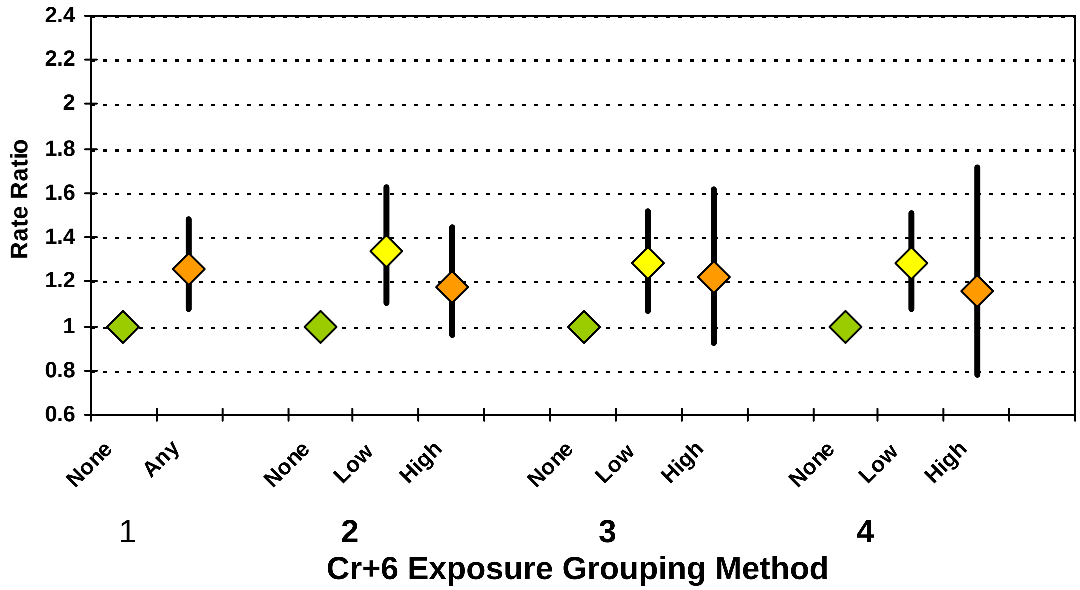


Figure 6. Adjusted Rate Ratios (RR) for Combined Esophageal, Stomach and Small Intestinal Cancers in Jersey City, by Sex and Exposure Intensity Group, 1979-2006. Vertical bars represent the 95% Confidence Interval.

Males



Females

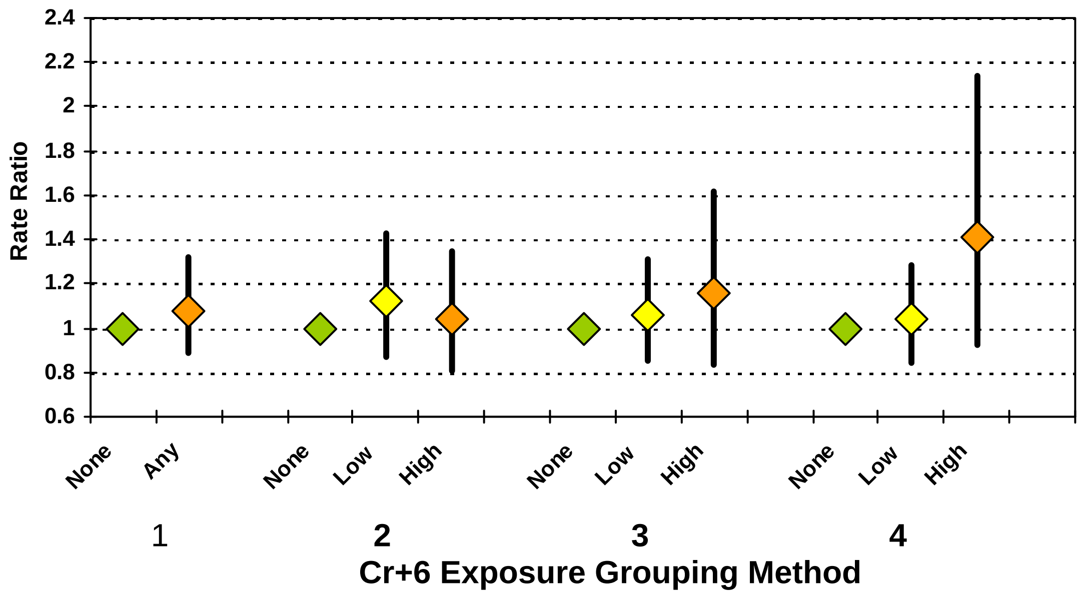
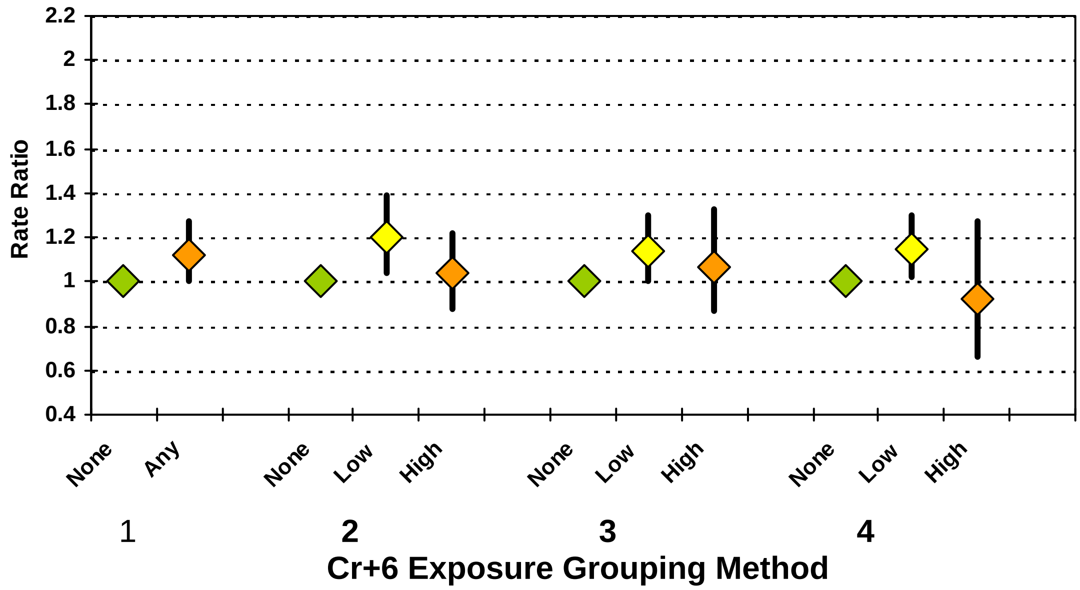
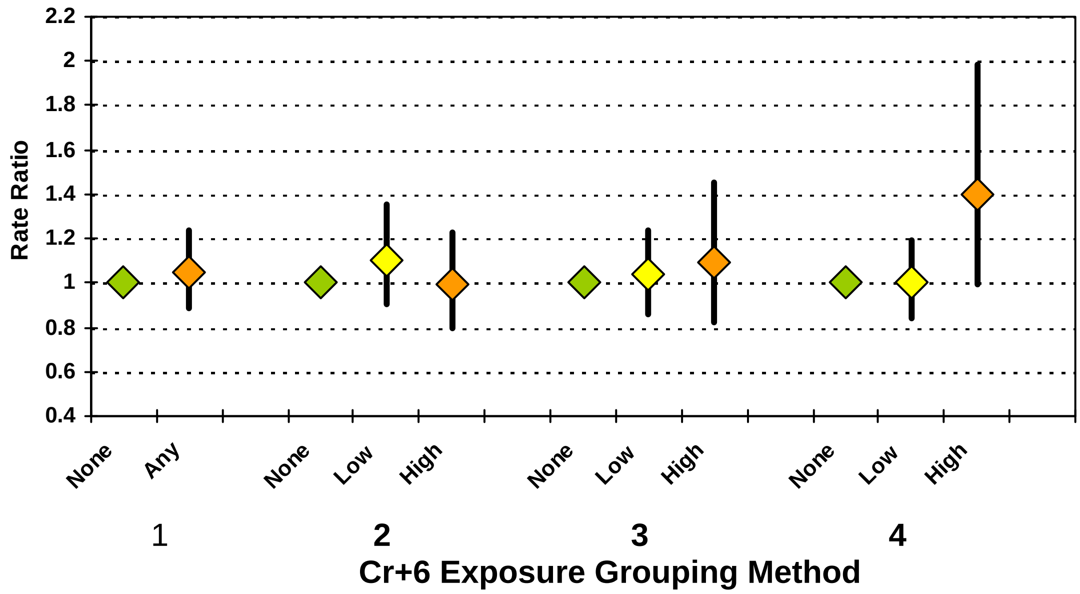


