Exhibit Q
DECLARATION OF TIMOTHY PORTER

I, Timothy Porter, declare as follows:

1. I submit this Declaration in support of Plaintiff Wheelabrator Baltimore’s Reply in Support of Plaintiffs’ Motion and Opposition to Defendant’s Cross-Motion for Summary Judgment. I am competent to testify to the facts set forth below and will so testify if called as a witness in this case.

2. I am the Director of Air Quality Management for Wheelabrator Technologies, Inc. (“Wheelabrator”). I have been employed by Wheelabrator in this position for 33 years.

3. I have been working in the air quality management, air permitting, and air pollution control industry for 40 years and hold a bachelor degree in environmental studies. I have participated in numerous state and EPA committees or work groups tasked with developing continuous emission monitoring and stack emission testing requirements for the waste to energy (“WTE”) industry.
4. In my capacity as the Director of Air Quality Management, I oversee compliance with all applicable clean air laws and regulations of all fifteen Wheelabrator WTE facilities located in the United States, including the Wheelabrator Baltimore WTE facility ("Wheelabrator Baltimore" or "WB") located at 1801 Annapolis Road in Baltimore, Maryland. I also have primary responsibility for emission control optimization and development, selection of continuous emission monitoring system technologies, management of EPA emission testing programs, and state and federal air regulation review and comment for all Wheelabrator facilities.

5. I was responsible for developing and submitting compliance plans for retrofitting Wheelabrator WTE facilities to come into compliance with the Large Municipal Waste Combustor standards under 40 C.F.R. § 60 subparts Eb and Cb. I am also responsible for the Title V and other air permitting activities for all Wheelabrator facilities.

6. This Declaration sets forth, to the best of my personal knowledge, facts pertaining to (i) the air quality and impacts of WB’s air emissions; (ii) the environmental benefits to the City of Baltimore and the region provided by WB; and (iii) the current permitting status of the WB facility and certain conflicts with the Baltimore Clean Air Act ("the Ordinance").

Public Health Impacts

7. Suggestions in the City’s October 15, 2019 brief [ECF 39] that the Wheelabrator Baltimore facility is a threat to public health are unfounded. Multiple scientific studies conducted in recent years confirm that the emissions from the facility result in minimal air quality impacts and do not threaten public health. Air pollution concerns in Baltimore are driven by emissions from gasoline and diesel fueled vehicles, which dwarf the emissions from Wheelabrator Baltimore. On an emission source category basis, WB emissions represent just 2% of total
emissions of CO, NOx, SO2, PM10, PM2.5 and VOCs from the top 20 source categories in the city. See U.S. EPA National Emissions Inventory database (2014). Gas and diesel fueled highway automobiles and trucks are the largest emission source category in the City, representing 47% of all emissions. See id. As various studies have indicated, including the Environmental Integrity Project’s (“EIP”) 2017 study funded by the Abel Foundation, traffic related air pollution is the most probable source of poor air quality and high asthma rates in cities given vehicle emissions are at or near ground level and are not dispersed, leading to higher exposure levels. These studies are summarized below:

8. **2018 – TRC Air Dispersion Study of Emissions from the Facility.** In June of 2018, TRC Environmental Corporation, a nationally recognized expert in air modelling, permitting, and risk analysis, performed air dispersion modeling to assess potential air quality impacts of the Wheelabrator Baltimore facility. See Wheelabrator Baltimore Air Modeling Report, dated June 29, 2018, Attachment 1. The modeling analysis used both potential and actual emissions from the facility and showed that impacts of the facility’s emissions are well below the United States Environmental Protection Agency’s (“EPA”) health-based air quality standards for air pollution. Id. at 9. Ambient air quality standards set by EPA and MDE are intended to protect public health with an adequate margin of safety. According to EPA ([https://www.epa.gov/criteria-air-pollutants/naaqs-table](https://www.epa.gov/criteria-air-pollutants/naaqs-table)), these standards “provide public health protection, including protecting the health of ‘sensitive’ populations such as asthmatics, children, and the elderly.”

1. The air quality modeling was conducted using the latest EPA air modeling guideline to compare air quality impacts from Wheelabrator Baltimore emissions to EPA’s National Ambient Air Quality Standards (“NAAQS”) and to existing background
levels. The highest Wheelabrator Baltimore emission levels from 2015-2017 were used to ensure that the air modeling was conservative, i.e., would show maximum worst case impacts. Id. at 1, 4.

b. The results of the air dispersion modeling show that maximum air quality impacts from Wheelabrator Baltimore emissions are well below EPA's NAAQS. Further, when facility impacts are added to background air quality data taken from Maryland Department of the Environment ("MDE") air quality monitoring sites around the city, Wheelabrator Baltimore's impacts remain well below the NAAQS and thus are protective of public health. Id. at 6-9.

9. **2019 – CPF Associates Study of Asthma in Baltimore.** This is a comprehensive scientific study performed on air emissions from the Wheelabrator Baltimore WTE facility in 2019. This study combined two independent reports from an air modeling consultant, TRC Environmental Corporation,¹ and an environmental epidemiologist, Dr. Rafael E. Guerrero-Preston,² into a comprehensive evaluation of air concentrations from facility emissions and a bio-statistical analysis of facility air concentrations and city asthma rates by city zip code. Additionally, Ben Hoffman, a physician with a master's degree in public health and CPF Associates LLC, an environmental science and health risk specialist consulting firm, provided overall support for the study. The study rigorously compared air concentration levels from facility emissions in the city to confirmed cases of asthma over a multi-year period and concluded that there was no significant association between city asthma rates and air

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¹ *Dispersion Modeling Analyses Baltimore RESCO Facility - In Support Of Asthma Study*, TRC Environmental Corporation, August 2019.
² *Hospital and emergency room asthma discharge rates are not associated with fine particulate matter, nitrogen dioxide or sulfur dioxide air concentrations due to emissions from waste-to-energy facility in Baltimore City*, Rafael E. Guerrero-Preston, Dr. PH., August 2019.
concentrations from facility emissions. The study found that asthma rates were strongly or significantly associated with social determinants of health such as homeownership rates, median family income level, and housing vacancy within the city. The study also included a summary of numerous scientific research papers on urban asthma rates which similarly confirm social determinants of health which also includes family history, diet, home conditions, and household smoking, were important drivers of asthma rates within cities. The study concluded that “[e]levated asthma rates that have been documented in Baltimore are similar to those in many other large urban areas in the US. These similarities are likely to be related to the importance and presence of social determinants of health as well as traffic related air pollution which has been shown in scientific studies to be a major factor affecting asthma rates in cities.” CPF Associates, LLC’s Evaluation of Asthma Emergency Room and Hospital Discharge Rates in Relation to Ambient Air Concentrations Associated with the Wheelabrator Waste-To-Energy Facility (“CPF Study”), dated September 25, 2019, Attachment 2.

a. The CPF Study further showed that the incremental impact of WTE facility emissions on annual average air concentrations was negligible compared to annual average background levels. Id. at 11. Further, modeled concentrations of facility emissions were orders of magnitude below detection limits of EPA and MDE ambient air quality monitors for particulate matter, nitrogen dioxide, and sulfur dioxide. Id. at 11, 25. The importance of this finding is that there likely would be no measurable impact on annual air quality within the city if the facility was forced to close as a result of the Ordinance.

b. The interdisciplinary team compiled and analyzed data from MDE and other scientific research sources, and used an EPA-approved air modeling protocol to
estimate annual air concentrations from emissions of the WB facility and evaluate the potential to impact asthma rates at the city zip code level. *Id.* at 7, 11, 24.

c. The CPF Study corroborates a 2017 study of asthma in Baltimore by a major public interest group, EIP. *Id.* at 23. The EIP study found "a very strong spatial correlation between the asthma hospitalization and emergency room visits in Baltimore’s zip codes and demographic measures of poverty, particularly median household income.” *Id.* EIP wrote, “it is likely that on-road vehicles are the largest contributor to the air pollution that people breathe in Baltimore” and “there is significant overlap between areas with relatively high roadway traffic pollution and high asthma hospitalization rates in the center of the city and in parts of East and West Baltimore.” *Id.* The EIP study further concluded that “there is not a significant association between city zip codes with the highest emissions of criteria pollutants from stationary facilities and the zip codes with the highest asthma rates.” *Id.*

d. Finally, Wheelabrator Baltimore operates under emissions limits set by EPA and MDE that are science-based and designed to protect public health with an adequate margin of safety. Since it opened in 1985, the facility has added substantial new emission control systems including spray dryer absorbers to reduce acid gases such as hydrogen chloride and sulfur dioxide and selective non-catalytic reductions system ("SNCR") to reduce NOx emissions and carbon injection systems to reduce mercury and dioxins. These additional controls were required to meet more stringent emissions limits pursuant to transparent and prescribed statutory and rule making processes followed by EPA and MDE.
10. **2019 - Study of toxic air pollutants required by Maryland Department of the Environment.** A separate study in 2019 on toxic air pollutants emitted by Wheelabrator Baltimore confirmed that air concentrations from facility emission are significantly below levels determined by MDE to be protective of public health. *See* Toxic Air Pollutant Evaluation, dated September 19, 2019, Attachment 3. Maryland’s toxic air pollutant (“TAP”) regulations require sources such as Wheelabrator Baltimore to quantify emissions of toxic air pollutants, apply best available control technology for toxics, and demonstrate that impacts from those emissions will not adversely affect public health by meeting a specific health risk-based ambient air quality screening level for each TAP. COMAR 26.11.15, *et seq.* Wheelabrator Baltimore complies with these standards and submits updated toxic air pollutant compliance demonstrations as necessary or when requested by MDE.

   a. In September of 2019, Wheelabrator Baltimore completed a TAP analysis. Wheelabrator Baltimore used EPA air dispersion modeling to calculate maximum 1-hour, 8-hour, and annual impacts of TAPs emitted from the facility for comparison to acceptable ambient screening levels for TAPs developed by MDE. Attachment 3 at 1. Wheelabrator Baltimore performed the analysis using the highest level of refinement of MDE’s “Demonstrating Compliance with the Ambient Impact Requirement under the TAP Regulations.” *Id.*

   b. For nine out of ten TAPs, emission impacts are an order of magnitude or more below MDE acceptable TAP screening levels, which are the concentrations of a TAP in the atmosphere used to evaluate the air quality impacts of a facility. *Id.* at 15. For the tenth, hydrogen chloride, the emission impact is at 15% of the MDE acceptable screening level. *Id.* at 16. This data demonstrates that emissions of TAPs from
Wheelabrator Baltimore do not adversely affect public health because emissions from these pollutants fall well below their respective TAP screening levels.

c. Furthermore, the area of maximum annual impact for emissions from the facility is approximately 1,000 meters East / South East of Wheelabrator Baltimore on I-95, and the maximum 1-hour and 8-hour impacts are in a commercial/industrial area between Horseshoe Casino and M&T Bank Stadium. Id. at 15-17. Thus, all maximum impacts are not in residential areas.

11. The above studies show that the City’s allegations that emissions from the Wheelabrator Baltimore facility pose a threat and must be drastically reduced are not supported by accepted air quality and public health risk assessment principles. EPA and Maryland standards for the facility already protect public health by a wide margin.

Environmental Benefits of the Wheelabrator Baltimore Facility

12. The City overlooks the collateral environmental benefits of the Wheelabrator Baltimore WTE facility.

a. Major energy and environmental benefits flow to the City from Wheelabrator Baltimore. As the City has confirmed, WB is a source of enough "clean, renewable energy" to power tens of thousands of homes, and "provides many benefits to the City." ECF 35-6 at 62-63. WB produces 510,000 pounds of steam per hour. A portion of that steam is used to heat 225 downtown businesses, including M&T Bank Stadium. ECF 39-7 at 8.

b. Because the WB facility is a major clean energy producer, Maryland has designated it as a Tier 1 renewable resource under Maryland’s Renewable Portfolio Standard. See Md. Code Ann. Pub. Util. § 7-701. Likewise, EPA considers WTE

c. By managing its waste at WB, “the City saves valuable landfill space while also contributing to vital, alternative energy production.” ECF 35-6 at 70. The City’s Solid Waste Management Plan estimates that the WB facility reduces the volume of landfill space that the debris would otherwise occupy by up to 90%. WB provides “a net carbon reduction” compared to landfiling, and recycles nearly 6,000 tons of scrap metal from the City’s waste stream each year. Id. at 44, 70.

Air Emissions Permitting for Wheelabrator Baltimore

13. The WB facility is an existing large WTE facility subject to federal and state regulation under 40 C.F.R. § 60, subpart Cb, implemented through COMAR 26.11.08.08. MDE issued WB its first Title V permit on November 5, 2001 and its current permit on April 1, 2014. The WB facility’s Title V permit incorporated all applicable Clean Air Act and state requirements for nitrogen oxides, sulfur dioxides, mercury, and dioxin/furans, among other regulated pollutants. The Title V permit also required a continuous emissions monitoring system (“CEMS”) for nitrogen oxides, sulfur dioxides, and carbon monoxide, plus continuous opacity monitoring system (“COMS”) for opacity.

14. Contrary to the City’s erroneous assertion, WB has a current Title V permit. Wheelabrator in 2019 applied for a renewal of its Title V permit and received an application completeness determination, which by law extends the current Title V permit indefinitely until
the permit renewal is issued. WB’s Title V permit application was the subject of a period of public comment and the City did not object or otherwise comment on WB’s application.

15. The WB facility is an existing large Municipal Waste Combustor ("MWC") [also known as WTE] facility subject to federal and state regulation under the Clean Air Act since it began operations in 1985. The Clean Air Act Amendments ("CAA") of 1990 required EPA to promulgate regulations and emissions guidelines ("EG") reflecting the maximum achievable control technology ("MACT") for nine specific pollutants that Congress and EPA deemed to be of most concern for solid waste combustion facilities, including MWCs. The CAAA also required that states implement and enforce the promulgated MACT standards and EG in an EPA-approved state plan, as MDE has done in Maryland. The MACT standards and EG were promulgated by EPA in 1995 and MDE state plan approved by EPA in June 1999. WB installed extensive new air pollution controls and complied with the new MACT EG in December 1999.

16. As also required by the CAAA, EPA must review and revise the MACT standards every five years. The EG were revised in 2006 making the regulations more stringent for certain pollutants. Maryland incorporated these EPA amendments verbatim in October 2007, and the revised EG standards became effective on April 28, 2009. COMAR 26.11.08.08.

17. This steady pace of stricter EPA and MDE regulations has been accomplished through public notice and comment rule making and a vast scientific record. WB has invested tens of millions of dollars in upgrades to the facility to meet these standards and has relied on the regulatory certainty provided by this orderly federal and state governance of the facility’s environmental performance.

18. Most recently, in 2017, MDE conducted a rulemaking to further tighten its regulations regarding WTE facilities and lower the nitrogen oxides emission limit to implement
Reasonably Available Control Technology ("RACT") pursuant to the federally enforceable State Implementation Plan ("SIP") to meet the federal ozone ambient air quality standard. In 2018, MDE adopted a final rule for inclusion in its SIP reducing the WB facility's nitrogen oxides emission limit to 150 ppmvd effective May 1, 2019, and further reducing the limit to 145 ppmvd effective May 1, 2020. COMAR 26.11.08.10. MDE's final rule also requires that no later than January 1, 2020, WB submit to MDE a feasibility analysis conducted by an independent engineer for the additional control of nitrogen oxide emissions, and propose with it new nitrogen oxides RACT limits based on the results of the feasibility analysis. COMAR 26.11.08.10.E. The objective of the study is for MDE to determine if further NOx reductions could be achievable using RACT As MDE discussed in the Technical Support Document to the NOx RACT regulation: "Adding SCR NOx emission control technologies, or other comparable NOx emission reduction strategies, would likely not be considered RACT because of the complex design requirements and cost issues. SCR NOx emission control strategies are standard equipment on new Large MWCs. The intent of the feasibility analysis is to evaluate what lower NOx RACT emission limit could be achieved at Wheelabrator Baltimore Inc. without a re-build of the entire facility." ECF 39-3 at 9.

19. Likewise, the stack test results for the recently constructed Palm Beach, Florida, WTE facility cited by the City are not relevant to determining appropriate permit limits for an existing facility like WB. This is due to the difference between designing a new facility to incorporate the latest technology versus the difficult engineering and economic challenges associated with retrofit of an existing facility. As noted above, MDE rules require that a feasibility study be conducted on NOx control technologies that could further lower nitrogen oxide emissions, including SCR. Also, the Palm Beach WTE facility's stack test results provide
only a snap-shot of emissions at one point in time that does not reflect performance or variability of emissions over longer periods. Regulators do not set permit limits based on one stack because one test does not determine whether the same emissions can be sustained over a period of time, as needed to establish an achievable emission standard. WTE facility emissions vary substantially based on the inherent variability of the waste stream (including seasonal variability), and operational factors including moisture levels, temperature, and other factors. ECF 39-7 at 6. To ensure compliance with 24-hour and 30-day rolling average emission standards, a facility's typical actual emissions will generally be well under those limits to account for such variability. Finally, the City's brief provides only a paper presented at a conference that discusses the stack test results and not the results themselves. ECF 39-1.

**Continuous Emissions Monitor Systems as Required Under Federal and State Law vs. the Ordinance**

20. The City's brief and exhibits also provide an inaccurate portrayal of the Ordinance's requirements for CEMS. The fact remains that there is no validated, EPA approved CEMS for WTE facilities for all of the pollutants that the City demands be monitored.

21. Under Sections 111 and 129 of the Clean Air Act, its implementing regulations, and MDE's regulations for large, existing WTE facilities, Wheelabrator Baltimore is required to install, calibrate, operate, and maintain CEMS for nitrogen oxides, sulfur dioxides, and carbon monoxide, and COMS for opacity, a surrogate for particulate emissions. In addition, WB is required to monitor operational indicators including boiler steam flow, air pollution control temperature, and carbon feed rate to ensure these remain within established ranges that ensure other emissions such as trace metals and dioxins are minimized and emission limits are achieved. See 42 U.S.C. § 7411; 42 U.S.C. § 7429(c); 40 C.F.R. §60.58b; COMAR 26.11.08.08.
22. These federal and state regulations also require that Wheelabrator Baltimore obtain valid emissions data for a minimum of 90% of operational hours per calendar quarter, and 95% of operational hours per calendar year that the facility is combusting municipal solid waste. See 40 C.F.R. § 60.38b; 40 C.F.R. § 60.58b; COMAR 26.11.08.08. These availability criteria were established as EPA and MDE recognized that CEMS and COMS must be taken offline for calibration and maintenance, making it impossible to gather data during 100% of operational hours.

