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EXAMINATION OF HEAVY METALS AND PARTICULATE MATTER EXPOSURES AND EFFECTS IN SUSCEPTIBLE WARDS IN THE WASHINGTON, D.C. REGION

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Abstract. The District of Columbia has one of the greatest health disparities of cancer in the nation and ranks seventh highest as one of the unhealthiest places to live due to poor air quality (EPA Report, 1999). Also, a 1999 report from the Centers for Disease Control stated that the District had the highest overall rate of cancer incidence in the nation. Particulate matter is one of the major contributors to pollution in the environment. Quite often particulate matter is composed of toxic materials including heavy metals, pesticides, and spores. In some cases, the heavy metal particulates are considered carcinogenic. They are typically characterized as particles with diameters smaller than 1 μm and are easily deposited into the alveolar regions of the human lungs, which can impose threatening health risks. In this study, I will design and execute an environmental exposure assessment for $PM_{2.5}$, PM_{10}, and heavy metals like chromium, as well as lead, cadmium and arsenic, in four observed wards of Washington, DC. Most interestingly, spatial distributions of both aerosols and heavy metals will be characterized as a function of size and mass properties. This will formulate a limited climatology of both types of particulate matter and selected heavy metals for specific regions within the District of Columbia. This dataset will further be related to epidemiological data and health outcomes for the observed areas of study. The essence of this study lies in its notoriety as the first to generate a dataset that focuses on toxic air pollutants in *particular wards* and may be utilized in various aspects of public health.

Introduction.

Heavy metals are chemical elements that have a specific gravity (a measure of density) at least five times that of water. Naturally, they are components of the Earth's crust and cannot be degraded or destroyed. Once emitted, metals can reside in the environment for hundreds of years or more (Nriagu, 1996). Heavy metals often result in human poisoning due to their toxicity in large quantities. This poisoning of soft human tissue can and often does result in cramps, nausea, vomiting, diarrhea, stomach pain, headache, sweating, and a metallic taste in the mouth. Some of the metal particulates indicated in these effects are lead, mercury, arsenic, cadmium, zinc, and chromium. Moreover, some heavy metals, such as chromium, act as carcinogens, causing cancer, and may result in detrimental effects. There are at least five metallic elements in one form or another accepted as human carcinogens by the International Agency for Research on Cancer (IARC), including arsenic, cadmium, hexavalent chromium, and inorganic lead compounds (Sarkar, 2002). This study will focus on these heavy metals. In general, sources of heavy metal particulates are waste incinerations, electroplating, industrial facilities, smelters, and fertilizers.

The two largest sources of chromium emission in the atmosphere are from the chemical manufacturing industry and combustion of natural gas, oil, and coal. Other sources are cement-producing plants, wearing down of asbestos brake linings from automobiles, incineration of municipal refuse and sewage sludge, exhaust emission from catalytic converters in automobiles, welding, textile manufacturing, photo engraving, wood preservatives, ceramics manufacturing, and glassmaking (ATSDR, 1989). Human exposure to chromium is by ingestion of food and water and by inhalation of airborne particulate. When used in industrial processes, chromium is often converted to hexavalent chromium (chromium VI), which can be detrimental to human health and characterized as a human carcinogen. One of the major health risks is the development of lung cancer. There are also genotoxicity effects, such as DNA strand breaks, increasing chromium levels in plasma, and the alteration in the number of sister chromatid

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exchanges in the lymphocytes of exposed individuals.

Generally, human exposure to lead comes from using leaded gasoline, lead-based paint, having lead pipes in water supply systems, radiator repair shops, and exposure to some industrial sources. Some of those industrial processes are lead mining, smelting, welding, and coal combustion. Additionally, lead is used for many consumer products, including lead-acid batteries, metal products, ammunition (firing ranges), and ceramic glazes. The most significant contributors to lead emissions into the atmosphere are lead gasoline additives, smelters, and battery plants. In the U.S., lead and zinc processing facilities account for a large portion of lead released into the environment. According to EPA's Toxic Release Inventory (TRI), reporting industries released more than 370 million pounds of lead and lead compounds into the environment in the year 2000 (EPA 2000 TRI Public Data Report).