Figure 7. Adjusted Rate Ratios (RR) for Combined Oral, Esophageal, Stomach and Small Intestinal Cancers in Jersey City, by Sex and Exposure Intensity Group, 1979-2006. Vertical bars represent the 95% Confidence Interval.

Males



Females



Appendix to Health Consultation

Characterization of Chromium Exposure Potential for US Census Block Groups, Prepared by the New Jersey Department of Environmental Protection

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Characterization of Chromium Exposure Potential for US Census Block Groups, Prepared by the New Jersey Department of Environmental Protection

Overview

The New Jersey Department of Environmental Protection (NJDEP) used historic measurements from chromium ore processing residue (COPR) sites, air dispersion modeling, and geographic information system (GIS) analysis methods to estimate the residential population's potential exposure to past chromium contamination in Jersey City. The result of the analysis is the percentage of residential land use potentially exposed to three concentration categories of chromium, for each U.S. Census block group in Jersey City.

COPR Sites in Jersey City

The NJDEP Site Remediation Program (SRP) is responsible for all COPR sites in the state. SRP maintains a comprehensive site list and has assigned a site identification number to each. The list includes sites that are actively being investigated or remediated, as well as sites that have been capped, excavated, remediated, closed, or redeveloped. A total of 136 COPR sites on the list are located in Jersey City.

GIS Mapping of COPR Sites

Initial information on all COPR sites was obtained from an NJDEP SRP database in Excel. These records contained information on each site, including owner name, tax parcel lot and block and SRP site ID number. GIS point locations were available from SRP for 84 of the 136 sites. These point locations were based on submissions from the individual responsible party. Some of the GIS point locations were at the "front door" of a site, while others were at the center of the facility (i.e., centroids).

For the purpose of this investigation, site boundaries rather than point locations were needed. The air dispersion model, discussed below, calculates maximum contaminant migration distance from the site perimeter. Because of the inadequacy of the existing GIS information, the site property boundaries of all 136 COPR sites were mapped. COPR site mapping was conducted using historic or current descriptive records from SRP for each COPR site, together with four standardized GIS reference layers:

1) tax parcel data created and maintained by the Jersey City GIS office, with an accuracy of 1:6,000; and
2) three sets of high resolution, low altitude, orthorectified, digital aerial photography (taken in 1986, 1995, and 2001). These 3 sets of digital imagery were created specifically to

function as formal cartographic base layers for the purpose of GIS mapping. The orthophotography varies in accuracy from 1:24,000 to 1:2,400.

All four of the reference layers are valid mapping bases, meeting NJDEP's digital mapping standards and cartographic requirements, as well as the National Mapping Accuracy Standards reference base map requirements. These photographs and their metadata may be viewed at the NJDEP website, **www.state.nj.us/dep/gis/**. Maps developed using these base maps, and proper methods, meet National Map Accuracy Standards for professional cartographic products.