23. In its Final Rule governing existing WTE facilities, EPA explains that “it was not EPA’s intention to require installation of a second backup CEMS.” 71 Fed. Reg. 27324; 40 C.F.R. § 60, Subpart Cb. In the course of promulgating the Final Rule, EPA originally proposed a flat 95% CEMS data availability requirement. Id. However, most commenters agreed that legally requiring demonstration of such a high availability level would necessitate the installation of second backup CEMS to assure compliance. Id. In response, EPA deliberately provided for the 90% CEMS data availability requirement applied on a calendar quarter basis and the 95% data availability requirement applied on a calendar year basis so as to avoid the need for businesses to install redundant CEMS. Id.

24. In contrast with federal and state law, the Ordinance requires that CEMS be operational at all times that the facility is functioning, and categorizes data gaps of more than 30 minutes as criminal violations. Ordinance at § 8-115. The Ordinance does not account for any requisite downtime for calibration, maintenance, or repair of CEMS, nor for performing EPA-mandated periodic accuracy audits. Id.

25. The City also claims that the Ordinance allows for “considerable flexibility.” ECF 39 at 11. In support of this contention, the City alludes to the specific carve-out for dioxin/furans
monitoring, which permits monthly monitoring. See Ordinance at § 8-111(D)(3). However, this provision only makes an exception for dioxins/furans — not for any of the additional pollutants required to be continuously monitored by the Ordinance. Id. at § 8-114. The Ordinance on its terms provides no flexibility, because CEMS downtime of more than 30 minutes while the facility is operating is a violation, which under the Ordinance’s terms results in strict criminal liability. Id. at § 8-115.

26. CEMS are available for nitrogen oxides, sulfur dioxides, carbon monoxide, carbon dioxide, hydrochloric acid, particulate matter, and VOCs at WTE facilities in that they have a proven track record for reliability, accuracy, and meeting EPA or state CEM availability and calibration requirements. However, CEMS for hydrofluoric acid, polycyclic aromatic hydrocarbons (“PAHs”) and trace metals are not only unavailable, but have never been demonstrated to work in any fashion on WTE facilities. CEMS for mercury are available and used on coal fired utility boilers and some other sources. At the recently constructed Palm Beach WTE facility, a mercury CEMS was initially required to be installed and operated as an air construction permit condition. However, the state agency allowed the mercury CEMS to be removed and deleted the requirement from the revised air construction permit issued on November 8, 2018 because the mercury CEMS was found to be unreliable and unnecessary. See Palm Beach Renewable Energy Facility Final Air Construction Permit, dated November 8, 2018, attached to Plaintiffs’ Reply as Exhibit S at 17.
I declare under penalty of perjury that the foregoing is true and correct.

Executed on this 31st day of October, 2019, in Portsmouth, New Hampshire.

[Signature]

Timothy Porter
ATTACHMENT 1
June 29, 2018

Mr. Timothy Porter  
Director Air Quality Management  
Wheelabrator Technologies, Inc.  
100 Arboretum Drive, Suite 310  
Portsmouth, NH 03842  
Via Email: tporter@wtienergy.com

Subject: AERMOD Modeling Analysis  
Wheelabrator – Baltimore Facility  
TRC Project Number: 230687.0000.0000, Phase 000034

**Introduction**

Wheelabrator Technologies, Inc. (Wheelabrator) operates a 64 MW trash to energy facility in Baltimore, MD. In support of the Baltimore facility, TRC was tasked to perform a single air dispersion modeling run for internal business planning purposes. The following details the modeling approach and inputs utilized by TRC, and presents the modeling results for comparison to the National Ambient Air Quality Standards (NAAQS).

**Modeling Approach**

TRC selected the EPA’s AERMOD dispersion model (version 18081) and all of the accompanying preprocessors to model the facility. AERMOD is the recommended dispersion model in EPA’s “Guideline on Air Quality Models” (40 CFR 51, Appendix W, January 2017) for industrial site air quality impact analyses. The AERMOD modeling was conducted for the main stack at a unit emission rate (1.0 gr/sec) for a five year period for all regulatory averaging periods and concentrations, and then scaled for emission rates of PM$_{2.5}$, NO$_x$, Total PM and SO$_2$. The scaled modeling results were then combined with local background air quality data for comparison to the NAAQS. AERMOD was run in URBAN mode to account for increased surface heating associated with urbanized areas. The population used was the estimated 2017 Metropolitan Statistical Area (MSA) population for the Baltimore-Columbia-Towson area.
**Input Data**

**Meteorological Data**
TRC used five (5) years (2013-2017) of Baltimore-Washington International Airport (BWI) surface data (wind speed, wind direction, temperature, observed cloud cover) concurrently with upper air sounding data (vertical temperature profile) from Dulles International Airport at Sterling, VA. BWI is approximately 10 km south of the Wheelabrator facility and provided the most robust dataset and thus was selected as the representative meteorological site for air quality modeling. Both the surface and upper air sounding data were processed using AERMOD’s meteorological processor, AERMET (version 18081).

**Receptor Array**
TRC selected a modeling domain of 20 kilometers to model the Baltimore facility. A cartesian array was setup within the modeling domain with receptor spacing as follows:
- 25-meter spacing along the fenceline of the facility
- 50-meter spacing out to 2 kilometers
- 500-meter spacing from 2 to 5 kilometers
- 1,000-meter spacing from 5 to 20 kilometers

The receptor array was processed using AERMAP (the AERMOD receptor and terrain pre-processor) with 1/3 arc-second (10 m) elevation data that was obtained from the National Elevation Dataset provided by the United States Geological Survey. The resulting receptor array had a total of 8,504 receptors.

**Building Downwash Analysis**
A Good Engineering Practice (GEP) stack height analysis was conducted using the U.S. EPA approved Building Profile Input Program for PRIME (BPIPPRM, version 04274) to determine direction-specific downwash parameters. The controlling downwash structure was the Boiler Area with a peak height of 46.3 meters which was provided in the previous screening modeling analysis for the facility. Additional structure tiers were included in the downwash analysis, of which the structure heights were found using Google Earth Pro 3D-measurements. Figure 1 shows the source and structures included in the analysis.
Figure 1: Sources and Structure in BPIPPRM
Source Data

The source data for the modeling was provided by the client in response to the data request sent by TRC. At the Baltimore facility, there are 3 existing units that exhaust through three separate flues encapsulated by a single larger stack structure 96 meters tall. Because of the extremely close proximity of the flues to each other, they were modeled as a single co-located source. The modeled stack temperature was the average of the stack temperatures of all three units. An effective stack diameter was calculated using the diameters of the three flues, and the stack exit velocity was determined by totaling the flows from all three units and then calculated using the known effective stack diameter. The modeling source parameters can be seen below in Table 1.

Table 1: Source Parameters for AERMOD

<table>
<thead>
<tr>
<th>AERMOD ID</th>
<th>UTM NAD83 Zone 18 N Coordinates</th>
<th>Stack Height (m)</th>
<th>Stack Temp (K)</th>
<th>Exit Velocity (m/sec)</th>
<th>Stack Diameter (m)</th>
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</thead>
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<tr>
<td>STACK1</td>
<td>359,354 4,348,003</td>
<td>96</td>
<td>425</td>
<td>24.80</td>
<td>3.695</td>
</tr>
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</table>

Two separate categories of emission rates were also provided by the client. Subpart Cb emission limits were provided for NO\textsubscript{x}, SO\textsubscript{2}, and Total Particulate (PM\textsubscript{10}), and actual emission rates from 2015 - 2017 were provided for NO\textsubscript{x}, SO\textsubscript{2}, and PM. Also, Method 202 Condensable Particulate emission rates were provided which were used for the actual PM\textsubscript{2.5} emission rate. For the Cb emission limits, TRC conservatively assumed that Total Particulate emissions and PM\textsubscript{2.5} were equivalent. For actual emission rates, TRC utilized the maximum emission rate reported for the 2015-2017 time period. Emission rates used can be seen in Table 2.

Table 2: Emission Rates

<table>
<thead>
<tr>
<th></th>
<th>NO\textsubscript{x}</th>
<th>SO\textsubscript{2}</th>
<th>PM\textsubscript{2.5}</th>
<th>PM\textsubscript{10}</th>
<th>CO</th>
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<tbody>
<tr>
<td></td>
<td>lb/hr g/sec</td>
<td>lb/hr g/sec</td>
<td>lb/hr g/sec</td>
<td>lb/hr g/sec</td>
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<td>Facility Potentials (Subpart Cb Limits)</td>
<td>341 43.0</td>
<td>67.1 8.45</td>
<td>21.8 2.74</td>
<td>21.8 2.74</td>
<td>101 12.8</td>
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<tr>
<td>Facility Actuals (max from 2015-2017)</td>
<td>283 35.6</td>
<td>76.7 9.67</td>
<td>4.22 0.532</td>
<td>4.22 0.532</td>
<td>18.7 2.35</td>
</tr>
</tbody>
</table>

Background Data

Air quality monitoring sites were selected based on their proximity to the facility and quality of data. Each site was deemed to be representative of an urbanized area and thus suitable for use in combination with a facility being modeled that is located in an urban area. Each monitor utilized the latest 2017 data. The sites selected were as follows:

- NO\textsubscript{2} – The Lochearn (Site ID 24-005-0009)
- SO\textsubscript{2} – Essex (Site ID 24-005-3001)
- PM\textsubscript{10} and PM\textsubscript{2.5} – Baltimore Oldtown (Site ID 24-510-0040)

The air quality data selected was used to add to modeling results for comparison to the NAAQS. The location of the air quality monitors can be seen below in Figure 2.
Figure 2: Location of Air Quality Monitors
**Results**

The unitized emission rate (1.0 g/sec) modeling results for all pollutants and rank are summarized in Table 3. These results are based on the full five years of modeling data, (e.g. the highest second high (H2H) 1-hour concentration is the second highest predicted 1-hour concentration over all receptors for the five year period). These results were then scaled by multiplying the predicted unitized impact times and the provided emission rates for each pollutant to obtain the predicted concentration impact for the facility. The appropriate background concentration was also added so that they could be compared to the NAAQS. Results for both categories of emission rates provided were summarized. Table 4 shows the results for the Subpart Cb Limits and Table 5 shows the results for the actual emission rates.

The NAAQS are based on the following statistics:

- NO$_2$ 1-hour - 98th percentile (H8H each year) of 1-hour daily maximum concentrations, averaged over 3 years
- NO$_2$ annual - Annual Mean (H1H)
- SO$_2$ 1-hour - 99th percentile (H4H each year) of 1-hour daily maximum concentrations, averaged over 3 year
- SO$_2$ 3-hour - Not to be exceeded more than once per year (H2H)
- PM$_{2.5}$ 24-hour - 98th percentile (H8H each year), averaged over 3 years
- PM$_{2.5}$ annual - annual mean (H1H each year), averaged over 3 years
- PM$_{10}$ 24-hour - Not to be exceeded more than once per year on average over 3 years (H2H each year)

Following EPA modeling conventions, 5 years of meteorology were run and those NAAQS requiring 3 years of data were based on 5 years for this analysis. Further, since a single 5 year modeling run was conducted, annual modeling results were not available and thus conservative approaches were used to prepare Tables 4 and 5. For example, rather than averaging the 1-hour H8H of each year for NO$_2$, the H8H for the entire 5 years is presented in Tables 4 and 5. A similar, conservative approach was used for each pollutant and averaging period. The only NAAQS for which this approach may not be conservative is the annual NO$_2$, which is based on each year of data. However, the predicted long term impact of NO$_2$ is so small, 1.26 µg/m$^3$, that even in the worst possible case (assuming all impacts occur in a single year: 5 * 1.26 µg/m$^3$ = 6.30 µg/m$^3$) the NAAQS would not be violated.

**Table 3: Unitized Modeled Impacts**
Table 4: Scaled Modeling Results with Background for Subpart Cb Emission Rates

<table>
<thead>
<tr>
<th>Avg. Period</th>
<th>Rank</th>
<th>Concentration</th>
<th>Distance from Source (m)</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hour</td>
<td>H1H</td>
<td>0.625</td>
<td>584</td>
<td>NE</td>
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<tr>
<td></td>
<td>H2H</td>
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<td>584</td>
<td>NE</td>
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<td></td>
<td>H4H</td>
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<td>533</td>
<td>NE</td>
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<td></td>
<td>H8H</td>
<td>0.596</td>
<td>571</td>
<td>NE</td>
</tr>
<tr>
<td>3-Hour</td>
<td>H1H</td>
<td>0.579</td>
<td>604</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>H2H</td>
<td>0.564</td>
<td>604</td>
<td>NE</td>
</tr>
<tr>
<td>24-Hour</td>
<td>H1H</td>
<td>0.243</td>
<td>1,121</td>
<td>ENE</td>
</tr>
<tr>
<td></td>
<td>H2H</td>
<td>0.223</td>
<td>792</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>H8H</td>
<td>0.192</td>
<td>876</td>
<td>NE</td>
</tr>
<tr>
<td>Annual</td>
<td>--</td>
<td>0.029</td>
<td>604</td>
<td>NE</td>
</tr>
</tbody>
</table>

Table 5: Scaled Modeling Results with Background for Actual Emission Rates

<table>
<thead>
<tr>
<th></th>
<th>National Ambient Air Quality Standard (NAAQS) (µg/m³)</th>
<th>Modeled AERMOD Impact (µg/m³)</th>
<th>Monitor Background (µg/m³)</th>
<th>Modeled + Background Concentration for Comparison to NAAQS (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hour H8H</td>
<td>188</td>
<td>21.2</td>
<td>79.0</td>
<td>100</td>
</tr>
<tr>
<td>Annual</td>
<td>--</td>
<td>100</td>
<td>27.2</td>
<td>28.4</td>
</tr>
<tr>
<td>SO₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hour H4H</td>
<td>196</td>
<td>5.9</td>
<td>22.2</td>
<td>27.4</td>
</tr>
<tr>
<td>3-Hour H2H</td>
<td>1,300</td>
<td>4.9</td>
<td>20.1</td>
<td>24.9</td>
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<tr>
<td>PM₂.₅</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-Hour H8H</td>
<td>35.0</td>
<td>0.53</td>
<td>18.0</td>
<td>18.5</td>
</tr>
<tr>
<td>Annual</td>
<td>--</td>
<td>12.0</td>
<td>8.19</td>
<td>8.3</td>
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<tr>
<td>PM₁₀</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-Hour H2H</td>
<td>150</td>
<td>0.12</td>
<td>28.0</td>
<td>28.6</td>
</tr>
</tbody>
</table>
The location of the maximum impacts are shown in Figure 3.

**Figure 3: Location of Maximum Impacts (all pollutants) from Unitized Modeling for Each Averaging Period**
The modeling results were also compared to previous modeling performed by Gray Sky Solutions. Modeling was done by Gray Sky using two meteorological datasets, one from the years 2005 – 2009, and the other from years 2006 – 2010. The NO₂ results from each dataset are compared to the TRC NO₂ results in Table 6. TRC modeling results for NO₂ are approximately 50% lower for both the 1-hour and annual impacts. Without access to the Gray Sky modeling runs to review, it is not possible to determine why the results are different.

### Table 6: Gray Report vs. TRC NO₂ Modeling Results

<table>
<thead>
<tr>
<th></th>
<th>Maximum 8th High 1-Hour Concentration (µg/m³)</th>
<th>Maximum Annual Concentration (µg/m³)</th>
</tr>
</thead>
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<tr>
<td>TRC Modeling - Cb Emission Limits</td>
<td>25.6</td>
<td>1.263</td>
</tr>
<tr>
<td>TRC Modeling - Actual Emissions</td>
<td>21.2</td>
<td>1.048</td>
</tr>
<tr>
<td>Gray Report (2005 - 2009)</td>
<td>63.9</td>
<td>2.260</td>
</tr>
<tr>
<td>Gray Report (2006 - 2010)</td>
<td>56.8</td>
<td>2.560</td>
</tr>
</tbody>
</table>

### Conclusion

TRC performed air dispersion modeling for the Wheelabrator – Baltimore facility to assess potential air quality impacts of the facility. A simplified modeling analysis was performed to conservatively assess the facilities air quality impacts using potential and actual emissions. The results of the analysis demonstrate that the facilities modeled impacts, when combined with local background air quality data, are all well below the acceptable National Ambient Air Quality Standards (NAAQS) when using Subpart Cb emission rates or actual emission rates.