Arsenic is ubiquitous in our environment and has both natural and anthropogenic sources, the atmosphere being the major transport pathway for this element (Hutchinson and Meema, 1987). Total arsenic emissions into the atmosphere from anthropogenic sources are on the order of 75,000 tons/year (Gomaine website – As.html). About 60% of those results from two major sources, copper smelting and coal combustion. Other primary sources are wood preservatives, insecticides, leaded gasoline, glass production, and electronic manufacturing, such as microwave devices, lasers, and semiconductor devices.

Some of cadmium's sources are metal plating industries, sites using pigments in plastic, ceramics and glass manufacturing, welding, and smelting. The two largest sources of cadmium to the environment are fossil fuel emissions and incineration of municipal wastes (ATSDR – Toxicological Profile for Cadmium, 1999). According to the EPA's Toxic Release Inventory, reporting industries released more than 9 million pounds (9,000 tons) of cadmium and related compounds into the environment in the year 2000.

It is well known that the D.C. area has one of the greatest health disparities in cancer in the nation. Yet, there have been few publications regarding the effects of chromium and other heavy metals in the D.C. environment and none, particularly discussing its relation to epidemiological data.

Discussion of Selected Wards.

Four wards have been selected for this study. Those wards are: Ward 1, Ward 4, Ward 5, and Ward 7 (refer to Figure 1). Each of these wards has characteristics of interest to this projects' mission. More than others, Ward 4 is of special concern due to its persistently high cancer death rate (average of 246) according to the DC Public Health data from 1995 to 1999, as shown in Table 1. Ward 5 is running a close second to this data with an average of 214.4 cancer deaths per 100,000 persons. A recent report in The Washington Post stated that Washington, D.C. had the highest overall rate of cancer incidence (667.1) during 1999 in the nation (refer to Table 2). It also stated other important facts regarding D.C. cancer rates, such as: prostate cancer for whites was 144 cases per 100,000 population, whereas blacks was 275, a 91% increase; lung cancer had a rate of 63.7 cases per 100,000 population, whereas blacks more than doubled that number with 134.6. The primary focus of this study is to relate this data, particularly lung and prostate cancer, to exposures of heavy metals, such as chromium.

Table 1

CANCER DEATH RATE DURING 1995 - 1999 FOR SELECTED WARDS IN WASHINGTON, D.C.

	Ward 1	Ward 4	Ward 5	Ward 7
1995	139	265	238	213
1996	137	250	224	197
1997	112	218	191	155
1998	136	265	209	179
1999	134	232	210	183
Average	131.6	246	214.4	185.4

Table 2

COMPARISON OF CANCER INCIDENCE RATES FOR MALES (1999)

Region	All Races	White	Black
U.S.	552.3	542.0	617.4
D.C.	667.1	453.9	758.7
L.A., CA	497.1	490.1	597.5
New York	537.9	531.0	517.6
Florida	587.5	582.1	627.3
Arizona	458.9	465.0	457.9
Idaho	503.6	506.5	N/A

http://www.cdc.gov/cancer/npcr/uscs/report/Incidence_Area/table211.htm

Ward 1 is home to Howard University and Adams-Morgan. It is mostly residential, with more than 80% of its land devoted to housing units. Ward 1 includes both Howard Hospital and Washington Hospital Center, which much of the data collected stems from. It has a population of 73,364 with 45.7% Black, 31.7% White, 24.7% Hispanic, and 3.5% Asian.

Ward 4 encompasses the northern-most point in the district with 87% of its land devoted to residential use, which is the highest percentage of any ward. A stretch of the city's longest commercial corridor, Georgia Avenue, runs down in the middle of Ward 4. There is a population of 74,092 with 70.7% Black, 17.7% White, 12.5% Hispanic, and 1% Asian.

Ward 5 is home to two major commuter arteries, New York Avenue and Rhode Island Avenue, which are gateways to the District. The ward has more industrial acreage than any other in the city, including welding and cementing facilities. The population is 72,527 with 86.7% Black, 9.4% White, 2.6% Hispanic, and 0.8% Asian.