Municipal tax block and lot parcels from the current Jersey City tax parcel mapping, or the historic Jersey City parcel mapping, were matched to the NJDEP registered block and lot parcels from the SRP files. These parcels were then extracted from the 42,721 tax parcels in the municipal GIS record. Aerial photography was used to confirm that the indicated tax parcels matched the written description of each site by NJDEP staff. Many of the older sites, especially those closed many years ago, have been redeveloped. This necessitated using aerial photography from the appropriate time period to match to the written description. Site boundaries were then mapped using the combination of tax parcels and photography.

As a final check, the street addresses for each COPR site were available in the NJDEP SRP records. Each site's street address was located in the GIS using both the U.S. Census Tiger road files and the TeleAtlas street files. The address-based point locations were then cross-checked against tax lot and block locations for consistency. One hundred and twenty seven (93.4%) of the 136 COPR sites had consistency between the many independent data sources, and were mapped with high confidence at a 1:12,000 scale.

For eight of the nine sites with less confident mapping, the issue involved a question of the full extent of the original site. In these cases, the entire local area was selected to avoid eliminating any possible area with chromium contamination.

For the single remaining site, it was not possible to identify the original parcel. The street name in the file no longer existed in Jersey City. Occasionally, in old data files one finds records where the local "common name" for a site was used. Unfortunately, in this case there is no accompanying lot and block data. Examination of the aerial photography surrounding those Jersey City streets that have undergone name changes did not reveal any potential sites. With no reliable location information available this site (SRP site ID number 189) was excluded from the analysis.

Air Dispersion Modeling

With the COPR sites adequately mapped, the next step was to estimate the effective zone of influence of COPR particulates from a site. For this purpose, the U.S. EPA's ISCST3 Model (version 02035), a Gaussian plume model, was used to estimate both deposition and ambient concentration of PM_{10} (i.e., particles with a diameter of 10 microns or less), as a function of site size and distance from the site. The model was run under several different assumptions -- no deposition, dry deposition, and wet deposition -- and for several site sizes. The modeling was performed using meteorological data from Newark International Airport which is located close to Jersey City (approximately 5 miles). Model results from the quarter and half acre runs assuming both dry and wet deposition concentrations were predicted to be the same as the dry deposition results. Consequently, only dry deposition was evaluated for the remainder of the site sizes.

The concentration in the air of particulates from a ground-level source will decrease with distance from the source, because particulates deposit out of the air and because of dilution. In theory, particulate dispersion can occur over an infinite distance from a source. In practice, however, most site specific deposition will occur in the near-field relative to the site, and the ambient PM_{10} contribution from a site will become independent of site size as distance from the site increases.

The distance from the site boundary within which substantial particulate deposition can be assumed was determined by comparing the output for the dry deposition and no deposition models. The specification of the near-field for the majority of particulate deposition was based on identifying the distance from a site at which predicted ambient PM_{10} concentrations for the deposition model decreased below the predicted ambient concentration for the no deposition model. This distance, determined by models for sites of different sizes from 0.25 to 3 acres, was about 70 to 100 feet beyond the site boundary. For example, Table A1 shows that for a 1 acre site the crossover point (yellow highlight) occurs at approximately 53 - 32 = 21 meters, or about 70 feet from the site boundary , while for the 2 acre site the crossover point occurs at approximately 76 – 45 = 31 meters, or about 100 feet from the boundary.

Table A1. Modeled PM_{10} concentrations for 1 acre and 2 acre sites from dry deposition and no deposition models.

Site Size (Distance from Center to Site Boundary)	Model Type	PM Concentration at X Feet (Meters) from Center														
		50 (15)	75 (23)	100 (30)	125 (38)	150 (46)	175 (53)	200 (61)	250 (76)	300 (91)	350 (107)	400 (122)	450 (137)	500 (152)	600 (183)	700 (213)
1 acre (32 meters)	Dry deposition	--	--	--	1275	464	229	149	81.1	52	36.6	27.2	21.1	16.8	11.5	8.3
	No deposition	--	--	--	927	380	243	198	120	82.4	60.9	47	37.5	30.7	21.7	16.2
2 acre (45 meters)	Dry deposition	--	--	--	--	793	717	351	102	57.5	38.1	27.8	21.3	16.9	11.4	8.3
	No deposition	--	--	--	--	609	499	316	138	86.7	61.6	47.1	37.3	30.4	21.5	16.1

In addition, the distance necessary to reduce the PM_{10} air concentrations by approximately 98% of the PM_{10} level at the site boundary was estimated for sites of varying sizes. Table A2 presents the modeled PM_{10} air concentrations at increasing distances for selected site sizes. Boundary distances needed for a 98% reduction in PM_{10} air concentrations (yellow highlight) were approximately 225 feet for a 0.5 acre site (91 - 22 meters), 300 for a 1 acre site (122 – 32 meters), and 350 feet for a 2 acre site (152 – 45 meters).

Consequently, a value of 300 feet was chosen as a reasonable buffer distance from site boundaries, which represents a distance within which most particulate deposition would occur and ambient PM_{10} concentrations are substantially reduced. This distance is thus intended as a reasonable estimate of the zone of influence of a site for exposure to airborne particulates from that site. This distance is not intended to express the limit of the distance that wind can carry particulates from a site.

Table A2. Modeled PM_{10} concentrations at increasing distances from the centers of 0.5, 1, and 2 acre sites.

Site Size (Distance from Center to Site Boundary)	PM Concentration at X Feet (Meters) from Center														
	50 (15)	75 (23)	100 (30)	125 (38)	150 (46)	175 (53)	200 (61)	250 (76)	300 (91)	350 (107)	400 (122)	450 (137)	500 (152)	600 (183)	700 (213)
0.5 acre (22 meters)	--	2621	1389	466	271	182	130	77.1	51.1	36.5	27.2	21.1	16.8	11.5	8.4
1 acre (32 meters)	--	--	--	1275	464	229	149	81.1	52	36.6	27.2	21.1	16.8	11.5	8.3
2 acre (45 meters)	--	--	--	--	793	717	351	102	57.5	38.1	27.8	21.3	16.9	11.4	8.3

Using the GIS, a 300-foot buffer was extended beyond the parcel boundary to account for dispersion of site material. Figure A1 displays the COPR sites and their 300 foot buffer zone.