Best Regards,

[Signature]

Gary T. Hunt, QEP
Vice President and Principal Scientist
TRC Environmental Corporation
ATTACHMENT 2
EVALUATION OF ASTHMA EMERGENCY ROOM AND HOSPITAL DISCHARGE RATES IN RELATION TO AMBIENT AIR CONCENTRATIONS ASSOCIATED WITH THE WHEELABRATOR WASTE-TO-ENERGY FACILITY

Prepared by:

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Bethesda, MD

Ben Hoffman MD, MPH
Houston, TX

Prepared for:

Wheelabrator Technologies
Portsmouth, NH

September 25, 2019
TABLE OF CONTENTS

EXECUTIVE SUMMARY .................................................................................................................. iii
1.0 INTRODUCTION ........................................................................................................................ 1
2.0 ASTHMA AND SOCIO-DEMOGRAPHIC DATA ........................................................................... 3
   2.1 Asthma Health Data .............................................................................................................. 3
   2.2 Socio-Demographic Data .................................................................................................... 3
3.0 AIR DISPERSION MODELING .................................................................................................... 7
   3.1 WTE Emissions ................................................................................................................... 7
   3.2 Modeling Methodology ........................................................................................................ 8
   3.3 Modeling Results ................................................................................................................ 8
4.0 ENVIRONMENTAL EPIDEMIOLOGY ANALYSIS ........................................................................ 15
   4.1 Methodology ...................................................................................................................... 15
   4.2 Results ................................................................................................................................ 16
      4.2.1 Bivariate Linear Correlation Analysis .................................................................... 16
      4.2.2 Multivariate Regression Modeling ............................................................................ 20
   4.3 Statistical Analyses Conclusions ...................................................................................... 20
5.0 DISCUSSION ............................................................................................................................ 20
6.0 SUMMARY AND CONCLUSIONS .............................................................................................. 24
7.0 REFERENCES ............................................................................................................................. 25

LIST OF TABLES

| Table 1 | Asthma Health Data for 2011, 2012 and 2013 |
| Table 2 | Socio-Demographic Data from the US Census for 2010 |
| Table 3 | Stack Emission Rates Used in Air Dispersion Modeling |
| Table 4 | Stack Parameters Used in Air Dispersion Modeling |
| Table 5 | Annual Average Ambient Air Concentrations for PM$_{2.5}$, NO$_2$ and SO$_2$ by Zip Code and Year |
| Table 6 | Comparison of Modeled Annual Average Air Concentrations to Background Air Quality |
| Table 7 | Matrix of Bivariate Statistical Analyses and Results |
| Table 8 | Multivariate Linear Regression Modeling for Emergency Room Discharge Rates |
| Table 9 | Multivariate Linear Regression Modeling for Hospital Discharge Rates |

LIST OF FIGURES

| Figure 1 | Site Setting |
| Figure 2 | City of Baltimore Zip Codes and Waste-to-Energy Facility Location |
| Figure 3 | 250 Meter Spaced Receptor Points Used in Air Modeling Study |
| Figure 4 | Ambient Air Quality Monitoring Stations in Baltimore City Area |
| Figure 5 | Comparison of Background and Modeled Incremental Annual Average Concentrations by Zip Code |
| Figure 6 | Example Scatterplots: 2013 Asthma Emergency Room Discharge Rates Relative to Annual Average Air Concentrations and Median Family Income by Zip Code |

APPENDICES

Appendix A Participant CVs
ACRONYMS AND ABBREVIATIONS

AERMOD  American Meteorological Society/Environmental Protection Agency Regulatory Model
ER       annual asthma emergency room discharge rates
HD       annual asthma hospital discharge rates
MDE      Maryland Department of the Environment
NO₂      nitrogen dioxide
NWS      US National Weather Service
PM₂.₅    particulate matter less than or equal to 2.5 microns in size
SO₂      sulfur dioxide
TRAP     traffic related air pollution
USEPA    US Environmental Protection Agency
WTE      waste-to-energy
EXECUTIVE SUMMARY

This report presents a study conducted to evaluate if there is an association between asthma rates in the City of Baltimore and emissions from the Wheelabrator Baltimore waste-to-energy (WTE) facility.

Asthma hospital and emergency room annual discharge rates for 2011, 2012 and 2013 in 21 zip codes categorized as City of Baltimore zip codes in Maryland’s Environmental Public Health Tracking Web portal were selected for this study. In addition, several socio-demographic factors from the US census were included by zip code – race, median family income, housing vacancy rate and homeownership rate. Median family income, vacancy rate and homeownership rate are all proxies for “social determinants of health”. Social determinants of health are conditions in which people are born, grow, live, and work which in turn relate to income, poverty, education, race, and neighborhood and housing conditions. They have been found in scientific studies to be the main drivers of asthma.

Annual average ambient air concentrations due to emissions from the WTE facility in the 21 zip codes were calculated using the latest USEPA-approved air dispersion model (AERMOD) for particulate matter less than or equal to 2.5 microns in size (PM$_{2.5}$), nitrogen dioxide (NO$_2$), and sulfur dioxide (SO$_2$). Inputs to the modeling included annual average WTE facility emission rates, as reported to the Maryland Department of Environment (MDE), and hourly meteorological data for the same three years. The modeled incremental impacts of WTE facility emissions on annual average air concentrations of PM$_{2.5}$, NO$_2$, and SO$_2$ were shown to be negligible compared to background air quality levels.

An environmental epidemiology analysis of the asthma health data and the modeled annual average air concentrations was performed, taking into account the socio-demographic parameters, across the 21 Baltimore City zip codes for each of the three years. The analysis showed there were no statistically significant associations between annual emergency room or hospital discharge rates for asthma in relation to annual average PM$_{2.5}$, NO$_2$ or SO$_2$ air concentrations due to emissions from the WTE facility during 2011, 2012 and 2013. The analysis did, however, identify consistent statistically significant associations between discharge rates for asthma and median family income for all three years and instances where discharge rates were also significantly associated with other socio-demographic parameters, such as race, homeownership rate and housing vacancy rate. These results suggest that social determinants of health at the zip code level, for which income and housing characteristics are proxies, are driving the rates of emergency room discharges and hospital discharges due to asthma in Baltimore City.

The results of this analysis are in agreement with scientific research showing the importance of social determinants of health on asthma in urban US areas like the City of Baltimore. Examples of social determinants of health include: poverty, unsafe and stressful neighborhoods, and unhealthy neighborhood and home environments. Home environments, where people spend most of their time, can be unhealthy due to indoor pollution which includes household dust, pet dander, smoking, rodents, mold, cockroaches and unvented indoor gas stoves. Elevated asthma rates that have been documented in Baltimore are similar to those in many other large urban areas in the US. These similarities are likely to be related to the importance and presence of social determinants of health as well as traffic related air pollution (TRAP) which has been shown in scientific studies to be a major factor affecting asthma rates in cities.
1.0 INTRODUCTION

This report presents a study conducted to evaluate if there is an association between asthma rates in the City of Baltimore and emissions from the Wheelabrator Baltimore waste-to-energy facility (WTE), formerly BRESCO. The aim of the study was to understand the relationship between ambient air concentrations due to emissions from the WTE facility and asthma rates in surrounding communities. The study also allowed for a comparison of ambient air concentrations due to facility emissions and background ambient air concentrations.

There were several key steps in the study process which are described below:

- Obtaining asthma and socio-demographic data\(^1\) for the City of Baltimore
- Calculating ambient air concentrations due to emissions from the WTE facility
- Conducting statistical analyses to evaluate associations between the asthma data and the ambient air concentrations

The study was conducted at the request of Wheelabrator by a multidisciplinary team of independent environmental consulting firms and scientists. The project team consisted of: Dr. Ben Hoffman, MD, MPH; Ms. Sarah Foster (CPF Associates, LLC); Dr. Rafael E. Guerrero-Preston, DrPH, MPH; and Mr. Gary Hunt (TRC). The TRC Team led by Mr. Hunt (with Dana Lowes-Hobson and Doug Smith) was responsible for the modeling of air concentrations associated with facility emissions. Dr. Guerrero-Preston performed an environmental epidemiology analysis to examine the association between annual average air concentrations associated with WTE facility emissions and publicly available asthma hospital and emergency room discharge rates in Baltimore City for the years 2011, 2012 and 2013. Dr. Hoffman and Ms. Foster provided overall support for the study. Study team biographies are provided in Appendix A.

The Wheelabrator WTE facility began operations in 1985. It is located in the City of Baltimore, adjacent to the intersection of Interstate 95 and Maryland 295 (Baltimore-Washington Parkway), and 0.6 miles southwest of the M&T Bank Stadium (home of the Baltimore Ravens) (see Figure 1). The facility processes up to 2,250 tons of post-recycled solid waste from Baltimore area homes and businesses and other areas. Solid waste received at the facility is screened in order to remove recyclable metal materials, which totaled more than 11,500 tons in 2018. The facility supplies up to 52 megawatts (MW) of electricity for sale to the local utility, equal to the amount of power used by approximately 38,000 Maryland homes. Additionally the facility provides steam to the downtown Baltimore heating loop, serving more than 255 businesses including M&T Bank Stadium. Emissions from the plant are regulated under the US Clean Air Act and the State of Maryland. Facility emissions are controlled by emission control technology meeting US Clean Air Act Maximum Achievable Control Technology standards. These standards include emission limits for many compounds, monitoring systems which continuously track emissions and the performance of emission control devices, and additional periodic stack testing.

\(^1\) Socio-demographic data describe characteristics of a population, such as age, sex, education, ethnicity, religious affiliation, marital status, household, employment, and income.
Figure 1
Site Setting
2.0 ASTHMA AND SOCIO-DEMOGRAPHIC DATA

2.1 Asthma Health Data

The first step in this study required obtaining asthma health data for the City of Baltimore. Sources of publicly available data on as fine a geographic scale as possible were investigated in order to evaluate potential relationships between air concentrations and asthma rates across the city. A description of the compilation and statistical analysis of the asthma data, which was performed by Dr. Rafael E. Guerrero-Preston, is provided in a separate report (Guerrero-Preston 2019).

Asthma hospital and emergency room discharge rates available at the zip code geographic level within the City of Baltimore data were selected for this study. The State of Maryland Environmental Public Health Tracking Web portal provides these two types of health data by zip code. The three most recent years of published data were used in this study, for 2011, 2012 and 2013. Figure 2 shows the boundaries of the city, zip codes, and the location of the WTE facility. Table 1 presents the asthma health data used in this study by zip code. Twenty-one (21) zip codes categorized as City of Baltimore zip codes in the Public Health Tracking Web portal with reported asthma discharge rates for the three years were included.

2.2 Socio-Demographic Data

Asthma is a well-studied and complex disease. It can be triggered by a wide variety of different factors leading to different symptoms in different people. These factors include biology and genetics (e.g., age and sex), individual behaviors (e.g., smoking), social determinants of health (i.e., conditions in which people are born, grow, live, and work which in turn relate to income, poverty, education, race, and neighborhood and housing conditions), outdoor air pollution and access to preventive medical care.

Due to the complexity of this disease, a number of factors known to be associated with asthma for which data are readily available at the zip code level were also included in this study – race, median family income, housing vacancy rate and homeownership rate. These parameters were obtained from the 2010 US census. Median family income, housing vacancy rate and homeownership rate are all proxies for social determinants of health. Table 2 presents the socio-demographic data by zip code included in this study (also see Guerrero-Preston 2019).

---

2 https://maps.health.maryland.gov/epht/query.aspx. Note that these data were also evaluated in a report prepared in late 2017 by the Environmental Integrity Project (EIP 2017).

3 Some zip codes within the City of Baltimore extend beyond the city boundary into adjacent counties. Some of these are categorized in the MD Public Health Tracking Portal as county-based zip codes. This study included zip codes categorized as City of Baltimore zip codes in the MD Public Health Tracking Portal.

4 See for example https://www.cdc.gov/socialdeterminants/index.htm and https://www.who.int/social_determinants/sdh_definition/en/

5 https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_SYR_DP02&src=pt. The 2010 census data were determined to be representative of the three evaluated years (2011, 2012 and 2013) (see Guerrero-Preston 2019). The census parameter units were as follows: race = percent of population, all ages, which was of Black, White, Asian, or American Indian or Alaska Native origins; Median family income = US dollars; homeownership rate = percent of houses owned by residents; and housing vacancy rate = percent of housing units that were unoccupied.
Figure 2
City of Baltimore Zip Codes and Waste-to-Energy Facility Location
Table 1
Asthma Health Data for 2011, 2012 and 2013 (a)

<table>
<thead>
<tr>
<th>Health Data</th>
<th>Age-adjusted annual number of asthma emergency room discharges per 10,000 population per year</th>
<th>Age-adjusted annual number of asthma hospital discharges per 10,000 population per year</th>
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<tbody>
<tr>
<td></td>
<td>Year 2011 2012 2013</td>
<td>2011 2012 2013</td>
</tr>
<tr>
<td>Zipcode</td>
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<td>371.47 367.32 307.8</td>
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<td>343 306.73 293.94</td>
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</tr>
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<td>55.37 48.64 70.9</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>0.64 1.18 0.55</td>
</tr>
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<td>24.02 14.78 18.1</td>
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<td>25.64 24.26 19.47</td>
</tr>
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<td>50.73 49.89 55.56</td>
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<td>161.59 151.05 130.64</td>
<td>21.65 22.85 23.12</td>
</tr>
<tr>
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<td>271.05 289.16 274.73</td>
<td>49.25 52.02 45.5</td>
</tr>
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<td>243.81 227.45 211.76</td>
<td>36.1 39.53 34.53</td>
</tr>
</tbody>
</table>

(a) Data obtained from https://maps.health.maryland.gov/epht/query.aspx. For additional information about the statistical analyses of the data, see Guerrero-Preston (2019).
Table 2
Socio-Demographic Data from the US Census for 2010 (a)

<table>
<thead>
<tr>
<th>Zipcode</th>
<th>White (%)</th>
<th>Black (%)</th>
<th>AI_AN (%)</th>
<th>Asian (%)</th>
<th>Median Family Income ($)</th>
<th>Vacancy Rate (%)</th>
<th>Home-ownership Rate (%)</th>
</tr>
</thead>
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<td>21201</td>
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<td>0.85</td>
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<td>1.1</td>
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<td>0.7</td>
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<td>42,981</td>
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<td>0.64</td>
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<td>3.3</td>
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<td>0.09</td>
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</tr>
<tr>
<td>21230</td>
<td>64.4</td>
<td>27.8</td>
<td>0.3</td>
<td>4.1</td>
<td>73,762</td>
<td>0.13</td>
<td>0.55</td>
</tr>
<tr>
<td>21231</td>
<td>59.7</td>
<td>30.4</td>
<td>0.4</td>
<td>4.4</td>
<td>61,307</td>
<td>0.18</td>
<td>0.78</td>
</tr>
<tr>
<td>21239</td>
<td>13.8</td>
<td>80.8</td>
<td>0.1</td>
<td>2.1</td>
<td>59,889</td>
<td>0.06</td>
<td>0.52</td>
</tr>
</tbody>
</table>

AI-AN = American Indian-Alaska Native
(a) Data obtained from https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_DP02&src=pt. For additional information about the statistical analyses of the data, see Guerrero-Preston (2019).
Some factors related to asthma that are known to be important were not addressed, as this was beyond the scope of this study and due to lack of readily available population data at the zip code level. This includes indoor pollution in the home (household dust, pet dander, rodents, mold, cockroaches, smoking and use of unvented gas stoves) and traffic related air pollution. Many studies have documented the significant impact on asthma of the indoor environment, where people generally spend more time than outdoors (e.g., Matsui 2014, Matsui et al. 2016, Alicea-Alvarez et al. 2017, Paulin et al. 2013, 2017, Kreiger et al. 2000, Breysse et al. 2010). Studies have also shown that traffic related air pollution (TRAP) is the primary outdoor air pollution source affecting asthma rates in large cities, including Baltimore (e.g., Alotaibi et al. 2019, EIP 2017, Khreis et al. 2018).

3.0 AIR DISPERSION MODELING

Air dispersion modeling was conducted to calculate ambient air concentrations due to emissions from the WTE facility in the surrounding area. A detailed description of the modeling, which was performed by TRC, is provided in a separate report (TRC 2019). A brief summary of the modeling is provided below.

3.1 WTE Emissions

This study addressed emissions of three criteria pollutants from the WTE facility that may be associated with asthma: particulate matter less than or equal to 2.5 microns in size (PM$_{2.5}$), nitrogen dioxide (NO$_2$), and sulfur dioxide (SO$_2$). These criteria pollutants are regulated under the US Clean Air Act for which National Ambient Air Quality Standards have been set by the US Environmental Protection Agency (USEPA) to protect public health with an adequate margin of safety.

Annual average emission rates for years 2011-2013 used in the air modeling were taken directly from the annual emission inventory reports submitted to the Maryland Department of the Environment (MDE). Emission rates for total PM$_{2.5}$ were based on periodic stack testing using USEPA Method 5 for filterable PM$_{2.5}$ and Method 202 for condensable PM$_{2.5}$. Method 202 accounts for secondary PM$_{2.5}$ particulate that forms in the atmosphere from SO$_2$ and NO$_2$ after leaving the facility stack. Collectively the Method 5 and Method 202 results are combined to provide total PM$_{2.5}$ emissions. NO$_2$ and SO$_2$ emissions were based on measurements from the continuous monitoring systems during 2011, 2012 and 2013. Annual average emission rates were calculated from these monitoring data for each of the three years examined in this study, as shown in Table 3.

<table>
<thead>
<tr>
<th>Year</th>
<th>Stack</th>
<th>NO$_x$ Emissions (lbs/hr)</th>
<th>NO$_x$ Emissions (g/s)</th>
<th>PM$_{2.5}$ Emissions (lbs/hr)</th>
<th>PM$_{2.5}$ Emissions (g/s)</th>
<th>SO$_2$ Emissions (lbs/hr)</th>
<th>SO$_2$ Emissions (g/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1</td>
<td>285.7</td>
<td>35.99</td>
<td>5.2</td>
<td>0.65</td>
<td>65.9</td>
<td>8.30</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>260.7</td>
<td>32.85</td>
<td>4.6</td>
<td>0.58</td>
<td>50.1</td>
<td>6.31</td>
</tr>
<tr>
<td>2013</td>
<td>1</td>
<td>273.0</td>
<td>34.39</td>
<td>8.2</td>
<td>1.03</td>
<td>82.25</td>
<td>10.36</td>
</tr>
</tbody>
</table>
3.2 Modeling Methodology

Ambient air concentrations were calculated using the most recent version of a state-of-the-art air dispersion model called The American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) (version 18081). As described by the USEPA, AERMOD is a preferred air quality model that can assess potential air concentration impacts within 50 km of an emission source, taking into account both simple (flat) and complex terrain.

The AERMOD model incorporated a variety of inputs that describe the WTE facility (e.g., stack height, stack gas exit velocity and temperature), the surrounding area (e.g., urban land use and ground terrain elevations) and meteorological weather data. Table 4 presents the stack parameters input to AERMOD for each of the three years under study; these were based on operating data collected at the facility during 2011, 2012 and 2013. Two meteorological datasets were used in AERMOD from the closest U.S. National Weather Service (NWS) stations to the facility: 1) hourly surface meteorological observations from Baltimore-Washington International Airport (BWI) for three years (2011, 2012 and 2013) and 2) upper air data from Dulles International Airport at Sterling, VA for the same three years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Stack*</th>
<th>Stack Height (m)</th>
<th>Stack Exit Temperature (F)</th>
<th>Stack Exit Temperature (K)</th>
<th>Stack Exit Velocity (ft/s)</th>
<th>Stack Exit Velocity (m/s)</th>
<th>Stack Diameter (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1</td>
<td>96</td>
<td>301</td>
<td>423</td>
<td>77.3</td>
<td>23.5</td>
<td>3.70</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>96</td>
<td>299</td>
<td>422</td>
<td>79.2</td>
<td>24.1</td>
<td>3.70</td>
</tr>
<tr>
<td>2013</td>
<td>1</td>
<td>96</td>
<td>307</td>
<td>426</td>
<td>89.2</td>
<td>27.2</td>
<td>3.70</td>
</tr>
</tbody>
</table>

*Stack Location is NAD 83 zone 18 (meters): Easting: 359354.09, Northing: 4348002.51, Elevation: 4.6

Air concentrations were calculated by AERMOD at over 17,600 points (called receptor points) that were evenly spaced at 250-meter intervals extending outwards from the WTE stack. Figure 3 illustrates the receptor grid across the modeling area.