Last, Ward 7 uses about half of its land as parkland. The ward sits on the right bank of the Anacostia River. This area could be used as a background source, due to its lack of industrial and residential zones. The population in Ward 7 is 70,540 with 96.8% Black, 1.4% White, 0.9% Hispanic, and >>1% for all other.

Scientific Objectives.

Through the development of this study, the following questions are to be addressed:

- Is there a meaningful statistical relationship between aerosol-borne toxins or heavy metals (Cr, Pb, As, Cd) and any significant health indicators in the Washington, D.C. area? Can a specific connection to cancer be made?

- Is there a seasonal (Summer and/or Fall) variability in toxic exposures of heavy metals in the Washington, D.C. region?

The objectives of this study are two-fold. The study will develop a climatology and accurate exposures statistical model for particulate matter and heavy metals (Cr, Pb, As, Cd) in the four chosen wards of Washington, DC during both the summer and fall. The measurement data sets will then be compared and related to the epidemiological data and health outcomes as noted by the D.C. Public Health Department. The power of this study lies in its ability to quantify emitted heavy metals and particulate matter to the amount that people are exposed to via air in selected wards of Washington, DC. During the year 1999, EPA reported the following emissions data for the District of Columbia: $PM_{2.5}$ (200 Tons/yr), PM_{10} (390 Tons/yr), Chromium Compounds (189 Pounds/yr), Lead Compounds (834 Pounds/yr), Arsenic Compounds (63.6 Pounds/yr), and Cadmium Compounds (70.9 Pounds/yr).

Operational Strategy and Instrumentation.

The project will be implemented in four distinct phases. The first phase will develop a study to determine all possible heavy metal exposure pathways in the Washington, D.C. environment and produce an emissions inventory focused on heavy metal particulate matter. This will provide the baseline for identifying measurement needs for the following phases. The second phase will execute a focused field measurement campaign in D.C. to quantify heavy metal exposures near known sources and in neighborhoods having high cancer incidences. Phase three will incorporate

the emission inventory and measurement data from phases one and two to refine the particulate matter exposure for each ward in the D.C. area and for individually high-risk neighborhoods. This will be integrated into a GIS database to perform a spatial analysis of the heavy metal exposure pathways in each of the four chosen wards. The fourth phase is designed to bring a closure to the project. Consultation with environmental toxicologists and medical researchers will occur to determine whether the type of heavy metals detected and levels of exposures are significant in relationship to DNA damage or genotoxicity effects.

The experimental equipment needed for this study ranges from a laser particle counter (LPC), to measure in situ aerosol data in the D.C. area, to a scanning electron microscope used to gain elemental compositions of collected heavy metals. A CLiMET Instruments 500 and 550 LPC has been proven efficient for such research and will be utilized throughout this project. They provide both number densities and size distributions for six stages of measurements. Those stages for the CLiMET 500 are: > .3, > .5, > 1.0, > 5.0, > 10, and > 25 μm. The stages change slightly for the CLiMET 550, with the removal of the > 25 μm stage and the addition of the > 3.0 μm stage. The operation of these LPC instruments focuses on the procedure of electron dispersion. The energy released from the charged particles within the LPC reveals the size and concentration of those particular particles. Secondly, a quartz crystal microbalance (QCM) cascade impactor is needed to obtain size and mass properties of particulate matter. The QCM also provides six stages (0.15, 0.3, 0.6, 1.2, 2.5, and 5.0 μm) of measurements. The aerosols collected in this study will focus on diameter ranges of 2.5 microns or less. To complete the analytical period of the sampling plan or the post analysis, scanning electron microscopy, mass spectrometry, and a micro-FTIR is useful in determining the types of aerosols collected, particularly in determining elemental compositions and molecular information. This instrumentation will reveal the heavy metals that were collected during sampling.

The plan for the intensive operational period (IOP), or the portion of the study dedicated to the field measurements, is to complete the data collection for all four wards once each week for a consecutive six-week period. This will result in sampling about 7-9 sites per day (Ward 1 - 7 sites, Ward 4 – 9 sites, Ward 5 – 9 sites, Ward 7 – 7 sites), as shown by the points noted in Figure 1. This IOP will be carried out for both the summer and fall period so that a comparative analysis of the two seasons can be completed. The summer IOP has been completed and is now in its final stage of analysis. Thus, some *preliminary* conclusions have been made due to the lack of chemical analyses for the summer data and fall measurements.