Figure A1. COPR Site Boundaries Extended by a 300 Foot Buffer

Hexavalent Chromium Concentrations at COPR Sites

A hexavalent chromium (Cr^{+6}) concentration was assigned to each COPR site and its buffer zone. Where possible, this was done based on historical measurement of Cr^{+6} concentration collected by the NJDEP. The highest Cr^{+6} soil measurement available in a site's data record was used to characterize the entire site. Of the 135 COPR sites in Jersey City (after exclusion of site 189), 23 sites (16.9%) had Cr^{+6} data available. Of the remaining 112 sites, 94 sites (69.1% of the total) had historic measurements of total chromium concentrations available, and 18 sites (13.2% of the total) had no chromium measurements of any kind. Where possible, these sites were assigned an estimate for the Cr^{+6} value, as described below. Table A3 lists each of the Jersey City COPR sites, indicates which type of information was used, and the final value determined for chromium concentration.

To characterize the 94 sites with only total chromium data, NJDEP evaluated the ES&E database containing information on 42 sites (ES&E, 1989). Of the sites in the ES&E database, 28 sites had both Cr^{+6} and total chromium measurements that could be used to estimate the ratio of Cr^{+6} to total chromium in the COPR material. For these 28 sites, the Cr^{+6} and total chromium measurements were moderately correlated (r=0.37) with an overall mean ratio of 0.03 (standard deviation=0.04). However, it was found that this ratio was dependent on the Cr^{+6} concentration such that as the Cr^{+6} concentration increased, it tended to make up a larger proportion of the total chromium. The 95th percentile of the Cr^{+6} to the total chromium ratio was 0.12. The largest ratio value was 0.18. However, this value was a statistical outlier of the overall relationship between the ratio and Cr^{+6} concentration. The next largest ratio, 0.14, was consistent with this relationship. Therefore, a ratio of 0.14 was selected to represent the upper end of the range of the proportion of Cr^{+6} of total chromium.

To address the potential variability of the ratio of Cr^{+6} to total chromium in COPR material, the Cr^{+6} estimates for the 94 sites with only total chromium measurements were initially calculated using both the 3% mean estimate and the 14% upper percentile estimate of the percentage of total chromium that was Cr^{+6}.

Of the 18 sites with no historical chromium data of any kind, six sites are adjacent to sites with values, and were operationally linked to the adjacent site in the historical site case files. These six sites were assigned the same value as that measured at the adjacent site. Table A3 identifies these sites in the *Source* column as having no data, and notes the site identification number in which data was used.

The remaining 12 "no data" sites are not able to be assigned a chromium value. Ten of the 12 sites were more than 300 feet from any residential area and only impacted non-residential areas. Therefore, these ten "no data" sites would not have influenced the outcome of the analysis regardless of their true Cr^{+6} value, since their buffered areas do not intersect any residential areas.

The remaining two sites were assigned a "no data" classification with unknown impact. The buffered areas of these two sites intersect three census block groups: 38001, 38002, and 45002. One should note that much of the buffer zones of the "no data" sites are overlapped by the buffer zone from other sites with data. Where overlap occurs, the air dispersion buffer with a known value overwrites the "no data" buffer.

Table A3. List of the COPR sites and data used to classify each site.

Site ID	Source: SRP unless noted	Sampling Result (ppm)	Cr*3% (ppm)	Cr*14% (ppm)
1		5,900	177	826
2		8,400	252	1,176
3		6,200	186	868
4	no data	no residential impact		
5		5,800	174	812
6		19,000	570	2,660
7		360	11	50
8		4,300	129	602
10		4,700	141	658
11		10,000	300	1,400
12		8,800	264	1,232
13		11,000	330	1,540
14		6,400	192	896
15		6,600	198	924
16		7,900	237	1,106
17		18,000	540	2,520
18		13,000	390	1,820
19		9,940	298	1,392
20		8,100	243	1,134
22		43,700	1,311	6,118
23		2,900	87	406
24		4,400	132	616
25		37	1	5
26		55	2	8
27		90	3	13
28		270	8	38
29		620	19	87
30		22	1	3
31		23	1	3
32		7,710	231	1,079
33		64	2	9
34		51	2	7
35		46	1	6
36		38	1	5
37		8,900	267	1,246
38		13,000	390	1,820
39		19,800	594	2,772

Site ID	Source: SRP unless noted	Sampling Result (ppm)	Cr*3% (ppm)	Cr*14% (ppm)
63		3,150	95	441
65		910	27	127
66		7,320	220	1,025
67		5,510	165	771
68		19,500	585	2,730
69		4,240	127	594
70		2,613	78	366
71	Cr^{+6}/ES&E	8,500	8,500	8,500
73	Cr^{+6}/ES&E	15,000	15,000	15,000
74		472	14	66
75	no data/Site 36	38	1	5
76		705	21	99
77	no data/Site 76	705	21	99
79	Cr^{+6}	12,840	12,840	12,840
80		12,200	366	1,708
81		12,100	363	1,694
82		14,492	435	2,029
83		230	7	32
84		377	11	53
85		4,910	147	687
86		1,397	42	196
87	Cr^{+6}/ES&E	15,000	15,000	15,000
88	Cr^{+6}/ES&E	15,000	15,000	15,000
89		2,044	61	286
90	Cr^{+6}/ES&E	25,000	25,000	25,000
91	no data/Site 204	15	15	15
92	no data/Site185	20	20	20
93	no data	no residential impact		
94		280	8	39
95	no data	no residential impact		
96		26,200	786	3,668
97		39	1	5
98		39	1	5
99		35	1	5
100		4,990	150	699
101		5,423	163	759
102		13,800	414	1,932
107		5,468	164	766
108		18,240	547	2,554
112		23,500	705	3,290
114		63,040	1,891	8,826