3.3 Modeling Results

Annual average concentrations of PM$_{2.5}$, NO$_2$ and SO$_2$ were calculated at every 250-meter spaced receptor point for each of the three modeled years. The modeled results were then post-processed by TRC to calculate an annual average concentration within each zip code. This was done by averaging the results for all receptor points located within each zip code. The resulting concentrations are shown in Table 5.

---

6 An air dispersion model uses mathematical equations to calculate ambient air concentrations across an area due to emissions sources.
7 Since the asthma health data are not publicly available for time increments less than one year, annual average air concentrations were calculated to match the annual asthma data time frame.
Figure 3

250 Meter Spaced Receptor Points Used in Air Modeling Study
Table 5
Annual Average Ambient Air Concentrations for PM$_{2.5}$, NO$_2$ and SO$_2$ by Zip Code and Year (a)
(All concentrations in µg/m$^3$)

<table>
<thead>
<tr>
<th>Zip code</th>
<th>Modeled Annual Average Concentrations Associated with WTE Facility Emissions</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>21201</td>
<td></td>
<td>0.388</td>
<td>0.309</td>
<td>0.345</td>
<td>0.096</td>
<td>0.063</td>
<td>0.111</td>
<td>0.008</td>
<td>0.006</td>
<td>0.012</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21202</td>
<td></td>
<td>0.421</td>
<td>0.334</td>
<td>0.374</td>
<td>0.103</td>
<td>0.068</td>
<td>0.119</td>
<td>0.008</td>
<td>0.007</td>
<td>0.012</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21205</td>
<td></td>
<td>0.292</td>
<td>0.259</td>
<td>0.266</td>
<td>0.068</td>
<td>0.05</td>
<td>0.082</td>
<td>0.006</td>
<td>0.005</td>
<td>0.009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21206</td>
<td></td>
<td>0.178</td>
<td>0.145</td>
<td>0.165</td>
<td>0.04</td>
<td>0.027</td>
<td>0.048</td>
<td>0.004</td>
<td>0.003</td>
<td>0.005</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>0.103</td>
<td>0.082</td>
<td>0.087</td>
<td>0.022</td>
<td>0.015</td>
<td>0.025</td>
<td>0.002</td>
<td>0.002</td>
<td>0.003</td>
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<td></td>
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<td></td>
<td>0.123</td>
<td>0.093</td>
<td>0.101</td>
<td>0.027</td>
<td>0.017</td>
<td>0.029</td>
<td>0.002</td>
<td>0.002</td>
<td>0.003</td>
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<td>0.027</td>
<td>0.047</td>
<td>0.004</td>
<td>0.003</td>
<td>0.005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21212</td>
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<td>0.122</td>
<td>0.093</td>
<td>0.106</td>
<td>0.027</td>
<td>0.017</td>
<td>0.031</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>21213</td>
<td></td>
<td>0.283</td>
<td>0.224</td>
<td>0.256</td>
<td>0.067</td>
<td>0.044</td>
<td>0.079</td>
<td>0.006</td>
<td>0.004</td>
<td>0.009</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>21214</td>
<td></td>
<td>0.18</td>
<td>0.132</td>
<td>0.157</td>
<td>0.041</td>
<td>0.025</td>
<td>0.046</td>
<td>0.004</td>
<td>0.003</td>
<td>0.005</td>
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<tr>
<td>21215</td>
<td></td>
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<td>0.107</td>
<td>0.114</td>
<td>0.03</td>
<td>0.02</td>
<td>0.033</td>
<td>0.003</td>
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<td>0.004</td>
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<td>0.216</td>
<td>0.176</td>
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<td>0.034</td>
<td>0.055</td>
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<td>0.003</td>
<td>0.006</td>
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<tr>
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<td>0.248</td>
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<td>0.215</td>
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<td>0.041</td>
<td>0.068</td>
<td>0.005</td>
<td>0.004</td>
<td>0.007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td>0.225</td>
<td>0.169</td>
<td>0.197</td>
<td>0.053</td>
<td>0.033</td>
<td>0.06</td>
<td>0.005</td>
<td>0.003</td>
<td>0.007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21223</td>
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<td>0.3</td>
<td>0.293</td>
<td>0.27</td>
<td>0.073</td>
<td>0.06</td>
<td>0.087</td>
<td>0.006</td>
<td>0.006</td>
<td>0.009</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
<td>0.341</td>
<td>0.315</td>
<td>0.284</td>
<td>0.079</td>
<td>0.061</td>
<td>0.087</td>
<td>0.007</td>
<td>0.006</td>
<td>0.009</td>
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<td></td>
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<tr>
<td>21225</td>
<td></td>
<td>0.171</td>
<td>0.192</td>
<td>0.167</td>
<td>0.041</td>
<td>0.038</td>
<td>0.052</td>
<td>0.003</td>
<td>0.004</td>
<td>0.006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21229</td>
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<td>0.198</td>
<td>0.195</td>
<td>0.176</td>
<td>0.046</td>
<td>0.038</td>
<td>0.054</td>
<td>0.004</td>
<td>0.004</td>
<td>0.006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21230</td>
<td></td>
<td>0.44</td>
<td>0.464</td>
<td>0.4</td>
<td>0.11</td>
<td>0.096</td>
<td>0.13</td>
<td>0.009</td>
<td>0.009</td>
<td>0.013</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21231</td>
<td></td>
<td>0.437</td>
<td>0.404</td>
<td>0.398</td>
<td>0.106</td>
<td>0.082</td>
<td>0.126</td>
<td>0.009</td>
<td>0.008</td>
<td>0.013</td>
<td></td>
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<td>0.032</td>
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<td>0.002</td>
<td>0.004</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) Zip codes with asthma health data within the City of Baltimore are shown in this table. Also see TRC (2019).
Over the three years considered, the incremental annual average modeled PM2.5 concentrations across the 21 zip codes associated with WTE facility emissions ranged from 0.002 µg/m³ to 0.013 µg/m³. Annual average concentrations of SO₂ ranged from 0.015 – 0.13 µg/m³ and NO₂ concentrations ranged from 0.082 – 0.464 µg/m³.

3.4 Evaluation of Modeling Results Relative to Background Air Quality

The incremental impact of the WTE facility on air quality can be examined by comparing the modeled annual average air concentrations to background concentrations. As described in TRC (2019), annual average background concentrations of PM_{2.5}, NO₂, and SO₂ were compiled from two different data sources, a study by Alotaibi et al. (2019) and USEPA and MDE ambient air quality monitors. Figure 4 shows the locations of the ambient air quality monitoring stations.

One set of background air concentrations was obtained from a study by Alotaibi et al. (2019a,b) which investigated the relationship between childhood asthma and traffic related air pollution. The air concentrations from this study included values for the year 2010 and were provided by census block centroid. The annual average PM_{2.5}, NO₂ and SO₂ concentrations were estimated using data from regulatory air quality monitors taking into account geographic variables (e.g., land use, population, satellite-derived estimates of land use and air pollution, impervious surfaces, elevation, and roads). The census block centroid data were grouped and averaged by TRC to calculate average background concentrations by zip code. These results are shown in Table 6, along with the 2011 modeled concentrations associated with emissions from the WTE facility (i.e., the closest modeled year to 2010). As can be seen in Table 6 and Figure 5, the incremental annual average concentrations associated with emissions from the WTE facility were negligible compared to annual average background levels.

The second source of background data was from USEPA and MDE ambient air quality monitors, with locations selected based on their proximity to the WTE facility. Several different monitor locations were considered depending on whether they had collected data during the 2010-2013 time period. Though these monitors are not located very close to the WTE facility, they can still provide some context for the modeling results. The annual average background concentrations measured at the air quality monitoring stations are also presented Table 6. Again, the incremental annual average concentrations associated with emissions from the WTE facility were negligible compared to the monitored background concentrations. Further, modeled concentrations of facility emissions were orders of magnitude below detection limits of USEPA and MDE ambient air quality monitors for PM_{2.5}, NO₂ and SO₂.

---

8 The air concentrations by census block centroid were provided to Alotaibi et al. from researchers at the University of Washington (e.g., see Bechle et al. 2015 and Kim et al. 2018). The annual average air concentrations by census block centroid for the State of Maryland were provided to S. Foster by R. Alotaibi on 4/29/2019.
Figure 4
Ambient Air Quality Monitoring Stations in Baltimore City Area
Table 6
Comparison of Modeled Annual Average Air Concentrations to Background Air Quality
(All concentrations in µg/m³)

<table>
<thead>
<tr>
<th>Location</th>
<th>Modeled Annual Average Concentrations Associated with WTE Facility Emissions</th>
<th>Estimated Background Concentrations from Alotaibi et al. (2019a,b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO₂ Concentration</td>
<td>SO₂ Concentration</td>
</tr>
<tr>
<td>21201</td>
<td>0.388</td>
<td>0.309</td>
</tr>
<tr>
<td>21202</td>
<td>0.421</td>
<td>0.334</td>
</tr>
<tr>
<td>21205</td>
<td>0.292</td>
<td>0.259</td>
</tr>
<tr>
<td>21206</td>
<td>0.178</td>
<td>0.145</td>
</tr>
<tr>
<td>21209</td>
<td>0.103</td>
<td>0.082</td>
</tr>
<tr>
<td>21210</td>
<td>0.123</td>
<td>0.093</td>
</tr>
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<td>0.142</td>
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<td>21212</td>
<td>0.122</td>
<td>0.093</td>
</tr>
<tr>
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<td>0.283</td>
<td>0.224</td>
</tr>
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<td>21214</td>
<td>0.18</td>
<td>0.132</td>
</tr>
<tr>
<td>21215</td>
<td>0.134</td>
<td>0.107</td>
</tr>
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<td>0.176</td>
</tr>
<tr>
<td>21217</td>
<td>0.248</td>
<td>0.204</td>
</tr>
<tr>
<td>21218</td>
<td>0.225</td>
<td>0.169</td>
</tr>
<tr>
<td>21223</td>
<td>0.3</td>
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<td>0.341</td>
<td>0.315</td>
</tr>
<tr>
<td>21225</td>
<td>0.171</td>
<td>0.192</td>
</tr>
<tr>
<td>21229</td>
<td>0.198</td>
<td>0.195</td>
</tr>
<tr>
<td>21230</td>
<td>0.44</td>
<td>0.464</td>
</tr>
<tr>
<td>21231</td>
<td>0.437</td>
<td>0.404</td>
</tr>
<tr>
<td>21239</td>
<td>0.145</td>
<td>0.106</td>
</tr>
</tbody>
</table>

Background Concentrations from Air Quality Monitoring Stations (a)

Old Town | 34.0 | 30.9 | 27.5 |
Essex    | 5.2  | 4.6  | 3.6  |
Multiple Stations |   33.1 |
|        | 5.7  |

(a) All monitoring stations are in Baltimore City except the Essex station in Essex, MD. PM₂.₅ monitoring stations are Old Town; Northwest Police Station; and BCFD Truck Company (respectively).
Figure 5
Comparison of Background and Modeled Incremental Concentrations by Zip Code

Sources: Background data from Alotaibi et al. 2019a,b. Incremental concentrations associated with the WTE facility based on modeling in TRC (2019).
4.0 ENVIRONMENTAL EPIDEMIOLOGICAL ANALYSIS

An environmental epidemiology statistical analysis of the asthma health data, the modeled air concentrations and the socio-demographic parameters was conducted across the 21 Baltimore City zip codes for each of the three years (2011, 2012 and 2013). The epidemiological approach was a cross-sectional study, which is a type of investigation that focuses on a population (rather than individuals) at specified times, in this case in the years 2011, 2012 and 2013. The cross-sectional population study examined the pattern of asthma discharges across city zip codes relative to the modeled air concentrations, taking into account the socio-demographic data. The detailed epidemiological analysis, which was performed by Dr. Guerrero-Preston, is provided in a separate report (Guerrero-Preston 2019). A summary of the methodology and findings is provided below.

4.1 Methodology

The environmental epidemiology analysis was conducted to explore if there was an association between annual asthma rates and modeled annual average air concentrations. Bivariate linear analyses (i.e., linear relationships between two variables) were initially explored. Multivariate linear regression models (i.e., looking at linear relationships between multiple variables in one model), were then performed to understand what other factors may be affecting relationships between asthma rates and air concentrations. As described above, two sets of asthma data were evaluated - asthma hospital discharge rates (HD) and asthma emergency room discharge rates (ER). The statistical calculations were performed using a software program called Stata (version 14) (Statacorp 2015).

The relationship between variables was evaluated based on several statistical measures. Collectively these measures indicate the likelihood that there is a relationship (or correlation) between two or more variables (or conversely that there is not a relationship between the variables). One of these measures is called statistical significance, which is measured by a “p value”. The smaller the p value, the more likely that the tested variables are correlated. Common values used to assess statistical significance include p<0.05, p<0.01, and p<0.001. For example, a value of p<0.001 indicates a very strong statistically significant correlation while p<0.05 indicates a moderate statistically significant correlation. Commonly, p values greater than 0.05 indicate correlations that are not statistically significant. Another statistical measure is the correlation coefficient (or r-value) which was calculated in the initial bivariate (two variable) linear analyses. The r-value can be positive or negative, with the sign of the r-value representing the direction of the association. For positive associations, when one variable increases, the other variable increases as well. For negative, or inverse, associations, when one variable increases, the other variable decreases. The magnitude of the r-value indicates the strength of the relationship, with larger r-values indicating a stronger relationship. For example, r-values of 0.8 and higher indicate a strong linear relationship between the tested variables. Scatterplots were also prepared to visualize relationships between the asthma data relative to the air concentrations and socio-demographic variables. Scatterplots display data for two variables at a time, with one variable represented on the x-axis and the asthma data on the y-axis. Lastly, the multivariate linear regression analyses also indicated the direction of statistically significant associations (positive or negative) and further explored which variables best explained the asthma data.
4.2 Results

4.2.1 Bivariate Linear Correlation Analysis

For the two-variable (bivariate) correlation analysis, the HD and ER rates across all of the Baltimore City zip codes were compared individually to each of the other parameters across the same set of zip codes. This step of the investigation resulted in 30 two-variable correlations for HD across the three years and 30 two-variable correlations for ER also across the three years, producing a total of 60 two-variable statistical correlations.

Table 7 presents the bivariate correlation analysis results. It indicates whether each correlation was or was not statistically significant, whether the correlation was strong \( r > 0.8 \) and, for statistically significant results, the direction of correlation (positive or negative). Additional discussion and details are provided in Guerrero-Preston (2019).

The bivariate results in Table 7 show that there were no statistically significant associations between asthma discharge rates (ER or HD) and the modeled air concentrations of PM\(_{2.5}\), NO\(_2\) or SO\(_2\) in 2011, 2012 or 2013. Highly significant associations were, however, observed for several socio-demographic parameters in bivariate analyses, particularly for indicators of race (e.g., percent of population that is black or white) and social determinants of health (e.g., median family income and housing vacancy rate). For example, highly significant associations and strong correlations were observed between median family income and both asthma emergency room discharge rates and hospital discharge rates, with \( p < 0.001 \) for all three evaluated years. This particular association was negative, meaning that as median family income decreased across the zip codes, both sets of asthma rates increased.

Example scatterplots of 2013 emergency room discharge rates relative to median family income, the most consistent variable shown in the bivariate analyses to be strongly associated with asthma, and to PM\(_{2.5}\), SO\(_2\) and NO\(_2\) air concentrations, are provided in Figure 6. (Additional scatterplots for the tested variables are provided in the supplemental figures in Guerrero-Preston (2019).) Each data point on these plots represents the annual ER rate on the y-axis and the corresponding air concentration or median family income value on the x-axis for one zip code. These example scatterplots support the conclusions noted above. There was no statistically significant correlation between annual emergency room discharge rates and annual average PM\(_{2.5}\), SO\(_2\) and NO\(_2\) air concentrations.\(^9\) For example, there are zip codes with 2013 annual ER rates of approximately 200-300 (cases per 10,000 persons) that have both high and low annual average PM\(_{2.5}\), SO\(_2\) and NO\(_2\) air concentrations. In contrast, there is a strong inverse correlation between 2013 annual ER rates and median family income \( (r = -0.93) \) that is highly statistically significant \( (p<0.001) \). Zip codes with higher median family incomes have lower ER asthma rates, while zip codes with lower median family income have higher ER asthma rates.