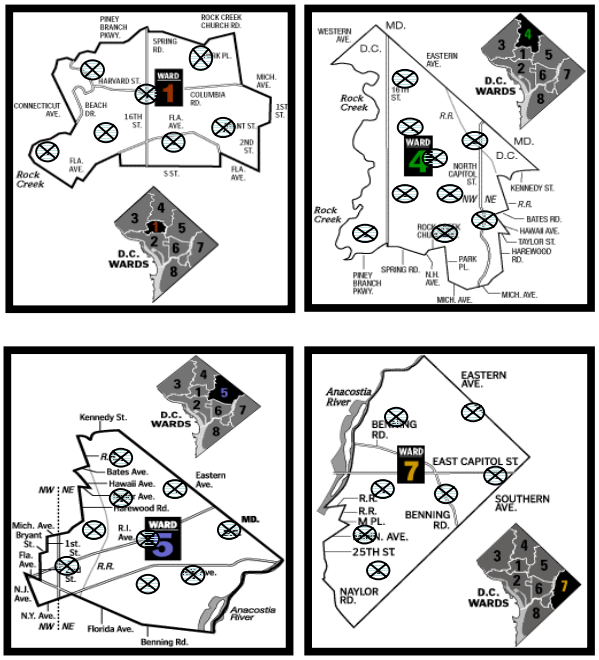

Figure 1. Sampling Wards and Site Locations

Preliminary Analyses.

The summer IOP weekly charts of averaged concentrations for each selected ward showed that there are peak concentrations on *different* days of the week for each ward (refer to Figures 2-5). For instance, Ward 1 has its peak concentration on Tuesday and Ward 4 has its peak on Thursday. One possible reason for this outcome is rain influence. The meteorological data collected (not shown here) has reflected that the day with a higher relative humidity in a particular ward, neglecting days that had rain influences, yields higher concentration of the 0.3 μm particles, and thus the peak concentration for the week. This can be supported by the fact that rain is a form of wet deposition and acts as a sink to atmospheric particles, by washing out the air, thus lowering the concentration of subsisting particles. Yet, these particular influences now

present the biggest challenge to analyzing the data because a *typical* summer in the Washington, D.C. area is not as inclined to rain. Hence, the data collected in the 2003 summer IOP tends to differ from trends, in which higher values of $PM_{2.5}$ emissions are in the peak of the summer season, and lower values in the fall, spring, and winter months due to *precipitation*, lower temperatures, and snow.

Another possible reason for the results is wind trajectories. Currently, we are working on a wind climatology that correlates to the sampling period. GIS applications will provide further insight into this output due to spatial analysis of the data and VIS 5-D applications will yield animated sequences of the data collected, including overlaps of latitude, longitude, concentration of $PM_{2.5}$, and wind measurements.

Analyses of the weekly average concentrations for each selected ward showed that each peak day, the day with the highest concentration value, focused on the 0.3 μm mode size. This is the common diameter size of aerosols that act as carriers for heavy metals throughout the atmosphere, thus plays an extremely significant role in the study. Data also reflected that Ward 4 consistently ranks highest in concentration values for both $PM_{2.5}$ and PM_{10} (refer to Figure 6).

The charts of mass distribution reveal that the 0.3 μm particle distribution for all wards coincides with the ranking of cancer incidence rate in the D.C. area (Figures 7-8), which may yield pertinent information in the development of this project.