Site ID	Source: SRP unless noted	Sampling Result (ppm)	Cr*3% (ppm)	Cr*14% (ppm)
115		35,000	1,050	4,900
117		25,900	777	3,626
118		63	2	9
119		16,000	480	2,240
120	no data/Site 115	35,000	1,050	4,900
121		730	22	102
123		3,520	106	493
124	Cr^{+6}/ES&E	15,000	15,000	15,000
125	Cr^{+6}/ES&E	15,000	15,000	15,000
127		2,223	67	311
128		1,927	58	270
129		184	6	26
130		16,560	497	2,318
132		6,101	183	854
133		17,510	525	2,451
134	Cr^{+6}/ES&E	15,000	15,000	15,000
135		3,145	94	440
137	no data	no residential impact		
140	Cr^{+6}/ES&E	15,000	15,000	15,000
142		2,277	68	319
143		1,214	36	170
151		17,720	532	2,481
153	no data	no residential impact		
154	Cr^{+6}	13,000	13,000	13,000
155	Cr^{+6}	10,000	10,000	10,000
156		10,340	310	1,448
157	no data	no residential impact		
159		445	13	62
160		2,000	60	280
161		303	9	42
163	Cr^{+6}/ES&E	15,000	15,000	15,000
165		9,560	287	1,338
172		20,100	603	2,814
173		31,000	930	4,340
175		12,000	360	1,680
178		100	3	14
180	no data	no residential impact		
183	no data/Site 200	38	38	38
184	Cr^{+6}	25,000	25,000	25,000
185	Cr^{+6}	20	20	20
186	no data	unknown impact		

Site ID	Source: SRP unless noted	Sampling Result (ppm)	Cr*3% (ppm)	Cr*14% (ppm)
187	Cr^{+6}	726	726	726
188	no data	unknown impact		
189	no parcel found	Excluded	Excluded	Excluded
194		25,000	750	3,500
196		28,000	840	3,920
197		11,000	330	1,540
198	Cr^{+6}	51	51	51
199	Cr^{+6}	11,900	11,900	11,900
200	Cr^{+6}	38	38	38
202	Cr^{+6}	23	23	23
203	Cr^{+6}	17	17	17
204	Cr^{+6}	15	15	15
205	Cr^{+6}	111	111	111
206	no data	no residential impact		
207		27,683	830	3,876
208	no data	no residential impact		
211	no data	no residential impact		

Determination of Cr^{+6} Concentration Categories

The NJDEP then classified each COPR site into one of three hexavalent chromium concentration "categories" based on the measured or estimated Cr^{+6} value, in parts per million (ppm). The three categories include:

1) Cr^{+6} concentration of $\geq$ 900 ppm;
2) Cr^{+6} concentration of < 900 ppm; or
3) a known COPR site, but no available total or hexavalent chromium value.

The purpose of this categorization was to differentiate those COPR sites with higher Cr^{+6} concentration from the other known sites, assuming that those sites with higher Cr^{+6} concentrations would have posed a greater potential for exposure. There is no one value that uniquely differentiates high concentration sites from all other sites. However, a cutoff value of 900 ppm Cr^{+6} was chosen. This is approximately the median Cr^{+6} value under the assumption that Cr^{+6} constitutes 3% of total chromium in COPR, and approximately the 30^{th} percentile value under the assumption that Cr^{+6} constitutes 14% of total chromium.

Figure A2 shows the chromium site buffers, shaded according to chromium concentration category, based on a 3% ratio of Cr^{+6} to total chromium. Figure A3 shows the chromium site buffers shaded according to chromium concentration category, based on a 14% ratio of Cr^{+6} to total chromium. In every instance that an air dispersion buffer from one site overlaps with the buffer from another site, the highest value "overwrites" the lower value.

Figure A2. COPR Site Characterized by Highest Cr^{+6} Concentration using 3% Total Chromium