\(^9\) The \( p \) values and \( r \)-values for the not statistically significant correlations between 2013 annual emergency room discharge rates and annual average air concentrations were as follows: PM\(_{2.5}\) \( (r=0.40, p=0.08) \), SO\(_2\) \( (r=0.36, p=0.11) \) and NO\(_2\) \( (r=0.35, p=0.12) \) For more information, see Guerrero-Preston (2019).
## Table 7
Matrix of Bivariate Statistical Analyses and Results (a)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Asthma hospital discharge rates (HD)</th>
<th>Asthma emergency room discharge rates (ER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO2_2011</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>NO2_2012</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>NO2_2013</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PM_2011</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PM_2012</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PM_2013</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>SO2_2011</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>SO2_2012</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>SO2_2013</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Black_2011</td>
<td>p&lt;0.01 (+)</td>
<td>p&lt;0.001 (+)</td>
</tr>
<tr>
<td>Black_2012</td>
<td>p&lt;0.01 (+)</td>
<td>p&lt;0.001 (+) (r=0.77)</td>
</tr>
<tr>
<td>Black_2013</td>
<td>p&lt;0.01 (+)</td>
<td>p&lt;0.01 (+)</td>
</tr>
<tr>
<td>White_2011</td>
<td>p&lt;0.01 (-)</td>
<td>p&lt;0.001 (-) (r=-0.75)</td>
</tr>
<tr>
<td>White_2012</td>
<td>p&lt;0.01 (-)</td>
<td>p&lt;0.001 (-) (r=-0.78)</td>
</tr>
<tr>
<td>White_2013</td>
<td>p&lt;0.01 (-)</td>
<td>p&lt;0.01 (-) (r=-0.80)</td>
</tr>
<tr>
<td>Asian_2011</td>
<td>NS</td>
<td>p&lt;0.01 (-)</td>
</tr>
<tr>
<td>Asian_2012</td>
<td>NS</td>
<td>p&lt;0.05 (-)</td>
</tr>
<tr>
<td>Asian_2013</td>
<td>NS</td>
<td>p&lt;0.01 (-)</td>
</tr>
<tr>
<td>Al_AN_2011</td>
<td>NS</td>
<td>p&lt;0.05 (+)</td>
</tr>
<tr>
<td>Al_AN_2012</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Al_AN_2013</td>
<td>NS</td>
<td>p&lt;0.05 (+)</td>
</tr>
<tr>
<td>Income_2011</td>
<td>p&lt;0.001 (-) (r=-0.83)</td>
<td>p&lt;0.001 (-) (r=-0.94)</td>
</tr>
<tr>
<td>Income_2012</td>
<td>p&lt;0.001 (-) (r=-0.82)</td>
<td>p&lt;0.001 (-) (r=-0.93)</td>
</tr>
<tr>
<td>Income_2013</td>
<td>p&lt;0.001 (-) (r=-0.79)</td>
<td>p&lt;0.001 (-) (r=-0.93)</td>
</tr>
<tr>
<td>Owner_2011</td>
<td>p&lt;0.05 (-)</td>
<td>NS</td>
</tr>
<tr>
<td>Owner_2012</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Owner_2013</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Vacancy_2011</td>
<td>p&lt;0.01 (+)</td>
<td>p&lt;0.001 (+) (r=0.76)</td>
</tr>
<tr>
<td>Vacancy_2012</td>
<td>p&lt;0.01 (+)</td>
<td>p&lt;0.001 (+)</td>
</tr>
<tr>
<td>Vacancy_2013</td>
<td>p&lt;0.05 (+)</td>
<td>p&lt;0.001 (+) (r=0.76)</td>
</tr>
</tbody>
</table>
Notes for Table 7

For additional details, see Guerrero-Preston (2019).
AI-AN = American Indian or Alaskan Native

P values:
NS  = Not statistically significant. The two variables are not significantly correlated with one another (i.e., p>0.05).
p<0.05  = Statistically significant at the p<0.05 level (not as strong a relationship compared to the p<0.01 level).
p<0.01  = Statistically significant at the p<0.01 level.
p<0.001 = Statistically significant at the p<0.001 level. The association between the two variables is highly significant.

Correlation direction:
(+) = The relationship is positively correlated (i.e., as the value of the parameter increases across zip codes, the asthma discharge rate also increases).
(-)  = The relationship is negatively correlated (i.e., as the value of the parameter increases across zip codes, the asthma discharge rate decreases).

Strength of correlation (r-values):
$r \geq 0.8$ = The correlation is strong. All r-values greater than or equal to 0.8 are shown (including r-values of 0.75-0.79 which round up to 0.8).
Figure 6
Example Scatterplots: 2013 Emergency Room Discharge Rates (ER) Relative to Annual Average Air Concentrations and Median Family Income by Zip Code

6a: 2013 ER and Median Family Income

Statistically significant:
p<0.001
r-value = -0.93

6b: 2013 ER and PM2.5 Air Concentrations

Not statistically significant:
P=0.08
r-value = 0.40

6c: 2013 ER and NO₂ Air Concentrations

Not statistically significant:
P=0.12
r-value = 0.35

6d: 2013 ER and SO₂ Air Concentrations

Not statistically significant:
P=0.11
r-value = 0.36

For additional details, see Guerrero-Preston (2019).
4.2.2  Multivariate Regression Modeling

The multi-variable (multivariate) statistical analyses explored the relationship between asthma discharge rates and the modeled air concentrations after taking into account (i.e., adjusting for) the socio-demographic parameters examined in this study. In these models, all of the socio-demographic parameters were simultaneously included in the regression model along with air concentration (i.e., each modeled air concentration in addition to seven socio-demographic parameters across the 21 zip codes). The results of the multivariate analyses are provided in Guerrero-Preston (2019) and summarized in Tables 8 and 9 for ER and HD discharge rates, respectively.

The multivariate regression analyses showed that there were no statistically significant associations between asthma discharge rates (ER or HD) and the modeled air concentrations of PM$_{2.5}$, NO$_2$ or SO$_2$ in 2011, 2012 or 2013. The highly significant associations observed in the bivariate correlation analyses between asthma discharge rates and median family income remained significant in the multivariate regression analyses.

4.3  Statistical Analyses Conclusions

The population-based statistical analyses performed at the zip code level showed there were no statistically significant associations between annual emergency room or hospital discharge rates for asthma in relation to annual average PM$_{2.5}$, NO$_2$ or SO$_2$ air concentrations due to emissions from the WTE facility in Baltimore City during 2011, 2012 and 2013. The analyses did, however, identify statistically significant associations between discharge rates for asthma and median family income for all three years, and instances where discharge rates were also significantly associated with housing vacancy rate, homeownership rates and race. These results suggest that social determinants of health at the zip code level, for which income and housing characteristics are proxies, are driving the rates of emergency room discharges and hospital discharges due to asthma in Baltimore City.

5.0  DISCUSSION

The results of this study are in agreement with scientific research on factors associated with asthma in urban US areas like the City of Baltimore. While there are many different triggers for asthma and each person’s triggers can differ, this study found, consistent with studies of urban areas, that asthma in the City of Baltimore is mostly affected by social determinants of health.

Social determinants of health include poverty, unsafe and stressful neighborhoods, and unhealthy neighborhood and home environments. Home environments, where people spend most of their time, can be unhealthy due to indoor pollution which includes household dust, pet dander, smoking, rodents, mold, cockroaches and unvented indoor gas stoves. Several studies have documented the presence of these types of social determinants of health, including high poverty rates, in the City of Baltimore and their relationship to asthma (BCHD 2017, VCU 2012, DePriest et al. 2018, AAFA 2019, EIP 2017, Keet et al. 2015, 2017). These factors all contribute to elevated asthma rates in the city. Indeed, it has been well documented that asthma rates in Baltimore are higher than elsewhere in the State of Maryland and average US asthma rates. The city’s asthma rates are, however, similar to those in many other large urban areas in the US (AAFA 2019, CDC 2018). These similarities are likely to be related to the importance and presence of social determinants of health in many cities across the country (Northridge et al. 2010, Alicea-Alvarez et al. 2017, Hughes et al. 2017).
Table 8
Multivariate Linear Regression Modeling for Emergency Room Discharge Rates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PM$_{2.5}$ Model</th>
<th></th>
<th>NO$_2$ Model</th>
<th></th>
<th>SO$_2$ Model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{2011}$</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PM$_{2012}$</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PM$_{2013}$</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Median family income</td>
<td>p&lt;0.05 (-)</td>
<td>p&lt;0.001 (-)</td>
<td>p&lt;0.01 (-)</td>
<td>p&lt;0.01 (-)</td>
<td>p&lt;0.001 (-)</td>
<td>p&lt;0.01 (-)</td>
</tr>
<tr>
<td>Housing vacancy rate</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.05 (+)</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.05 (+)</td>
</tr>
<tr>
<td>Home ownership rate</td>
<td>NS</td>
<td>p&lt;0.05 (-)</td>
<td>p&lt;0.01 (-)</td>
<td>NS</td>
<td>p&lt;0.05 (-)</td>
<td>p&lt;0.01 (-)</td>
</tr>
<tr>
<td>Black</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>White</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Asian</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>AI_AN</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Notes
For additional details, see Guerrero-Preston (2019). AI-AN = American Indian or Alaskan Native
P values:
- NS = Not statistically significant. The two variables are not significantly correlated with one another (i.e., p>0.05).
- p<0.05 = Statistically significant at the p<0.05 level (not as strong a relationship compared to the p<0.01 level).
- p<0.01 = Statistically significant at the p<0.01 level.
- p<0.001 = Statistically significant at the p<0.001 level. The association between the two variables is highly significant.
Correlation direction:
- (+) = The relationship is positively correlated (i.e., as the value of the parameter increases across zip codes, the asthma discharge rate also increases).
- (-) = The relationship is negatively correlated (i.e., as the value of the parameter increases across zip codes, the asthma discharge rate decreases).
### Table 9
Multivariate Linear Regression Modeling for Hospital Discharge Rates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PM$_{2.5}$ Model</th>
<th>NO$_2$ Model</th>
<th>SO$_2$ Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{2011}$</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PM$_{2012}$</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PM$_{2013}$</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Median family income</td>
<td>p&lt;0.001 (-)</td>
<td>p&lt;0.001 (-)</td>
<td>p&lt;0.01 (-)</td>
</tr>
<tr>
<td>Housing vacancy rate</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Home ownership rate</td>
<td>p&lt;0.01 (-)</td>
<td>p&lt;0.05 (-)</td>
<td>NS</td>
</tr>
<tr>
<td>Black</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.05 (+)</td>
</tr>
<tr>
<td>White</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Asian</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>AI_AN</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Notes**
For additional details, see Guerrero-Preston (2019). AI-AN = American Indian or Alaskan Native

**P values:**
- NS = Not statistically significant. The two variables are not significantly correlated with one another (i.e., p>0.05).
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- p<0.01 = Statistically significant at the p<0.01 level.
- p<0.001 = Statistically significant at the p<0.001 level. The association between the two variables is highly significant.

**Correlation direction:**
- (+) = The relationship is positively correlated (i.e., as the value of the parameter increases across zip codes, the asthma discharge rate also increases).
- (-) = The relationship is negatively correlated (i.e., as the value of the parameter increases across zip codes, the asthma discharge rate decreases).
Traffic related air pollution (TRAP) can also contribute to elevated asthma rates in cities. Scientific studies, including some focused on the Baltimore area, point to TRAP as a major factor affecting asthma rates in cities (EIP 2017, Alotaibi et al. 2019, Achakulwisut et al. 2019, Khreis et al. 2017a, 2017b, 2018, Hime et al. 2018). Emissions from vehicles traveling on roadways, in particular heavily-trafficked highways like Interstate 95, affect air quality and are related to high asthma rates in cities. While TRAP was not included in this study, it is estimated to be the largest contributor to nitrogen oxides and PM2.5 concentrations in air in the Baltimore area (EIP 2017, MDE 2018, Orozco et al. 2015, USEPA 2016).

The study presented here is similar in some respects to an evaluation of asthma in the City of Baltimore that was conducted by the Environmental Integrity Project (EIP 2017). Consistent with the analysis described above, the EIP study found “a very strong spatial correlation between asthma hospitalization and emergency room visits in Baltimore’s zip codes and demographic measures of poverty, particularly median household income.” The importance of TRAP was also highlighted in the EIP report which stated “it is likely that on-road vehicles are the largest contributor to the air pollution that people breathe in Baltimore” and “There is significant overlap between areas with relatively high roadway traffic pollution and high asthma hospitalization rates in the center of the city and in parts of East and West Baltimore.” The EIP report further concluded that “there is not a significant association between city zip codes with the highest emissions of criteria pollutants from stationary facilities and the zip codes with the highest asthma rates.”

The similarities in conclusions between this study and the EIP (2017) study occurred even though there were differences in evaluation approaches. While both studies evaluated asthma data and demographic data by zip code relative to air pollution, the approaches used to characterize air pollution and the methods used to evaluate relationships with asthma data differed. In this study, air pollution was characterized as PM2.5, NO2 and SO2 concentrations calculated from dispersion modeling specifically for the WTE facility. In other words, the scope of this project was limited to evaluating air concentrations that reflected the incremental impact on air quality due solely to emissions from the WTE facility. In the EIP study, in contrast, air pollution was characterized using several approaches that more broadly reflected air quality in the city. This study evaluated zip codes classified by the Maryland Environmental Public Health Tracking Web portal as City of Baltimore zip codes, whereas EIP also included a few zip codes that straddle the city boundary but are classified as neighboring county zip codes. The modeled annual average air concentrations and asthma rates for the few additional zip codes addressed by EIP were at the low end of those included in this study (i.e., these zip codes did not have high concentrations due to WTE facility emissions or high asthma discharge rates relative to the zip codes that were included). The methods used to evaluate the data also differed. In this study, the asthma, socio-demographic, and air concentration data by zip code were statistically evaluated in Guerrero-Preston (2019) using a well-established public health statistical approach used in environmental epidemiology studies. The EIP study relied mainly on visual comparisons using graphs and maps that compared each of the datasets.

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10 Air quality was assessed by EIP using: estimated concentrations by census tract due to vehicles on roadways using a modeling tool from the University of North Carolina and USEPA; estimates of respiratory health risk by census tract based on modeled concentrations of hazardous pollutants in air using USEPA modeling tools; power plant and other large facility emissions data by zip code from USEPA’s National Emissions Inventory; and monitoring data from air quality monitors in the City of Baltimore.
There are many approaches that can help reduce asthma rates among people living in large US cities. Taking preventive medications and removing asthma triggers (such as tobacco smoke, allergens and mold and replacing unvented gas stoves with electric stoves) can help reduce the frequency of asthma symptoms. Identifying household indoor exposure sources that can trigger asthma and developing control strategies to reduce these exposures are important (Colton et al. 2015, Matsui et al. 2016, Paulin et al. 2017). Reducing emissions from major air sources known to strongly affect air quality, such as TRAP, can also help. In this study, the annual average modeled air concentrations were substantially lower than background air quality levels. Increasing access to medical care and ensuring that patients see and follow-up with health-care providers are also critical factors that impact asthma ER and HD rates (KHN 2017). Programs that can provide help to Baltimore City residents with asthma include Baltimore’s Community Asthma Program for children (BCHD 2019), Maryland’s Asthma Control Program and the Greater Baltimore Asthma Alliance.11

6.0 SUMMARY AND CONCLUSIONS

This report presents a study conducted to evaluate if there is an association between asthma rates in the City of Baltimore and emissions from the Wheelabrator Baltimore waste-to-energy (WTE) facility (formerly BRESO). The aim of the study was to understand the relationship between ambient air concentrations due to emissions from the WTE facility and asthma rates in surrounding communities. The study also allowed for a comparison of ambient air concentrations due to facility emissions and background ambient air concentrations.

Asthma hospital and emergency room discharge rates available at the zip code geographic level within the City of Baltimore were selected for this study. These data were obtained for 21 zip codes categorized as City of Baltimore zip codes in Maryland’s Environmental Public Health Tracking Web portal for 2011, 2012 and 2013. In addition, several socio-demographic factors known to be associated with asthma at the zip code level were also included – race, median family income, housing vacancy rate and homeownership rate. These parameters were all obtained from the 2010 US census. Median family income, vacancy rate and homeownership rate are all proxies for “social determinants of health”. Social determinants of health are conditions in which people are born, grow, live, and work which in turn relate to income, poverty, education, race, and neighborhood and housing conditions. They have been found in scientific studies to be major drivers of asthma.

Air dispersion modeling, using the latest USEPA-approved model, was conducted to calculate ambient air concentrations due to emissions from the WTE facility in the surrounding area. Annual average air concentrations were calculated for particulate matter less than or equal to 2.5 microns in size (PM$_{2.5}$), nitrogen dioxide (NO$_2$), and sulfur dioxide (SO$_2$), the three types of emissions from the WTE facility that may be associated with asthma. Annual average WTE facility emission rates for 2011-2013 as reported to the Maryland Department of Environment (MDE) along with hourly meteorological data for the same years were used to calculate corresponding annual average ambient air concentrations for each zip code area for each of these three years.

The incremental annual average air concentrations of PM$_{2.5}$, NO$_2$, and SO$_2$ were also compared to background concentrations from two different data sources - a study providing modeled 2010 concentrations by zip code and actual measurements from USEPA air quality monitors. Both sets of

11 See www.asthmacommunitynetwork.org and php.health.maryland.gov/mch/Pages/asthma.aspx.
background data showed that the incremental impact of WTE facility emissions on annual average air concentrations was negligible compared to annual average background levels. Further, modeled concentrations of facility emissions were orders of magnitude below detection limits of USEPA and MDE ambient air quality monitors for PM$_{2.5}$, NO$_2$ and SO$_2$.

An environmental epidemiology analysis of the asthma health data and the modeled annual average air concentrations was performed, taking into account the socio-demographic parameters, across the 21 Baltimore City zip codes for each of the three years (2011, 2012 and 2013). The analysis showed there were no statistically significant associations between annual emergency room or hospital discharge rates for asthma in relation to annual average PM$_{2.5}$, NO$_2$ or SO$_2$ air concentrations due to emissions from the WTE facility during 2011, 2012 and 2013. The analysis did, however, identify statistically significant associations between discharge rates for asthma and median family income for all three years and instances where discharge rates were also significantly associated with housing vacancy, homeownership rates and race. These results suggest that social determinants of health at the zip code level, for which income and housing characteristics are proxies, are driving the rates of emergency room discharges and hospital discharges due to asthma in Baltimore City.

The results of this analysis are in agreement with scientific research on factors associated with asthma in urban US areas like the City of Baltimore. While there are many different triggers for asthma and each person’s triggers can differ, this study found, consistent with studies of urban areas, that asthma in the City of Baltimore is mostly affected by social determinants of health. Examples of social determinants of health include: poverty, unsafe and stressful neighborhoods, and unhealthy neighborhood and home environments. Home environments, where people spend most of their time, can be unhealthy due to indoor pollution which includes household dust, pet dander, smoking, rodents, mold, cockroaches and unvented indoor gas stoves. Several studies have documented the presence of these types of social determinants of health, including high poverty rates, in the City of Baltimore and their relationship to elevated asthma rates in the city. It has been well documented that asthma rates in Baltimore are higher than elsewhere in the State of Maryland and average US asthma rates, but the city’s asthma rates are similar to those in many other large urban areas in the US. The similarities with other large cities is likely to be related to the importance and presence of social determinants of health in many cities across the country as well as traffic related air pollution (TRAP), which has been shown in scientific studies to be a major factor affecting asthma rates in cities.

7.0 REFERENCES


StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP.


