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Airborne Hexavalent Chromium Concentration, Particle Size Distribution, and Contributing Sources in NJ Meadowlands District- A Pilot Study

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Abstract

Airborne hexavalent chromium (Cr-VI) is a known pulmonary carcinogen and can be emitted from both natural and anthropogenic sources, including diesel emission. New Jersey Meadowlands (NJ ML) district is located close to NJ Turnpike (NJTPK), which has high truck traffic volume, and only several miles away from Kearny and Jersey City areas with more than 200 historic chromium waste sites. The Cr-VI contaminated particles may be transported to Meadowlands area and contribute to Cr-VI air pollution. However, Cr-VI was not measured in air quality monitoring programs in ML area. Also, the particle size distribution of Cr-VI in ambient air was not characterized. This pilot study measured the Cr-VI concentration in $PM_{2.5}$ for 2 weeks simultaneously at two sites, MERI site (~ 700 m from NJTPK) and William site (~ 50 m from NJTPK), during one summer and winter season. Cr-VI was detected in all of the field samples, with a mean±SD (median) of 0.52±0.32 (0.47) ng/m^3 at the MERI site and 0.40±0.20 (0.35) ng/m^3 at the William site. These values are marginally higher than Cr-VI in other NJ urban areas, but the difference in Cr-VI concentrations between the two sites was not significant. The Cr-VI distribution as a function of particle size at the William site was also determined by using a MOUDI sampler with 8 particle sizes, ranging from 0.18 to 18 µm. It was found that the Cr-VI was enriched in the particles with diameter less than 2.5 µm. The co-located $PM_{2.5}$ particles collected on Teflon filters will be analyzed for elemental concentrations and will be applied into a US EPA PMF (Positive Matrix Factorization) model to find potential sources contributing to the Cr-VI concentrations monitored in the NJ ML district.

Introduction

- Chromium is mostly found in the airborne particulate matter as two forms: hexavalent chromium (Cr-VI) & trivalent chromium (Cr-III).
- Cr-VI is human carcinogen via inhalation exposure by US EPA.
- Cr-III has limited toxicity compared to Cr-VI.
- Anthropogenic sources account for 60-70%, and major sources are metal processing, coal burning, and fossil fuel emission.
- The NJ ML district is located close to NJTPK with high truck traffic volume and distant only ~5 miles from Kearny and ~10 miles from Jersey city, areas with more than 200 historic chromium waste sites.
- The concentration of Cr-VI in ambient air has not been determined in NJ ML district and the particle size distribution for the Cr-VI has not been characterized in ambient air.

Objectives & Specific Aims

- To determine the hexavalent chromium concentration in $PM_{2.5}$ at two sites (i.e., MERI and William sites) which are located at different differences to the NJ Turnpike (NJTPK) during different seasons (summer and winter).
- To determine Cr-VI distribution as a function of particle size at the site that is close to the NJTPK (i.e. William site) using a MOUDI (Micro-Orifice Uniform Deposit Impactor) sampler.
- To evaluate the potential impact of gasoline/diesel traffic on Cr-VI levels in Meadowlands area by examining the association of the Cr-VI concentrations measured at the two sites with the traffic counts of the NJTPK.
- To examine the effect of meteorological factors and co-located air pollutant concentrations on Cr-VI concentrations.

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Methods

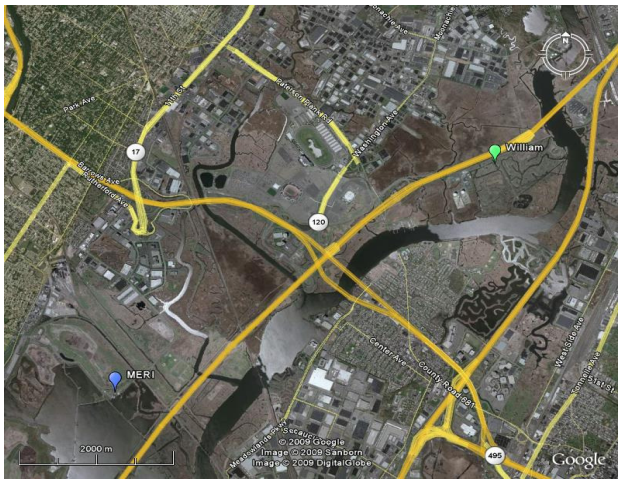

Figure 1. The two sampling locations of William site, distant < 50 m from the NJTPK and rooftop of MERI building, distant > 700 m from the NJTPK (source: Google Earth).