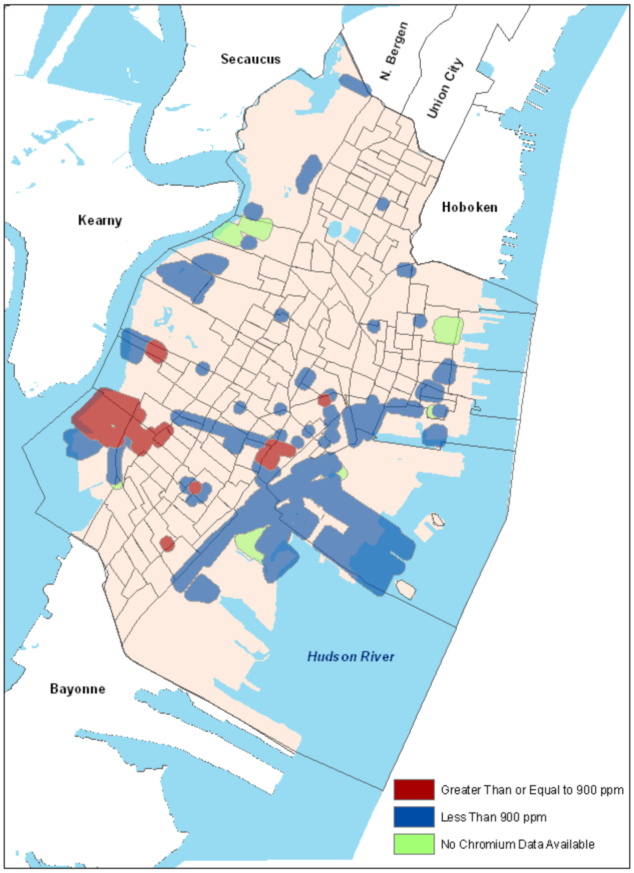
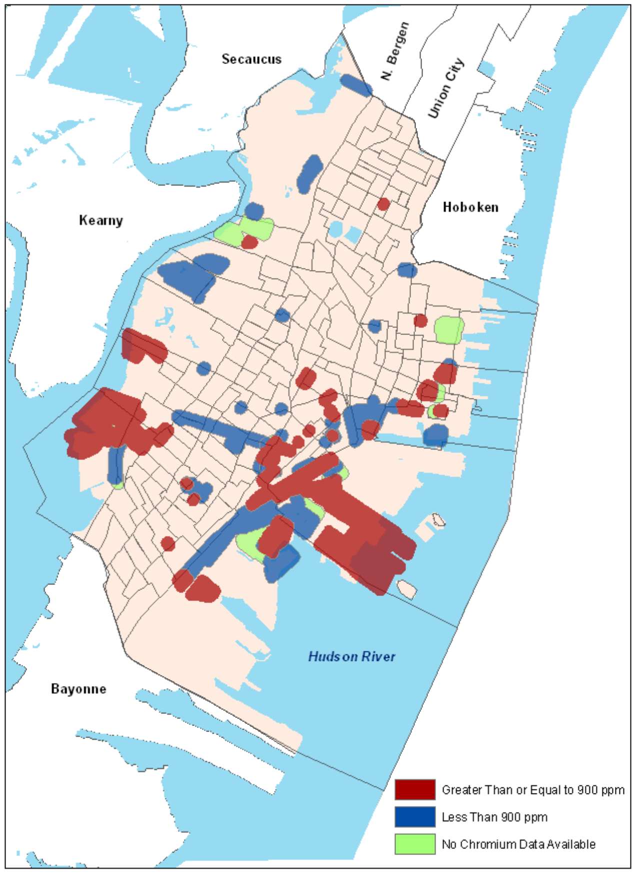


Figure A3. COPR Site Characterized by Highest Cr^{+6} Concentration using 14% Total Chromium



Determining the Relationship between Residential Areas and Chromium Exposure

High quality land use data in a GIS format was available for Jersey City for the years 1986, 1995, and 2002. This mapping was created from the low altitude aerial orthophotography. The metadata information for this data is available at **www.state.nj.us/dep/gis/**. Residential land use was extracted from the 1986 and 1995 layers. Residential areas developed from non-residential areas after 1995 were not included in the study. This is because we were characterizing historic residential land use in order to account for at least a ten year latency period for lung cancer. Therefore, more recent residential development of previously non-residential areas, and resultant exposures, if any, would not have been expected to have led to the onset of lung cancer during the study time period. Residential land use is shown in Figure A4.

GIS tools were then used to find the intersection of residential areas and the spatial extent of the 300-foot chromium site buffers. The results of this analysis are displayed in Figure A5. Figure A6 shows a detailed view of the spatial relationship between residential areas and air dispersion buffer zones.