Appendix A
Participant CVs
Dr. Ben Hoffman

Dr. Ben Hoffman MD, MPH is a highly-seasoned physician executive with an extensive background in occupational and environmental health, clinical medicine, and transportation safety. He has been employed by government agencies, non-profits and multinational corporations including GE, Baker Hughes, Waste Management, Anheuser-Busch and DuPont. Dr. Hoffman trained at Yale, Brown and Mt. Sinai School of Medicine and is board certified in internal medicine, preventive medicine and environmental/occupational health. He has published widely and holds Professorships (Adjunct) at the University of Texas School of Public Health and Tufts University Friedman School of Nutrition. He is active on numerous committees and boards including Global Health at the National Academy of Sciences/IOM, IPIECA/OGP and former Chair, US DOT/FMCSA Medical Review Board.
Ms. Foster has over 30 years of consulting and project management experience in environmental health sciences, with expertise in developing strategies for and conducting exposure and risk analyses related to environmental and public health issues. Ms. Foster has managed and performed numerous comprehensive risk assessment projects and public health evaluations across the US for waste management technologies such as waste-to-energy facilities, landfills, transfer stations and hazardous waste incinerators, contaminated sites including USEPA Superfund sites, and air toxics sources associated with industrial facilities. Projects typically included selection of compounds for evaluation, estimation of emissions, fate and transport modeling, identification of exposure pathways, calculation of potential human and environmental exposures, assessment of potential chronic and acute risks and evaluation of uncertainties. Hazardous waste site projects often included risk assessment of remedial alternatives and development of cleanup goals. Additional areas of work have included assessment of public health and odor impacts based on monitoring and modeling data, reviewing current and emerging public health and waste management issues, public health assessment of odor control products, participating in the evaluation, design and reporting of epidemiologic studies, coordinating multidisciplinary modeling efforts for risk assessments, estimating exposures to volatile compounds due to indoor water uses and peer review of risk assessments, public health evaluations and environmental impact assessments conducted by unaffiliated engineering and consulting firms. Ms. Foster is a member of several professional societies and has authored or co-authored many publications or presentations in the environmental field. Previous to CPF Associates, LLC, Ms. Foster was a Principal and Founding Partner of CPF Associates, Inc., a Senior Consultant with The Weinberg Group, a Project Manager with Clement Associates/ICF Consulting, a Data Reviewer for the Six Cities Study at Harvard School of Public Health, and an Environmental Protection Specialist at the US Environmental Protection Agency. She received a Master of Science Degree in Environmental Health Sciences from Harvard University School of Public Health and a B.A. in Political Science (Environmental Law/Energy Policy) from Williams College in Massachusetts.
CURRICULUM VITAE

RAFAEL E. GUERRERO-PRESTON

DEMOGRAPHIC AND PERSONAL INFORMATION

Appointments

Chief Scientific Officer and PI
LifeGene Biomarks, Inc.
3000 Manhattan Avenue
Baltimore, MD 21215

2013 - Present

1612 Avenida Ponce de León
Primer Piso
San Juan, PR 00909

rguerrero@lifegenedna.com
http://lifegenedna.com

Assistant Professor
Otolaryngology-Head and Neck Cancer Surgery
Johns Hopkins School of Medicine

2012 - 2016

Adjunct Professor
Obstetrics and Gynecology
University of Puerto Rico School of Medicine

2013 - 2018

Instructor
Otolaryngology-Head and Neck Cancer Surgery
Johns Hopkins School of Medicine

2008 - 2012

Personal Data

3000 Manhattan Avenue
Baltimore, MD 21215
787-630-7885
rafael.guerrerop@gmail.com

Education and Training

1976-1979 BA Columbia College, NYC Biology/Psychology
1979-1981 Basic Sciences Mount Sinai Medical School, NYC General Public Health
1991-1995 MPH University of Puerto Rico Environmental Health
1999-2004 DrPH University of Puerto Rico Environmental Health
2005-2007 Post-doc Mailman School of Public Health Cancer Prevention
2007-2008 Post-doc Johns Hopkins Medical School Cancer genomics/epigenomics
RESEARCH ACTIVITIES

A. Publications:

Journal Articles


0138


Journal Articles In-preparation

[1] Valle BL, Kuhn E, Herman J, Sidransky D, Shih IM, Diaz-Montes T, and Guerrero-Preston R. HIST1H2BB and MAGI2 differential promoter methylation and somatic mutations in multiple body compartments are markers for early detection of high-grade serous ovarian cancers. In-preparation


B. Patents:

Granted:


Pending:

C. Book Chapters

D. Presentations (selected)

Scientific Meeting Presentations (selected)


April 2016 Rafael Guerrero-Preston, Blanca L. Valle, Anne Jedlicka, Nitesh Turaga, Liliana Florea, Oluwasina Folawiyo, Francesca Pirini, Fahcina Lawson, Angelo Vergura, Maartje Noordhuis, Gabriela Pérez, Marisa Renehan, Carolina Guerrero-Diaz, Edgardo De Jesus-Rodriguez, Teresa Diaz-Montes, José Rodriguez Orengo, Keimari Josefina Romaguera, David Sidransky. Triage of high risk HPV positive women into colposcopy with reflex tests in pap smears and screening of high risk HPV in Transrenal DNA isolated from urine, using novel workflows to identify panels of methylated viral and human DNA. 2016 AACR Annual Meeting, New Orleans, LA.

**Oct 2015**  
Blanca L. Valle, Elisabetta Kuhn, Teresa Diaz-Montes, Herman, J, David Sidransky, Shih, IM, Rafael Guerrero-Preston. Bumphunting analysis identifies HIST1H2BB and MAGI2 as tumor suppressor genes differentially methylated in ovarian cancer. AACR Advances in Ovarian Cancer Research: Exploiting Vulnerabilities, Orlando FL.

**Sept 2015**  

**April 2015**  
Blanca L. Valle, Elisabetta Kuhn, David Sidransky, Rafael Guerrero-Preston. DNA promoter hypermethylation of genes as potential diagnostic and prognostic biomarkers for ovarian cancer. AACR Annual Meeting, Philadelphia, PA.

**April 2015**  

**April 2015**  

**Jan 2015**  

**Nov 2014**  

**Nov 2014**  
Oct 2014  **Rafael Guerrero-Preston.** Tal Hadar, Christina Michailidi, Luigi Marchionni, Curtis Pickering, Mitchell Frederick, Jeffrey Myers, Srinivasan Yegnasubramanian, Elana Fertig, Nishant Agrawal, Maartje G Nordhuis, William Westra, Wayne Koch, Joseph Califano, Victor E. Velculescu, David Sidransky. Key tumor suppressor genes inactivated by promoter methylation and somatic mutations are associated to survival differences in head and neck cancer. 19th World Congress on Advances in Oncology and 17th International Symposium on Molecular Medicine, Athens, Greece

April 2014  **Rafael Guerrero-Preston.** Blanca L. Valle, Elisabetta Kuhn, David Sidransky. DNA promoter hypermethylation of HIST1H2BB as a diagnostic and prognostic biomarker for ovarian cancer. AACR Annual Meeting, San Diego, CA.


April 2013  **Rafael Guerrero-Preston,** Anne Jedlicka, Teresa Díaz-Montes, Liliana Florea, Josefina Romaguer, Juan Carlos Roa, David Sidransky. Identification of circulating HPV Trans renal DNA in urine using qPCR and dual sequence-capture approaches. AACR Annual Meeting, Washington, DC.


April 2012  **Rafael Guerrero-Preston,** Takenori Ogawa, Mamoru Uemura, Rajani Ravi, David Sidransky, Michael Keidar, Barry Trink. Cold plasma selectively affects HNSCC cell lines by non-apoptotic pathways. AACR Annual Meeting, Chicago, IL.

April 2012  Priscilla Brebi-Mieville, Maartje G. Nordhuis, Carmen Ili, Pamela Leal-Rojas, Patricia García, Jimena Perez, Ethan Soudry, Oscar Tapia, Pablo Guzmán, Sergio Muñoz, Leander Van Neste, Wim Van Criekinge, David Sidransky, Juan Carlos Roa, and **Rafael Guerrero-Preston.** ZNF516 and FKBP6 promoter hypermethylation as companion diagnostic panel for HPV-positive and


April 2011 Carmen Ili, Priscilla Brebi, Patricia Garcia, Cynthia LeBron, Pamela Leal, Sonia Montenegro, Alejandro Corvalán, **Rafael Guerrero-Preston** and Juan Carlos Roa. c-FLIP knockdown increases apoptosis in cervical cancer cell lines. AACR Annual Meeting, Orlando, FL.

April 2011 Priscilla Brebi, Carmen Ili, Alejandra Sandoval, Pamela Leal, Patricia García, Kathleen Saavedra, Oscar Tapia, Pablo Guzman, Ethan Soudry, Jimena Pérez, David Sidransky, Sergio Muñoz, Rafael Guerrero-Preston and Juan Carlos Roa. Concurrent gene promoter hypermethylation and reduced immunohistochemical expression of potential biomarkers in cervical cancer: A Phase I biomarker development trial. AACR Annual Meeting, Orlando, FL.


April 2010 **Rafael Guerrero-Preston,** Ethan Soudry, Carmen Ili-Gangas, Priscilla Brebi-Mieville, Andrew Jaffe, Andrew Jaffe, Chris Barr, Rafael Irizarry, Maria Berdasco, Yumei Fu, Maria Orera, Julio Acero, Adolfo Blanco, Qiang Yang, Adriana Baez, Manel Esteller and David Sidransky. Genome-wide microarray platforms uncover novel hypermethylated genes in an oral squamous cell carcinoma case-control study: A phase I preclinical biomarker development study. AACR Annual Meeting, Washington DC.

Jan 2010 Pamela Leal-Rojas, Priscilla Brebi-Mieville, Carmen Ili, Mariana Brait, Leonel Maldonado, Patricia Garcia, Juan Carlos Roa, David Sidransky and **Rafael Guerrero-Preston.** Global and gene-specific DNA methylation alterations in gall bladder cancer: a proof of principle study. AACR Special Conference on Cancer
Epigenetics, San Juan, PR.

Jan 2010 **Rafael Guerrero-Preston**, Kimberly Laskie Ostrow, Miguel Echenique, David Sidransky, Jaime Matta. Molecular Analysis of Serum DNA for the Early Detection of Breast Cancer by Quantitative Methylation Specific PCR. AACR Special Conference on Cancer Epigenetics, San Juan, PR.

Jan 2010 Priscilla Brebi-Mieville, Carmen Ili-Gangas, Pamela Leal-Rojas, Ethan SoundryY1, Jimena Perez1, Juan Carlos Roa, David Sidransky, **Rafael Guerrero-Preston**. Comparison of three kits for DNA enrichment with the Methylated DNA Immunoprecipitation (MeDIP) method prior to use in genome-wide DNA methylation analysis. AACR Special Conference on Cancer Epigenetics, San Juan, PR.


April 2009 **Rafael Guerrero-Preston**, Maria Berdasco, Adriana Báez, Avirum Spira, Manel Esteller and David Sidransky. High-throughput platform uncovers smoking associated methylation landscapes in the upper airways epithelium. AACR Annual Meeting, Denver, CO.


May 2007 **Guerrero-Preston R.**, Baez A., Blanco A., Berdasco M., Ballestar E., Fraga M., Esteller M. Global DNA Methylation as a Common Early Event in Head and Neck Squamous Cell Carcinogenesis in Cases with Exposures to either Environmental Carcinogens or Viral Agents. AACR Special Conference: Approaches to Complex Pathways in Molecular Epidemiology, Albuquerque, New Mexico


**Invited Seminars (selected)**

Nov 2016 **Rafael Guerrero-Preston**. Microbiome modulation of the tumor associated immune response in HNSCC, Tumor Immunology Forum, MD Anderson Cancer Center, Houston, TX.

Oct 2016 **Rafael Guerrero-Preston**. Microbiome modulation of the tumor associated immune response in HNSCC, Microbiome Forum, Johns Hopkins University,
Baltimore, MD.

Oct 2016 Rafael Guerrero-Preston. Precision Medicine Tools for Cancer Prevention and Control, Baltimore City Cancer Control Coalition, Center to Reduce Cancer Health Disparities, Sidney Kimmel Comprehensive Cancer Center, Johns Hopkins School of Medicine.

Sep 2016 Rafael Guerrero-Preston. Precision medicine tools for early cancer detection, diagnosis and treatment, Biology Department Seminars, University of Puerto Rico, San Juan, PR

Sep 2016 Rafael Guerrero-Preston. Integration of microbiomes and epigenomes in Head and Neck Cancer Research. Department of Otolaryngology – Head and Neck Surgery, University of Arizona School of Medicine, Tucson, Arizona.

Aug 2016 Rafael Guerrero-Preston. Brief Introduction to the integration of epigenomes and microbiomes. Puerto Rico IDeA Network Biomedical Research Experience, InterAmerican University of Puerto Rico, Metropolitan Campus, San Juan, Puerto Rico

July 2016 Rafael Guerrero-Preston. Microbiome modulation of immunotherapy response in HNSCC. Johns Hopkins Clinical Research Network, Baltimore, MD

July 2016 Rafael Guerrero-Preston. Precision Medicine: Environment, exposures and epigenetics. Precision Medicine and Latino/Hispanic Health: Contributions to Reducing Health Disparities. National Heart Blood and Lung Institute, NIH, Bethesda, MD

May 2016 Social, Environmental, Psychosocial and Genomic/Epigenomic Causes of Cancer Disparities and the Promise of Precision Medicine.

May 2016 Rafael Guerrero-Preston. Social, Environmental, Psychosocial and Genomic/Epigenomic Causes of Cancer Disparities and the Promise of Precision Medicine. Prince Georges County Community Advisory Group, Center to Reduce Cancer Health Disparities, Sidney Kimmel Comprehensive Cancer Center, Johns Hopkins School of Medicine

Mar 2016 Rafael Guerrero-Preston. Precision medicine tools for early cancer detection, diagnosis and treatment. The 16th Annual Fellows and Young Investigators Colloquium, Center for Cancer Research, Office of the Director, National Cancer Institute, Shady Grove, Maryland.

Mar 2016 Rafael Guerrero-Preston. Social, Environmental, Psychosocial and Genomic/Epigenomic Causes of Cancer Disparities and the Promise of Precision Medicine. Baltimore Community Advisory Group, Center to Reduce Cancer Health Disparities, Sidney Kimmel Comprehensive Cancer Center, Johns Hopkins School of Medicine

Nov 2015 Rafael Guerrero-Preston. Health IT and the Transformation of Health Care Delivery. PR HIT Summit 2015, San Juan, PR

Sep 2015 Rafael Guerrero-Preston. Genomic, environmental and cultural dynamics of the cancer methylome in the clinic. International Symposium in Cancer Genomics, Buenos Aires, Argentina

Aug 2015 Rafael Guerrero-Preston. Methylation portraits from the front lines: Towards a worldwide network for cancer early detection and diagnosis research in low-income countries. National Cancer Institute, Molecular Course in Cancer Prevention, Bethesda, MD

June 2015 Rafael Guerrero-Preston. Bumphunting analysis identifies PAX5 promoter
methylations and p53 somatic mutations in genomic instability pathways linked to very poor survival in head and neck cancer. Department of Otolaryngology – Head and Neck Surgery, University of Arizona School of Medicine, Tucson, Arizona.

Nov 2014 **Rafael Guerrero-Preston.** Epigenomics in medicine and public health: from basic to translational outcomes. Seminario de Ciencias Básicas Biomédicas, Universidad de Antioquia, Medellín, Colombia.


Aug 2014 **Rafael Guerrero-Preston.** Epigenomics and Cancer Prevention. National Cancer Institute, Molecular Course in Cancer Prevention, Bethesda, MD.

Apr 2014 **Rafael Guerrero-Preston.** Identification of HPV Transrenal DNA using a dual sequence-capture approach. First South American Human Papilloma Virus meeting, Santiago, Chile.

Mar 2014 **Rafael Guerrero-Preston.** Key tumor suppressor genes inactivated by greater promoter methylation and somatic mutations in Head and Neck Cancer. Universidad de Los Andes, Santiago, Chile.


Oct 2013 **Rafael Guerrero-Preston.** Integrating HNSCC Cancer Genomics and Epigenomics for Personalized Medicine and Cancer Prevention and Control, Ponce Medical School, Ponce Puerto Rico.

Mar 2012 **Rafael Guerrero-Preston.** ZNF516 promoter hypermethylation as biomarker for early detection and prevention of cervical cancer. Elmhurst Hospital, New York City Health and Hospitals Corporation, NYC, NY.

Jan 2012 **Rafael Guerrero-Preston.** Translational and Public Health Epigenomics: Environmental determinants of epigenetic regulation in cancer, Universidad Adolfo Ibañez, Santiago, Chile.

Jan 2012 **Rafael Guerrero-Preston.** Translational and Public Health Epigenomics: Environmental determinants of epigenetic regulation in cancer, Universidad Católica, Santiago, Chile.

Jan 2012 **Rafael Guerrero-Preston.** Translational and Public Health Epigenomics: Environmental determinants of epigenetic regulation in cancer, CEPON, Florianopolis, Brazil.


Sept 2010 **Rafael Guerrero-Preston.** Epigenomic biomarkers of diagnosis and progression in cervical cancer. Fundación Universitaria de Ciencias de La Salud (FUCS), Bogotá, Colombia.


Sept 2010 **Rafael Guerrero-Preston.** HPV genotype prevalence among cervical cancer patients in Chile. Fundación Universitaria de Ciencias de La Salud (FUCS),
Bogotá, Colombia.


**Jan 2010** Rafael Guerrero-Preston, Cynthia LeBron. Genome-wide discovery and functional analysis of methylation alterations in cancer research. Universidad de La Frontera, Temuco, Chile.

**Jan 2009** Rafael Guerrero-Preston. Epigenomic biomarkers for early detection of cancer. Universidad de Concepción, Concepción, Chile.

**Jan 2009** Rafael Guerrero-Preston. Epigenomic biomarkers for early detection of cancer. Universidad de La Frontera, Temuco, Chile.


**May 2008** Rafael Guerrero-Preston. Public Health Epigenomics: Environmental determinants of epigenetic regulation in humans. Ponce School of Medicine, Ponce, Puerto Rico.


### E. Research Program Building / Leadership

*Molecular Disparities and Global Health Equity Program*

**Founder/Coordinator/ Principal Investigator**

- **1/2009 – Present** – “MeDIP-chip discovery in cervical cancer” Universidad de La Frontera, Temuco, Chile.
- **1/2009 – Present** – “Gastric cancer epigenomics case control study” Universidad Peruana Cayetano Heredia, Lima, Perú.
- **9/2010 – Present** – “Cervical cancer screening biomarkers” Universidad de La Frontera, Temuco, Chile.
- **10/2012 – Present** – “Cervical cancer screening biomarkers” University of Puerto Rico School of Medicine.
- **10/2013 – Present** - “Cervical cancer screening biomarkers” Universidad de Antioquia, Medellín, Colombia.