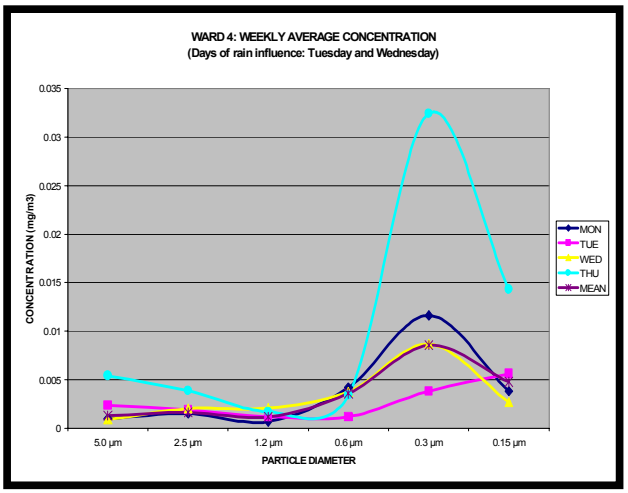

Figure 3. Ward 4: Weekly Avg. Concentration

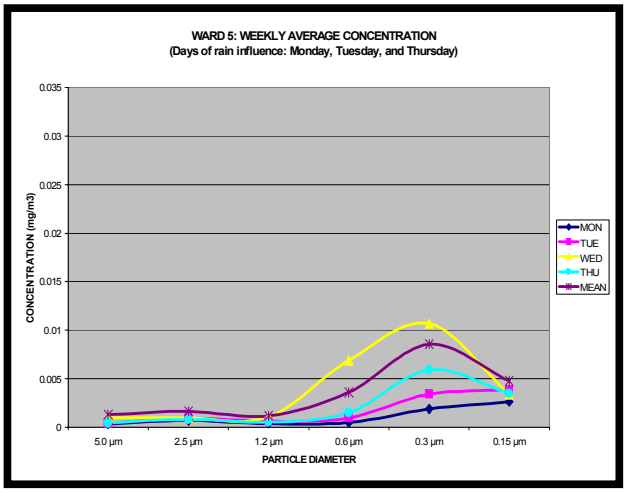

Figure 4. Ward 5: Weekly Avg. Concentration

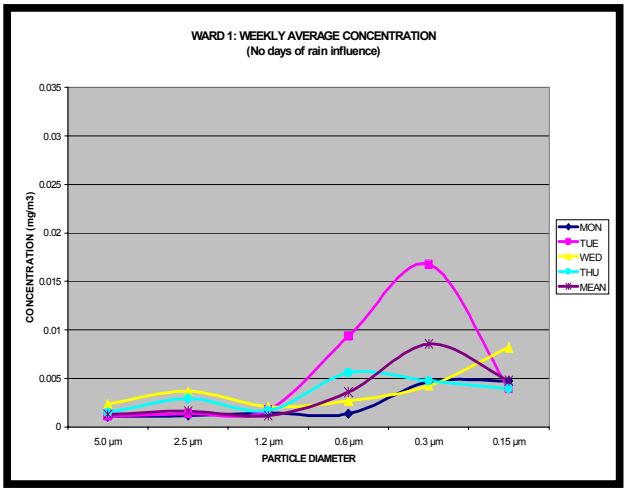

Figure 2. Ward 1: Weekly Avg. Concentration

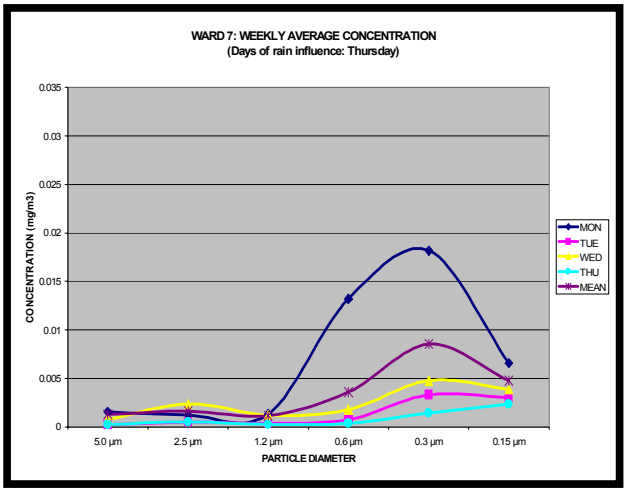

Figure 5. Ward 7: Weekly Avg. Concentration

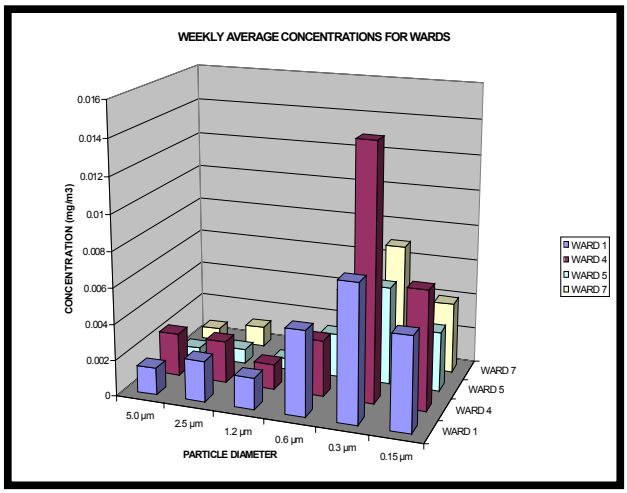

Figure 6. Weekly Avg. Concentration Chart

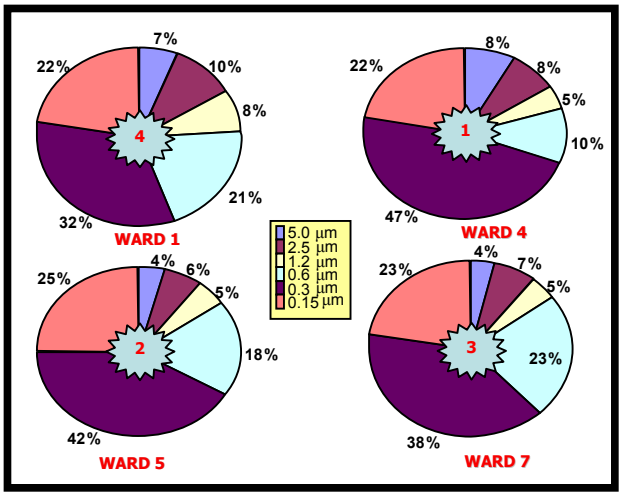

Figure 7. Mass Distribution of Particles

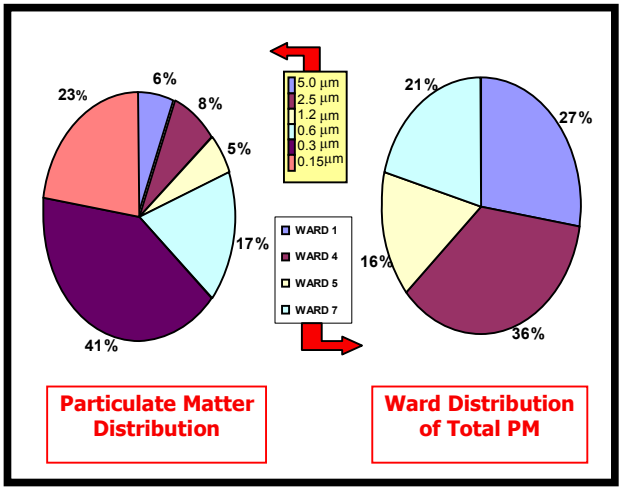

Figure 8. Mass Distribution for All Wards

Future Plans.

The future plans for this study are to:

- Continue with the Fall IOP, which consists of data measurements from late October thru early December.
- Gather surface meteorological data, such as relative humidity and temperature fields, and surface wind fields to correlate to the summer IOP dataset
- Use GIS applications to divide contours of these fields and get a visual of the demographics
- Use VIS 5-D applications to determine the effects of the wind trajectories through animated sequences of the data and to overlap data components (latitude, longitude, concentrations, wind)
- Consultation with toxicologists to relate the epidemiological health data to sample analysis.
- Last, but not least, comparative analysis will be done to see the differences and/or similarities between the summer and fall measurements.

Conclusion.

In retrospect, this project outlines significant concerns for both Howard University and for the public. It clearly addresses environmental health issues and seeks to improve our understanding of the impacts of particulate matter on public health. Particularly, it may aid by determining and identifying heavy metal exposure pathways and generating a limited climatology for future use with various aspects of public health. It will aid the scientific arena in its mission to provide a safer environment for their civilians by better controlling the air quality through mitigation of toxic heavy metals and particulate matter. Thus, this project presents the opportunity to better the quality of air for mankind and perhaps curtail the atmospheric exposures to possible carcinogenic agents.

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