Figure A4. Residential Land Use in Jersey City through 1996

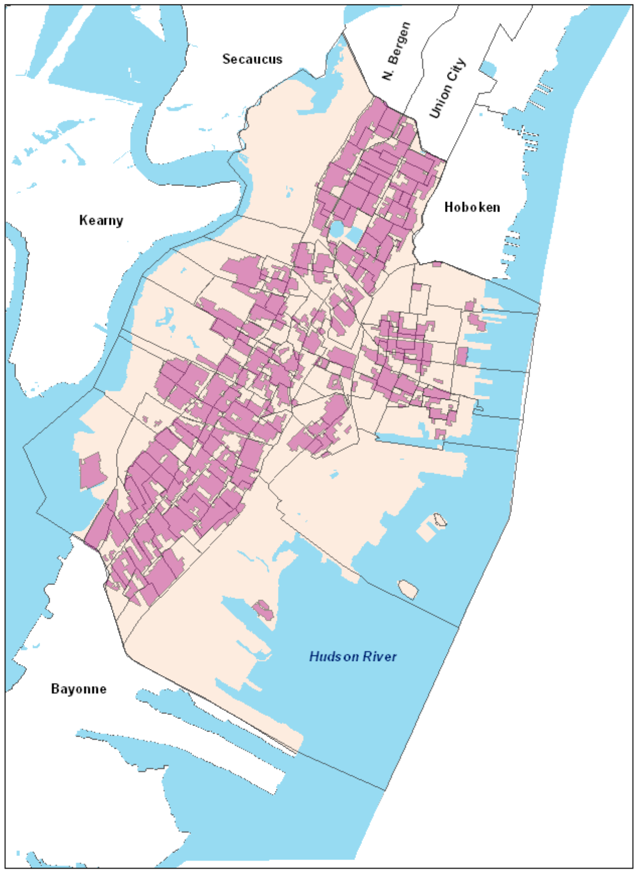


Figure A5. Residential Land Use in Relation to COPR Site Buffers

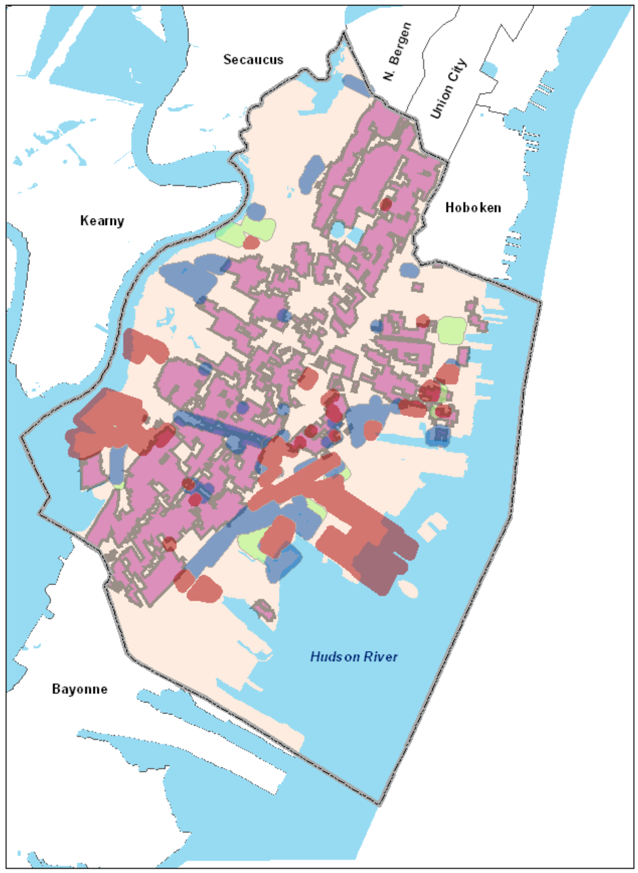
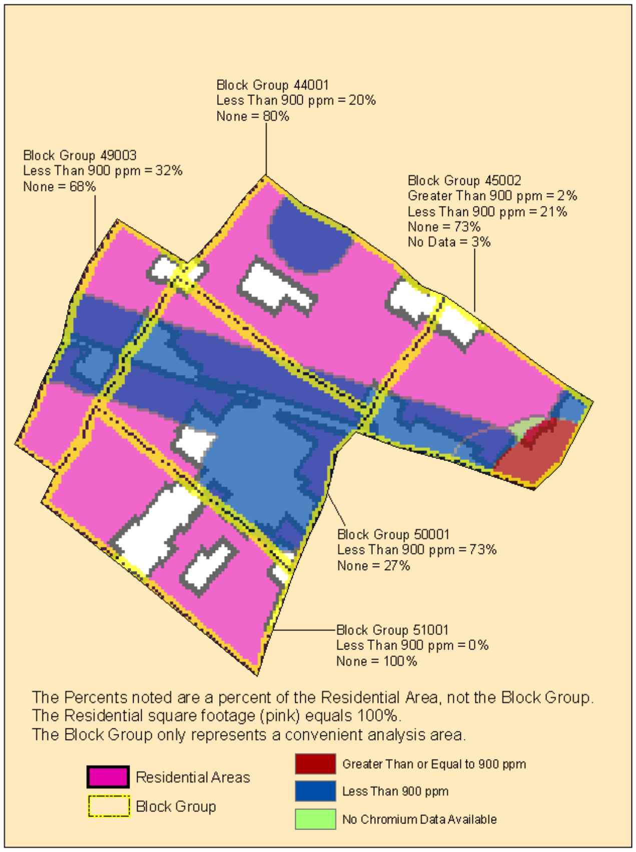


Figure A6. Close up of Buffers (blue, red, and green) Overlain on Residential Areas (pink)

Census Block Group Evaluation

The epidemiologic methods require that the exposure information be structured in a manner that enables it to relate to the Jersey City population data from the U.S. Census Bureau. Consequently, the exposure information was mapped to the U.S. Census Bureau's block group areas. Thus, the final step was to intersect chromium exposure buffers, with the residential area of the 161 census block groups in Jersey City. Figure A7 shows a map of this analysis.

Figure A7. Percent of Buffers (blue, red, and green) for Residential Areas (pink) by Census Block Groups



Residential square footage was determined for each census block group. Each of the 161 block groups were then assigned that residential square footage as 100 percent. Subsequently, the square footage for each category of chromium exposure ($\geq$ 900 ppm, 1-899 ppm, None, or Unknown) was determined for each of the block groups. The square footage for each chromium category was compared to the total residential square footage and a corresponding percentage was calculated. This was performed for all of the block groups.

This process was performed twice. The first iteration was performed assuming the hexavalent chromium to total chromium ratio was 3%. The calculations were performed again, assuming the hexavalent chromium ratio was 14%. Residential areas that were overlapped by more than one site buffer were always assigned the value of the highest hexavalent chromium category occurring. Table A4 provides a listing of each of the census block groups for Jersey City and the proportions of the block group potentially exposed to Cr^{+6}, measured or estimated using both the 3% and 14% assumptions.

Table A4. Proportion of census block group residential areas within 300-foot buffered areas around COPR site boundaries, by hexavalent chromium concentration category, using 3% and 14% assumptions.

Census Block Group	Cr^{+6} Assuming 3% of Total Chromium None	< 900 ppm	≥ 900 ppm	Unknown	Cr^{+6} Assuming 14% of Total Chromium None	< 900 ppm	≥ 900 ppm	Unknown
340170001001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170001002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170001003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170002001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170002002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170002003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170003001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170003002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170003003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170004001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170004002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170005001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170005002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170005003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170006001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170006002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170006003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170006004	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170007001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170007002	0.678	0.322	0.000	0.000	0.678	0.000	0.322	0.000
340170007003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170008001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170008002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170009019	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170009021	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170009022	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170009023	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170010001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170010002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170011001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170011002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170011003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170012011	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170012021	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170013001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170013002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170014001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170014002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170015001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170015002	0.955	0.045	0.000	0.000	0.955	0.045	0.000	0.000
340170016011	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000