F. Research Support

Ongoing:
DOD (Marchionni) 05/01/16-04/30/19
Developing a PTEN-ERG Signature to Improve Molecular Risk Stratification in Prostate Cancer
Utilizing a multitude of carefully curated human tumor datasets our studies will clarify the molecular basis for PTEN/ERG interaction in PCa progression and apply a novel technique to model the role of transcriptional network dynamics in this process. In addition to clarifying important questions in PCa biology, this will enable the identification of additional therapeutic targets in the most aggressive subset of tumors.
Role: Co-I

Completed:
5U01CA084986-09 Sidransky (PI) 03/01/08 – 07/31/10
NCI
Supplement to Promote Diversity in Health Related Research under Early Detection Research Network grant
Integrated Development of Novel Molecular Markers
The major goals of this project are aimed at developing early detection markers based on promoter hypermethylation and mitochondrial mutations in lung cancer.
Role: Principal Investigator

1RC2DE20957 Sidransky (PI) 09/24/09 – 08/31/11
NIDCR
Recovery Act Limited Competition: Research and Research Infrastructure “Grand Opportunities” (GO)
The major goal of this project was to identify the combined genetic and epigenetic alterations with clinical impact in HNSCC.
Role: Co-Investigator

EDRN Guerrero-Preston (PI) 09/01/11 – 06/30/14
NCI/UTSW
Trans Renal DNA HPV pilot project
The major goal of this project is to investigate the use of a deep sequencing based molecular platform, HPV transrenal DNA, for the detection of high risk HPV in urine from patients with cervical pre-malignancies.
Role: Principal Investigator

K01CA164092 Guerrero-Preston (PI) 09/22/11 – 08/31/15
NCI
Epigenomic Markers of HNSCC Survival Across Ethnic Groups
The major goals of this project are to study the association between HNSCC survival across ethnic groups and global DNA methylation and promoter hypermethylation.
Role: Principal Investigator

P50DE019032-12 Sidransky (PI) 09/17/10 – 07/31/15
NIDCR
Spore in Head and Neck Cancer: Career Development Core
This project studies novel tumor suppressor genes in HNSCC and their induction of chemoresistance.
Role: Co-Investigator (Career Development)

Clinical Innovator Awards 07/01/12 – 06/30/16
FAMRI (Flight Attendants Medical Research Institute)
Epigenomic Alterations Associated to ETS in Asthma
The major goal of this project is to examine the association of asthma (symptoms and severity of disease) with ETS driven global DNA hypomethylation and promoter hypermethylation in Peripheral Blood Cells.
Role: Principal Investigator

3210000112-16-064 (Dobs) 09/01/15-06/30/18
University of Kentucky Markey Cancer Center – Cancer Center Support Grant - P30CA177558-063S1 (Evers)
Geographical Management of Cancer Health Disparities Program (GMaP)
We propose to increase collaborative regional biospecimen/biobanking collection among racial/ethnically diverse and underrepresented populations for cancer health disparities research.
Role: Co-I

Pending:

SBIR- Fast Track 7/1/18-12/31/20 3 calendar
NCI $183,168
The goal of this project is to demonstrate the feasibility for the commercialization of a molecular triage test to stratify patients for high risk of cervical cancer. Cervical cancer, a largely preventable disease, is one of the most common cancers found in women living in low- and middle-income countries (LMICs). A highly sensitive and specific test that can distinguish which HPV positive women with cervical lesions will progress to cancer, will transform cervical cancer screening practices world-wide.

TEACHING
Advisees

Post-doctoral fellows
Current
Chani Broner, PhD

Prior
Pamela Rojas, PhD
Soledad Reyes Jorquera, MD, MS
Tal Hadar, MD  
Ethan Soudry, MD  
Hayashi Masamichi, MD  
Takenori Owaga, MD  
Maartje Nordhuis, MD, PhD  
Christina Michailidi, PhD  
Cynthia Lebron, PhD  
Rajagowthamee Thangavel, PhD  
Francesca Pirini, PhD  
Blanca Valle, PhD

**Doctoral Students**

**Current**
- Bianca Rivera, BS  
- Barbara Mora Lagos, BS  
- Bola Grace Ayandibu, BS

**Prior**
- Priscilla Brebi, PhD  
- Carmen Ili Gangas, PhD  
- Gustavo Rivera Alvarez, BS

**Master Students**

**Current**
- Hernando Cadet, MS

**Prior**
- Martha Jahuira Arias, MS  
- Fahcina Lawson MS

**Undergraduate/Post-Bac Students**

**Current**
- Julia Soto

**Prior**
- Jimena Pérez, BS  
- José Deschamps, BS  
- Christina Engstrom, BS  
- Carolina Guerrero-Díaz, BS  
- Gabriela Pérez, BS  
- Marissa Renehan, BS  
- Leah Friess, BS  
- Sebastián Rodríguez, BA  
- Edgar De Jesus Rodriguez, BS

**ORGANIZATIONAL ACTIVITIES**

**A. Editorial Activities** – Scientific Journals (2007-Present)
Reviewer: American Journal of Public Health; Cancer Epidemiology, Biomarkers and Prevention; Cancer Prevention Research; Cancer Research; DNA Cell Biology; Cellular and Molecular Life Sciences; Epigenetics; Clinical Epigenetics; Health Affairs; Head and Neck; International Journal of Molecular Sciences; Molecular Cancer; Oncotarget; Scientific Reports; Journal of American Aging Association; Journal of Occupational and Environmental Health; Journal of Urban Health; Molecular Sciences; Oral Oncology; PLoS Medicine; Biomarkers; Cellular and Molecular Neurobiology; Epigenomics; Expert Review of Molecular Diagnostics; Future Oncology; Gene; International Journal of Environmental Research and Public Health; Journal of Translational Medicine; Oncotarget; Scientific Reports; Science; and PLOS ONE.

B. Professional Societies
2005-2010 American Public Health Association
2007- Present American Association of Cancer Research

C. Community Service
2010 - Present Baltimore Community Advisory Group to the Center to Reduce Cancer Health Disparities, Johns Hopkins University Sidney Kimmel Comprehensive Cancer Center. – Member
2010 - Present Center to Eliminate Cardiovascular Disparities, Johns Hopkins University. - Member

D. Conferences
2014 Shifting Portraits: Latinos, Public Health, Inequality - National conference examining the interdisciplinary implications of shifting demographic patterns amongst populations categorized as Hispanic and Latino in the contemporary United States and Baltimore. – Conference Planning Committee

HONORS AND AWARDS
2016-17 Affymetrix Tumor Profiling Grant
2014 Johns Hopkins University Diversity Recognition Award, Baltimore, MD
2011-13 National Cancer Institute Early Detection Research Network Associate Member Award
2010 Comisión Nacional de Investigación Científica y Tecnológica (Conicyt), Visiting Professor Award, Universidad de La Frontera, Chile.
2009 International Union Against Cancer (UICC) ICRETT Training Workshop Award, Geneva, Switzerland.
2007 AACR Minority Scholar in Cancer Research Award
2007 Presidential Scholarship, University of Puerto Rico, Río Piedras, Puerto Rico
2006 Presidential Scholarship, University of Puerto Rico, Río Piedras, Puerto Rico
2005 Presidential Scholarship, University of Puerto Rico, Río Piedras, Puerto Rico
2001 Presidential Scholarship, University of Puerto Rico, Río Piedras, Puerto Rico
2000-03 Pre-doctoral Research Fellow – National Center for Environmental Research, Environmental Protection Agency, Washington, DC.
1999 Presidential Scholarship, University of Puerto Rico, Río Piedras, Puerto Rico
RECOGNITION/TRAINING

2016  Keynote Speaker - The 16th Annual Fellows and Young Investigators Colloquium, Center for Cancer Research, Office of the Director, National Cancer Institute

2015/16  Advanced Health Disparities Training Program, University of Arizona - NHLBI PRIDE Program

2015  Regional DC I-Corps, National Science Foundation

2015  Johns Hopkins Junior Faculty Leadership Program, Baltimore MD

2014  American Association of Medical Colleges Minority Faculty Career Development Seminar, Vancouver, Canada

2014  American Association of Medical Colleges Minority Faculty Career Development Seminar Writers Coaching Group, Vancouver, Canada

2014  Johns Hopkins Boot camp for BioMedical Entrepreneurs, Johns Hopkins University, Baltimore, MD

2013  Intermediate R/Bioconductor for Sequence Analysis, Seattle, WA

2008  Roche/Nimblegen Microarray Technical Training, Indianapolis, Indiana

2008  NIEHS SNP’s Workshop Center for Genetics/Molecular Medicine, Louisville, Kentucky

2007  MALDI-TOF Training, Johns Hopkins Proteomics Core, Baltimore, Maryland

2007  Pathobiology of Cancer: The AACR Edward A. Smacker Memorial Workshop, Aspen, CO

2007  UC Davis Environmental Health Entrepreneurship Academy, Incline Village, NV

2007  Cancer Stem Cells as Targets for Cancer Prevention/Early Detection, National Cancer Institute Bethesda, MD

2006  Cancer Epigenetics Laboratory Internship, Manel Esteller Laboratory, Centro Nacional de Investigaciones Oncológicas (CNIO), Madrid, Spain

2005  Summer Course in Cancer Prevention, National Cancer Institute, Rockville, MD

WEBSITES

Laboratory

1) [Lab TV - Rafael Guerrero's Cancer Research Lab: Part 1 – Introduction](#)

2) [Lab TV - Rafael Guerrero's Cancer Research Lab: Part 2 – Identity](#)

3) [Lab TV - Rafael Guerrero's Cancer Research Lab: Part 3 – HPV Project](#)
Gary T Hunt
Biographical Sketch

Mr. Gary Hunt is a Vice-President and Principal Scientist within TRC’s National Air Measurements Practice in their Lowell, MA office. He works principally in the environmental sector and, in particular, the characterization, quantification and control of toxic pollutant emissions from a variety of industrial sources, as well as their transport, fate and measurement in the environment.

Gary is a career environmental consultant for both industry and government and a life-long environmentalist. He has over 40 years of experience in the environmental services industry. He has a BS in Chemistry from Villanova University and an MS in Environmental Sciences from Rutgers University. Some areas of specialization include monitoring of stationary source emissions, ambient air monitoring, environmental chemistry, litigation support, air compliance audits and the distribution, occurrences, transport and fate of Persistent Organic Pollutants (POPs) in the environment. (e.g. Dioxins and PCBs).

Mr. Hunt is a Qualified Environmental Professional (QEP) and Fellow Member of the Air & Waste Management Association. He is also a member of the American Chemical Society (Environmental Chemistry Division), Sigma XI, and the American Society of Mechanical Engineers. Mr. Hunt has authored more than 100 journal manuscripts and symposia presentations on environmental topics.
ATTACHMENT 3
SECTION                       PAGE

1.0  INTRODUCTION .......................................................... 1
2.0  MODELING APPROACH OVERVIEW ....................................... 2
     2.1  AERMOD Setup .......................................................... 2
3.0  WB WTE FACILITY EMISSIONS AND STACK PARAMETER DATA .......... 3
4.0  BUILDING RELATED CONSIDERATIONS/GEP STACK HEIGHT
     DETERMINATION .................................................................. 5
5.0  SURROUNDING LAND USE .................................................. 7
6.0  RECEPTORS ...................................................................... 9
7.0  METEOROLOGY ............................................................... 12
8.0  RESULTS OF MODELING ANALYSES ..................................... 15

FIGURES

Figure 4-1:  3D Representation of Structures included in Downwash Input .................. 6
Figure 5-1:  WB WTE Facility Location with 3km Radius Circle and 2016 National Land Cover
     Data ...................................................................................... 8
Figure 6-1:  Near Field Receptor Array ............................................. 10
Figure 6-2:  Far Field Receptor Array .................................................. 11
Figure 8-1:  Location of Unitized Maximum Impacts ........................ 17

TABLES

Table 3-1:  Stack Parameters ..................................................... 4
Table 3-2:  WB WTE Facility Emission Rates and MDE TAP Screening Levels .......... 4
Table 7-1:  Monthly Seasonal Determinations for BWI ............................ 13
Table 7-2:  Moisture Determination for BWI ....................................... 14
Table 8-1:  WB WTE Facility Unitized Impacts .................................... 16
Table 8-2:  WB WTE Facility TAP Screening Analysis Results ...................... 16
1.0 INTRODUCTION

The Wheelabrator Baltimore Waste-To-Energy (WB WTE) Facility is a 64 MW/2250 ton per day municipal waste combustion waste-to-energy facility located in Baltimore, MD. TRC performed air dispersion modeling of the WB WTE Facility for a Toxic Air Pollutant (TAP) Regulations compliance analysis. The air dispersion modeling of the facilities TAPs was carried out as described in “Test 4”, the highest level of refinement, of Maryland Department of the Environment’s (MDE) “Demonstrating Compliance with the Ambient Impact Requirement under the Toxic Air Pollutant (TAP) Regulations (COMAR 26.11.15.06)”\(^1\). The predicted impacts were compared to TAP Screening Levels\(^2\) for 1-hour, 8-hour and annual averaging periods where appropriate. The following report presents the air modeling approach and inputs utilized by TRC and the results of the modeling analyses.

\(^1\)Demonstrating Compliance with the Ambient Impact Requirement under the Toxic Air Pollutant (TAP) Regulations (COMAR 26.11.15.06), Maryland Department of the Environment (March 21, 2016), https://mde.maryland.gov/programs/Permits/AirManagementPermits/Documents/TAP%20Compliance%20Demonstration%20Guidance%202003-21-2016.pdf

\(^2\)Toxic Air Pollutant Regulations Assistance, Screening Levels (April 2012), https://mde.maryland.gov/programs/Permits/AirManagementPermits/Documents/2012-Revised-TAP-Screening-Levels-cas-sort.xls
2.0 MODELING APPROACH OVERVIEW

This report documents the inputs, assumptions, and methods that were used to perform the modeling analyses. The following sections discuss the selection of the appropriate model and source operating scenarios, as well as the use of the model and input data to predict impacts at appropriate ambient air receptors.

This analysis follows the Maryland Department of the Environment’s (MDE) “Demonstrating Compliance with the Ambient Impact Requirement under the Toxic Air Pollutant (TAP) Regulations (COMAR 26.11.15.06)” Test 4 guidance and recommendations. As such, The American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) was selected as the appropriate air quality model for the compliance demonstration analysis. AERMOD is designated by U.S. Environmental Protection Agency’s (USEPA) 40 CFR 51 Appendix W, “Guideline on Air Quality Models” as a preferred air quality model for assessing potential impacts at receptors within 50 kilometers (km) of a subject emission source. AERMOD is capable of modeling point, volume, and area sources, including stack emissions, in both simple and complex terrain settings by calculating air pollutant concentrations. The version of AERMOD (version 18081) current at the time of analyses was chosen to predict ambient concentrations of TAPs.

2.1 AERMOD Setup

AERMOD was executed in a manner consistent with its regulatory default mode (i.e., DFAULT keyword) to predict ambient air concentrations (i.e., CONC keyword). As recommended by The Guideline - Appendix W, selecting the DFAULT option invokes the use of terrain elevation data, stack tip downwash and sequential data checking. AERMOD was executed in its default mode to calculate concentrations for all analyzed pollutants and averaging periods. A unit emission rate of 1.0 gram per second (g/s) was input in the model and results were scaled based off their actual emissions so multiple TAPs could be evaluated within a single model run.

---

3.0 **WB WTE FACILITY EMISSIONS AND STACK PARAMETER DATA**

The WB WTE Facility stack parameters and emissions are presented in Tables 3-1 and 3-2, respectively. The three WTE units exhaust into individual flues in a common stack. Each individual flue has a diameter of 2.13 meters (7.0 feet). The flue gas exhaust rate and temperature modeled were the averages of flue gas exhaust rates and temperatures as reported in the annual stack testing using USEPA test methods in accordance with the Maryland Department of the Environment (MDE) approved test protocol from the years 2011-2018. The exhausts of the three individual flues were modeled as a single merged plume in accordance with USEPA modeling guidelines\(^4\). The effective diameter for the merged plume was 3.70 meters calculated as follows in Equation 3-1:

\[
D_m = \sqrt{D_F^2 \times 3} \quad \text{(Eqn 3-1)}
\]

\(D_m\) = Diameter of the merged plumes  \\
\(D_F\) = Diameter of each flue  \\
3 = Number of flues

The WB WTE Facility emission rates for each TAP were taken from annual emission statements filed with the MDE. The maximum annual emission rate from the years 2011-2018 was utilized for each reported TAP at the facility so that the most conservative results were compared against the MD TAP screening levels.