- Sampling
  - Partisol 2000 Air Sampler for $PM_{2.5}$ sampling for 24-hour @ 16.7 LPM.
  - Micro-Orifice Uniform Deposition Impactor (MSRP) for collecting particles between 0.18 ~ 18 µm in diameter for 72-hour (summer) and 168-hour (winter) @ 30 LPM.
  - Before field sampling, 47-mm cellulose filter (VWR) was prepared as acid-cleaned, pretreated with sodium bicarbonate solution, and spiked /w ^{53}Cr-VI and ^{50}Cr-III to monitor interconversions during sampling and analysis.
- Sample Analysis
  - Extraction w/ 5mL HNO_3 (pH=4), sonicated 40 min @ 60ºC.
  - Injection of 400 µL of solution into ion chromatograph for separation Cr-VI and Cr-III.
  - Detection with VG Elemental Plasma Quad 3 ICPMS, dwell time 300 ms.
  - Concentrations were determined by SIDMS (Speciated Isotope Dilution Mass Spectrometry).
- QA/QC
  - No contamination in 9% field and lab blanks, and 28±21% of RPD for 6% duplicate samples.
  - MDL of 0.16 ng/mL, equivalent to 0.032 ng/m^3 in ambient air.

Table 1. Descriptive statistics for meteorological data and ambient air pollutant concentrations concurrently monitored in ML district.

Variables	Unit	Avg±SD	Range	Variables	Unit	Avg±SD	Range
Temperature	ºC	12.7±12	-2.7 ~ 29	Ozone	ppb	18.6±8.9	2.5 ~ 39
RH	%	64.0±10	44 ~ 83	CO_2	ppb	393±25	346 ~ 461
Solar radiation	W/m^2	56.3±42	0.03 ~ 185	NO_X	ppb	30.4±29	9.5 ~ 139
Precipitation	in	0.03±0.1	0.00 ~ 0.4	Gas-MERI	k#/day	112±10	98 ~ 135
Wind speed	m/sec	2.95±1.4	1.3 ~ 6.2	Gas-William	k#/day	78±8	68 ~ 96
Wind direction	degrees	205±77	41 ~ 312	Diesel-MERI	k#/day	17±1	13 ~ 18
Pressure	mmHg	762±4.7	749 ~ 769	Diesel-William	k#/day	13±1	10 ~ 15

Results

Table 2. Descriptive statistics for ambient Cr-VI concentrations (ng/m^3) and $PM_{2.5}$ concentrations (µg/m^3) at the William site and rooftop of MERI building in ML district.

Site	Season	Cr-VI (ng/m^3) N	Mean	SD	Min	Q1	Med	Q3	Max
MERI	Summer	18	0.57	0.38	0.07	0.29	0.48	0.68	1.39
William	Summer	16	0.44	0.25	0.15	0.24	0.38	0.58	0.94
MERI	Winter	16	0.48	0.23	0.23	0.30	0.42	0.58	0.98
William	Winter	14	0.35	0.13	0.22	0.26	0.29	0.43	0.67
Site	Season	$PM_{2.5}$ (µg/m^3) N	Mean	SD	Min	Q1	Med	Q3	Max
MERI	Summer	15	14.1	7.20	5.72	8.36	12.3	17.5	27.5
William	Summer	12	20.4	7.43	14.2	15.2	17.0	22.5	37.2
MERI	Winter	15	8.73	5.63	2.20	3.55	6.91	13.9	20.5
William	Winter	11	13.6	6.85	5.54	8.79	11.2	18.3	27.5

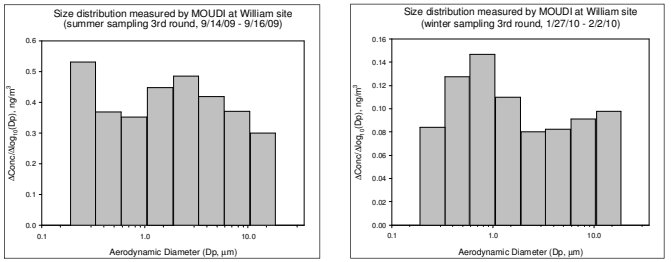

Figure 2. The ambient Cr-VI concentrations as a function of particle size at the William site, < 50 m from the heavy trafficked NJTPK for summer (left) and winter (right) seasons.

Table 3. The final multiple linear regression model to predict Cr-VI concentrations measured in the study.

	Parameter Estimate	Standardized Estimate	p-value	Model/Partial R^2
Cr-VI (N=64)			**<.0001**	**0.4836**
Intercept	-4.05891	0	<.0001	-
Precipitation (in)	2.23342	0.36550	0.0008	0.1565
Diesel traffic (#/day)	0.00008	0.24901	0.0159	0.0680
Downwind direction	0.30958	0.26489	0.0573	0.0663
Ozone concentration (ppb)	0.04732	0.69785	<.0001	0.0645
Temperature (°C)	-0.03141	-0.62993	0.0004	0.0845
Relative humidity (%)	0.02068	0.36157	0.0319	0.0438

Conclusions and Recommendation

- The Cr-VI was more concentrated in fine fraction (e.g., $PM_{2.5}$) than in coarse fraction (e.g., $PM_{2.5\text{-}10}$).
- No difference between MERI and William sites (p>0.05) or between summer and winter (p>0.05).
- The multiple linear regression model explained up to 48% of variability in Cr-VI concentrations measured in the study.
- Ozone is the most significant variable contributing to the increase of Cr-VI concentrations; diesel traffic count also significantly contributes to the increase of Cr-VI in the area.
- A full study is recommended to verify the findings and identify the sources of Cr-VI in the study area.

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