Census Block Group	Cr^{+6} Assuming 3% of Total Chromium None	< 900 ppm	≥ 900 ppm	Unknown	Cr^{+6} Assuming 14% of Total Chromium None	< 900 ppm	≥ 900 ppm	Unknown
340170016021	0.742	0.258	0.000	0.000	0.742	0.000	0.258	0.000
340170016022	0.983	0.017	0.000	0.000	0.983	0.017	0.000	0.000
340170017001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170017002	0.926	0.074	0.000	0.000	0.926	0.074	0.000	0.000
340170018001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170018002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170019001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170020001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170020002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170020003	0.497	0.503	0.000	0.000	0.497	0.503	0.000	0.000
340170021001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170021002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170021003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170022002	0.803	0.197	0.000	0.000	0.803	0.197	0.000	0.000
340170022003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170023001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170023002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170024001	0.999	0.001	0.000	0.000	0.999	0.000	0.001	0.000
340170024002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170025001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170025002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170026001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170026002	0.769	0.231	0.000	0.000	0.769	0.000	0.231	0.000
340170026003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170027001	0.973	0.027	0.000	0.000	0.973	0.027	0.000	0.000
340170027002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170027003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170028001	0.997	0.003	0.000	0.000	0.997	0.003	0.000	0.000
340170028002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170028003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170028004	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170028005	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170029001	0.969	0.031	0.000	0.000	0.969	0.031	0.000	0.000
340170029002	0.224	0.776	0.000	0.000	0.224	0.776	0.000	0.000
340170029003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170030001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170030002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170031001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170031002	0.894	0.106	0.000	0.000	0.894	0.000	0.106	0.000
340170032001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170032002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170033001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170033002	0.973	0.027	0.000	0.000	0.973	0.000	0.027	0.000
340170033003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170033004	0.373	0.532	0.095	0.000	0.373	0.071	0.556	0.000
340170034001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170034002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000

Census Block Group	Cr+6 Assuming 3% of Total Chromium None	< 900 ppm	≥ 900 ppm	Unknown	Cr+6 Assuming 14% of Total Chromium None	< 900 ppm	≥ 900 ppm	Unknown
340170035001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170036001	0.615	0.385	0.000	0.000	0.615	0.143	0.242	0.000
340170036002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170037001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170037002	0.286	0.714	0.000	0.000	0.296	0.000	0.704	0.000
340170038001	0.112	0.888	0.000	0.000	0.112	0.000	0.888	0.000
340170038002	0.256	0.499	0.000	0.246	0.256	0.000	0.499	0.246
340170039001	0.582	0.401	0.000	0.017	0.582	0.335	0.066	0.017
340170040001	0.898	0.102	0.000	0.000	0.898	0.102	0.000	0.000
340170040002	0.893	0.107	0.000	0.000	0.893	0.107	0.000	0.000
340170040003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170040004	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170041011	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170041012	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170041013	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170041014	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170041021	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170041022	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170042001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170042002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170042003	0.705	0.295	0.000	0.000	0.705	0.295	0.000	0.000
340170043001	0.976	0.024	0.000	0.000	0.976	0.024	0.000	0.000
340170043002	0.987	0.013	0.000	0.000	0.987	0.013	0.000	0.000
340170044001	0.794	0.206	0.000	0.000	0.794	0.206	0.000	0.000
340170045001	0.933	0.067	0.000	0.000	0.933	0.067	0.000	0.000
340170045002	0.734	0.233	0.002	0.031	0.734	0.215	0.020	0.031
340170045003	0.643	0.295	0.062	0.000	0.643	0.295	0.062	0.000
340170046001	0.611	0.389	0.000	0.000	0.611	0.036	0.353	0.000
340170046002	0.441	0.432	0.127	0.000	0.441	0.000	0.559	0.000
340170047001	0.119	0.881	0.000	0.000	0.119	0.337	0.544	0.000
340170047002	0.363	0.637	0.000	0.000	0.363	0.610	0.027	0.000
340170047009	0.874	0.126	0.000	0.000	0.874	0.031	0.094	0.000
340170048001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170048002	0.998	0.002	0.000	0.000	0.998	0.002	0.000	0.000
340170048003	0.517	0.119	0.363	0.000	0.517	0.119	0.363	0.000
340170049001	0.753	0.247	0.000	0.000	0.753	0.247	0.000	0.000
340170049002	0.625	0.375	0.000	0.000	0.625	0.375	0.000	0.000
340170049003	0.676	0.324	0.000	0.000	0.676	0.324	0.000	0.000
340170049004	0.961	0.020	0.019	0.000	0.961	0.020	0.019	0.000
340170050001	0.274	0.726	0.000	0.000	0.274	0.726	0.000	0.000
340170051001	0.995	0.005	0.000	0.000	0.995	0.005	0.000	0.000
340170052001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170052002	0.456	0.000	0.544	0.000	0.456	0.000	0.544	0.000
340170053001	0.994	0.006	0.000	0.000	0.994	0.006	0.000	0.000
340170053002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170054001	0.980	0.020	0.000	0.000	0.980	0.000	0.020	0.000
340170054002	0.844	0.000	0.156	0.000	0.844	0.000	0.156	0.000

Census Block Group	Cr^{+6} Assuming 3% of Total Chromium				Cr^{+6} Assuming 14% of Total Chromium			
	None	< 900 ppm	≥ 900 ppm	Unknown	None	< 900 ppm	≥ 900 ppm	Unknown
340170054003	0.802	0.198	0.000	0.000	0.802	0.024	0.174	0.000
340170055001	0.548	0.291	0.162	0.000	0.549	0.350	0.102	0.000
340170056001	0.962	0.038	0.000	0.000	0.962	0.004	0.034	0.000
340170056002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170056003	0.937	0.000	0.063	0.000	0.937	0.000	0.063	0.000
340170058011	0.758	0.242	0.001	0.000	0.758	0.020	0.222	0.000
340170058012	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170058013	0.849	0.151	0.000	0.000	0.849	0.151	0.000	0.000
340170058021	0.920	0.080	0.000	0.000	0.920	0.080	0.000	0.000
340170059001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170059002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170059003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170059004	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170059005	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170060001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170060002	0.946	0.000	0.054	0.000	0.946	0.000	0.054	0.000
340170061001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170061002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170061003	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170061004	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170061005	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170062001	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170062002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170063001	0.854	0.109	0.037	0.000	0.854	0.008	0.138	0.000
340170063002	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
340170063003	0.980	0.020	0.000	0.000	0.980	0.000	0.020	0.000