---

### Table 3-1: Stack Parameters

<table>
<thead>
<tr>
<th>Year</th>
<th>Stack*</th>
<th>Stack Height (m)</th>
<th>Stack Exit Temperature (F)</th>
<th>Stack Exit Temperature (K)</th>
<th>Stack Exit Velocity (ft/s)</th>
<th>Stack Exit Velocity (m/s)</th>
<th>Stack Diameter (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of 2011-2018</td>
<td>1</td>
<td>96</td>
<td>305</td>
<td>425</td>
<td>82.5</td>
<td>25.1</td>
<td>3.70</td>
</tr>
</tbody>
</table>

*Stack Location is UTM Coordinates NAD 83 zone 18 (meters)- Easting: 359354.09, Northing: 4348002.51, Elevation: 4.6

### Table 3-2: WB WTE Facility Emission Rates and MDE TAP Screening Levels

<table>
<thead>
<tr>
<th>Toxic Air Pollutant (TAP)</th>
<th>WB WTE Maximum Emissions (lbs/hr)</th>
<th>WB WTE Maximum Emissions (g/s)</th>
<th>1-Hour Screening Level (µg/m³)</th>
<th>8-Hour Screening Level (µg/m³)</th>
<th>Annual Screening Level (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>27.0</td>
<td>3.40</td>
<td>29.8</td>
<td>165.3</td>
<td>0.70</td>
</tr>
<tr>
<td>HF*</td>
<td>0.26</td>
<td>3.29E-02</td>
<td>16.4</td>
<td>4.1</td>
<td>n/a</td>
</tr>
<tr>
<td>Dioxin TEQ**</td>
<td>6.39E-08</td>
<td>8.05E-09</td>
<td>n/a</td>
<td>8.00E-04</td>
<td>3.00E-08</td>
</tr>
<tr>
<td>Cadmium</td>
<td>4.03E-03</td>
<td>5.07E-04</td>
<td>n/a</td>
<td>2.00E-02</td>
<td>6.00E-04</td>
</tr>
<tr>
<td>Lead</td>
<td>3.72E-02</td>
<td>4.69E-03</td>
<td>n/a</td>
<td>0.50</td>
<td>n/a</td>
</tr>
<tr>
<td>Mercury</td>
<td>8.80E-03</td>
<td>1.11E-03</td>
<td>0.30</td>
<td>0.10</td>
<td>n/a</td>
</tr>
<tr>
<td>Arsenic</td>
<td>1.50E-03</td>
<td>1.89E-04</td>
<td>n/a</td>
<td>0.10</td>
<td>2.00E-04</td>
</tr>
<tr>
<td>Chromium A</td>
<td>4.08E-03</td>
<td>5.14E-04</td>
<td>n/a</td>
<td>5.0</td>
<td>n/a</td>
</tr>
<tr>
<td>Nickel B</td>
<td>4.80E-03</td>
<td>6.05E-04</td>
<td>n/a</td>
<td>1.00</td>
<td>n/a</td>
</tr>
<tr>
<td>Barium</td>
<td>5.49E-03</td>
<td>6.92E-04</td>
<td>n/a</td>
<td>5.0</td>
<td>n/a</td>
</tr>
<tr>
<td>Beryllium*</td>
<td>1.31E-04</td>
<td>1.64E-05</td>
<td>n/a</td>
<td>5.00E-04</td>
<td>4.00E-04</td>
</tr>
<tr>
<td>Selenium*</td>
<td>1.86E-04</td>
<td>2.34E-05</td>
<td>n/a</td>
<td>2.0</td>
<td>n/a</td>
</tr>
<tr>
<td>Vanadium*</td>
<td>1.10E-04</td>
<td>1.38E-05</td>
<td>n/a</td>
<td>0.50</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Notes:* All results for all test runs below detection limit-detection limit based results show n

**: Total 2,3,7,8 tetra dioxin/furan toxic equivalents

A: standard for Chromium CAS No. 7440473 listed

B: standard for Nickel, soluble compounds CAS No. 7440020

n/a: no applicable TAP screening level
4.0 BUILDING RELATED CONSIDERATIONS/GEP STACK HEIGHT DETERMINATION

Good Engineering Practice (GEP), with respect to stack height, is defined as "the height necessary to insure that emissions from the stack do not result in excessive concentrations of any air pollutant in the immediate vicinity of the source as a result of atmospheric downwash, eddies, and wakes which may be created by the source itself, nearby structures, or nearby terrain obstacles." USEPA’s Building Profile Input Program for PRIME (BPIPPRM version 04274) was used to determine whether or not the modeled stack may be subject to aerodynamic downwash. Figure 4-1 shows a representation of the WB WTE Facility with the stack and significant building structures as contained in BPIPPRM. The analysis showed that the WB WTE Facility’s stack may be subject to aerodynamic downwash, and therefore building downwash parameters computed by BPIPPRM were included in these analyses.

---

Figure 4-1: 3D Representation of Structures included in Downwash Input
5.0 **SURROUNDING LAND USE**

The area within three kilometers of the WB WTE Facility in Baltimore, Maryland is shown in Figure 5-1 along with the 2016 National Land Cover Data\(^6\) (NLCD2016). There are few land uses that are classified as urban (Medium and High Intensity Developed areas) per the Auer Method \(^7\). Most land areas within the 3-kilometer radius circle are almost entirely classified as developed with much of that area being either medium or high intensity. Not considering open water areas, at least 70 percent of the area is classified as urban. By performing a qualitative analysis, the area around the WB WTE Facility was determined to be “urban” and the urban option was used in AERMOD by using the control keyword “URBANOPT.”

As recommended by the USEPA, the “URBANOPT” keyword was used to define the urban area of Baltimore in these analyses along with a population for the area. This option “allows the user to incorporate the effects of increased surface heating from an urban area on pollutant dispersion under stable atmospheric conditions.”\(^8\) A Baltimore Metropolitan population of 2,808,175 people was used\(^9\).

---


\(^7\) Auer, “Metropolitan Land Use in the Metropolitan St. Louis Area” (1975).


Figure 5-1: WB WTE Facility Location with 3km Radius Circle and 2016 National Land Cover Data
6.0 RECEPTORS

TRC selected a modeling domain of 20 kilometers to model the WB WTE Facility. A cartesian array was setup within the modeling domain with receptor spacing as follows:

- 25-meter spacing along the fenceline of the facility
- 50-meter spacing out to 2 kilometers
- 500-meter spacing from 2 to 5 kilometers
- 1,000-meter spacing from 5 to 20 kilometers

Receptor heights and locations were processed using AERMAP (version 18081) and United States Geological Survey (USGS) National Elevation Dataset 1/3-arc second data (approximately 10 meter (m) resolution or smaller)\(^ {10} \). The resulting receptor array had a total of 8,504 receptors. The near field and far field views of the array are presented in Figures 6-1 and 6-2, respectively.

Figure 6-1: Near Field Receptor Array
Figure 6-2: Far Field Receptor Array
7.0 METEOROLOGY

For any analysis conducted using the AERMOD model, two meteorological datasets are required: 1) hourly surface data and 2) upper air sounding data. According to The Guideline - Appendix W, the meteorological data used in an analysis should be selected based on its spatial and climatological representativeness of the facility site and its ability to accurately characterize the transport and dispersion conditions in the area of concern.

Five years (2013-2017) of meteorological data were processed. These data consisted of surface meteorological observations from Baltimore-Washington International Airport (BWI) and upper air data from Dulles International Airport at Sterling, VA, the closest National Weather Service observing sites. These data were processed using AERMET version 18081 to be consistent with AERMOD input requirements. BWI is approximately 10 km south of the WB WTE Facility in the same bay area. The BWI site is representative of meteorological conditions at the WB WTE Facility. The upper air station chosen is approximately 80 km west-southwest and is regionally representative of upper air conditions at the WB WTE Facility.

Included with the hourly surface observations from BWI were one-minute and five-minute averaged wind data processed with the AERMINUTE (Version 15272) preprocessor to AERMET to produce wind input. If only hourly averaged surface data are used it may have a high number of hours with variable wind data that would be read as calm by AERMOD and not produce a predicted concentration for that hour. AERMINUTE provides processed wind data that supplements hourly data.

AERSURFACE (version 13106) was used to determine the surface characteristics and the micrometeorological parameters (surface roughness, albedo and Bowen ratio) for the area surrounding the onsite station and the NWS station (BWI) for input into AERMET.

Surface roughness for the site was determined in 30-degree sectors for a 1 km radius circle around the observing site. The Bowen ratio and albedo were determined based on the average characteristics over a 10 by 10 km square centered on the observing site. The surface parameters were determined on a monthly basis, and the monthly seasonal category determinations are presented in Table 7-1. Those determinations were based on data that include but are not limited to first and last killing frost dates and frequency of freezing temperatures using BWI hourly surface station data. Each year (2013-2017) was characterized as wet, dry, or average based on a thirty-year period of climatological data from BWI. The precipitation data that were utilized in that characterization are summarized in Table 7-2.

These surface characteristics, in conjunction with the meteorological data, were processed using AERMET to create a surface data file and vertical profile file for use in the AERMOD model.
Table 7-1: Monthly Seasonal Determinations for BWI

<table>
<thead>
<tr>
<th>Month</th>
<th>Default Category</th>
<th>Modeling Year and Assigned Seasonal Category*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td>Jan</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Feb</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Mar</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Apr</td>
<td>5</td>
<td>5</td>
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<td>May</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Jun</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Jul</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Aug</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sep</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Oct</td>
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<td>2</td>
</tr>
<tr>
<td>Nov</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Dec</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

*Seasonal Category Descriptions:

<table>
<thead>
<tr>
<th>Category</th>
<th>(Nov 2004)</th>
<th>(Jan 2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;The term summer applies to the period when vegetation is lush.&quot;</td>
<td>&quot;Midsummer with lush vegetation&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;The term autumn refers to the period of the year when freezing conditions are common, deciduous trees are leafless, soils are bare after harvest, grasses are brown and no snow is present.&quot;</td>
<td>&quot;Autumn with unharvested cropland&quot;</td>
</tr>
<tr>
<td>3</td>
<td>(Does not address this category.)</td>
<td>&quot;Late autumn after frost and harvest, or winter with no snow&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Winter conditions apply to snow-covered surfaces and subfreezing temperatures.&quot;</td>
<td>&quot;Winter with continuous snow on ground&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Spring refers to the period when vegetation is emerging or partially green and applies to the 1-2 months after the last killing frost.&quot;</td>
<td>&quot;Transitional spring with partial green coverage or short annuals&quot;</td>
</tr>
</tbody>
</table>
Table 7-2: Moisture Determination for BWI

Minimum = 30.16 Count # of “Wet” = 9
30th Percentile = 38.75 Count # of “Average” = 12
Average = 43.60 Count # of “Dry” = 9
70th Percentile = 45.18 Sum of Count: 30
Maximum = 62.66

<table>
<thead>
<tr>
<th>#</th>
<th>Year</th>
<th>Annual Precipitation (inches)</th>
<th>Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1988</td>
<td>32.3</td>
<td>Dry</td>
</tr>
<tr>
<td>2</td>
<td>1989</td>
<td>51.88</td>
<td>Wet</td>
</tr>
<tr>
<td>3</td>
<td>1990</td>
<td>41.88</td>
<td>Average</td>
</tr>
<tr>
<td>4</td>
<td>1991</td>
<td>30.16</td>
<td>Dry</td>
</tr>
<tr>
<td>5</td>
<td>1992</td>
<td>38.93</td>
<td>Average</td>
</tr>
<tr>
<td>6</td>
<td>1993</td>
<td>42.5</td>
<td>Average</td>
</tr>
<tr>
<td>7</td>
<td>1994</td>
<td>43.32</td>
<td>Average</td>
</tr>
<tr>
<td>8</td>
<td>1995</td>
<td>36.93</td>
<td>Dry</td>
</tr>
<tr>
<td>9</td>
<td>1996</td>
<td>58.31</td>
<td>Wet</td>
</tr>
<tr>
<td>10</td>
<td>1997</td>
<td>38.34</td>
<td>Dry</td>
</tr>
<tr>
<td>11</td>
<td>1998</td>
<td>34.37</td>
<td>Dry</td>
</tr>
<tr>
<td>12</td>
<td>1999</td>
<td>43.94</td>
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<td>13</td>
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<td>Average</td>
</tr>
<tr>
<td>14</td>
<td>2001</td>
<td>34.57</td>
<td>Dry</td>
</tr>
<tr>
<td>15</td>
<td>2002</td>
<td>39.6</td>
<td>Average</td>
</tr>
<tr>
<td>16</td>
<td>2003</td>
<td>62.66</td>
<td>Wet</td>
</tr>
<tr>
<td>17</td>
<td>2004</td>
<td>45.67</td>
<td>Wet</td>
</tr>
<tr>
<td>18</td>
<td>2005</td>
<td>49.13</td>
<td>Wet</td>
</tr>
<tr>
<td>19</td>
<td>2006</td>
<td>43.24</td>
<td>Average</td>
</tr>
<tr>
<td>20</td>
<td>2007</td>
<td>34.97</td>
<td>Dry</td>
</tr>
<tr>
<td>21</td>
<td>2008</td>
<td>44.97</td>
<td>Average</td>
</tr>
<tr>
<td>22</td>
<td>2009</td>
<td>55.57</td>
<td>Wet</td>
</tr>
<tr>
<td>23</td>
<td>2010</td>
<td>43.47</td>
<td>Average</td>
</tr>
<tr>
<td>24</td>
<td>2011</td>
<td>56.52</td>
<td>Wet</td>
</tr>
<tr>
<td>25</td>
<td>2012</td>
<td>37.42</td>
<td>Dry</td>
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<tr>
<td>26</td>
<td>2013</td>
<td>42.93</td>
<td>Average</td>
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<tr>
<td>27</td>
<td>2014</td>
<td>52.58</td>
<td>Wet</td>
</tr>
<tr>
<td>28</td>
<td>2015</td>
<td>51.16</td>
<td>Wet</td>
</tr>
<tr>
<td>29</td>
<td>2016</td>
<td>40.52</td>
<td>Average</td>
</tr>
<tr>
<td>30</td>
<td>2017</td>
<td>38.28</td>
<td>Dry</td>
</tr>
</tbody>
</table>
8.0 RESULTS OF MODELING ANALYSES

The maximum AERMOD unitized impacts are presented in Table 8-1 and the resulting predicted concentrations for each TAP are presented in Table 8-2. This table represents the maximum impacts overall or highest modeled concentrations for the 5 year period 2013-2017. Distance and direction from the WB WTE Facility, as well as, Universal Transverse Mercator (UTM) coordinates for each of the locations are also shown. Maximum impacts or the highest annual modeled concentrations for each of the five years are summarized in Table 8-1. Distance and direction from the WB WTE Facility, as well as, UTM coordinates for each of these 5 impact locations are also shown. Presented in Figure 8-1 are the locations of the maximum unitized impacts displaying the distance and direction from the WB WTE Facility as well. All maximum impacts plotted up in the densest area of the receptor array indicating the maximum impact was captured.

The TAP Screening Levels for each pollutant and averaging period are also included with the predicted concentrations for reference, as well as, the percentages of the TAP screening levels for the predicted concentrations. As shown in Table 8-2, the AERMOD predicted concentrations are all below their respective TAP screening levels. Furthermore, with the exception of annual Hydrogen Chloride (HCl), all are at minimum an order of magnitude below their respective TAP screening level.
### Table 8-1: WB WTE Facility Unitized Impacts

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Easting (m)</td>
<td>359656.9</td>
<td>359756.9</td>
<td>360256.9</td>
<td>360306.9</td>
<td>360306.9</td>
<td>360306.9</td>
<td>360256.9</td>
</tr>
<tr>
<td>Northing (m)</td>
<td>4348502.1</td>
<td>4348602.1</td>
<td>4347552.0</td>
<td>4347602.1</td>
<td>434762.1</td>
<td>434762.1</td>
<td>4347802.1</td>
</tr>
<tr>
<td>Distance from WB-WTE (m)</td>
<td>584.2</td>
<td>722.3</td>
<td>968.4</td>
<td>1053.9</td>
<td>1033.5</td>
<td>999.0</td>
<td>924.8</td>
</tr>
</tbody>
</table>

### Table 8-2: WB WTE Facility TAP Screening Analysis Results

<table>
<thead>
<tr>
<th>Toxic Air Pollutant (TAP)</th>
<th>WB WTE Maximum Emissions (lbs/hr)</th>
<th>WB WTE Maximum Emissions (g/s)</th>
<th>1-Hour Impact (µg/m³)</th>
<th>1-Hour Screening Level (µg/m³)</th>
<th>% 1-Hour Screening Level</th>
<th>8-Hour Impact (µg/m³)</th>
<th>8-Hour Screening Level (µg/m³)</th>
<th>% 8-Hour Screening Level</th>
<th>Annual Impact (µg/m³)</th>
<th>Annual Screening Level (µg/m³)</th>
<th>% Annual Screening Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>27.0</td>
<td>3.40</td>
<td>2.11</td>
<td>29.8</td>
<td>7.1%</td>
<td>1.61</td>
<td>165.3</td>
<td>1.0%</td>
<td>0.11</td>
<td>0.70</td>
<td>15.4%</td>
</tr>
<tr>
<td>HF*</td>
<td>0.26</td>
<td>3.20E-02</td>
<td>2.04E-02</td>
<td>16.4</td>
<td>0.1%</td>
<td>1.55E-02</td>
<td>4.1</td>
<td>0.4%</td>
<td>1.04E-03</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Dioxin TEQ**</td>
<td>6.39E-08</td>
<td>8.05E-09</td>
<td>5.00E-09</td>
<td>n/a</td>
<td>n/a</td>
<td>3.81E-09</td>
<td>8.00E-04</td>
<td>0.0005%</td>
<td>2.55E-10</td>
<td>3.00E-08</td>
<td>0.8%</td>
</tr>
<tr>
<td>Cadmium</td>
<td>4.03E-03</td>
<td>5.07E-04</td>
<td>3.15E-04</td>
<td>n/a</td>
<td>n/a</td>
<td>2.40E-04</td>
<td>2.00E-02</td>
<td>1.2%</td>
<td>1.60E-05</td>
<td>6.00E-04</td>
<td>2.7%</td>
</tr>
<tr>
<td>Lead</td>
<td>3.72E-02</td>
<td>4.69E-03</td>
<td>2.91E-03</td>
<td>n/a</td>
<td>n/a</td>
<td>2.21E-03</td>
<td>0.50</td>
<td>0.4%</td>
<td>1.48E-04</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Mercury</td>
<td>8.80E-03</td>
<td>1.11E-03</td>
<td>6.88E-04</td>
<td>0.30</td>
<td>0.2%</td>
<td>5.24E-04</td>
<td>0.10</td>
<td>0.5%</td>
<td>3.51E-05</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Arsenic</td>
<td>1.50E-03</td>
<td>1.89E-04</td>
<td>1.17E-04</td>
<td>n/a</td>
<td>n/a</td>
<td>8.92E-05</td>
<td>0.10</td>
<td>0.1%</td>
<td>5.96E-06</td>
<td>2.00E-04</td>
<td>3.0%</td>
</tr>
<tr>
<td>Chromium A</td>
<td>4.08E-03</td>
<td>5.14E-04</td>
<td>3.19E-04</td>
<td>n/a</td>
<td>n/a</td>
<td>2.43E-04</td>
<td>5.0</td>
<td>0.005%</td>
<td>1.63E-05</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Nickel B</td>
<td>4.80E-03</td>
<td>6.05E-04</td>
<td>3.75E-04</td>
<td>n/a</td>
<td>n/a</td>
<td>2.86E-04</td>
<td>1.00</td>
<td>0.03%</td>
<td>1.91E-05</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Barium</td>
<td>5.49E-03</td>
<td>6.92E-04</td>
<td>4.29E-04</td>
<td>n/a</td>
<td>n/a</td>
<td>3.27E-04</td>
<td>5.0</td>
<td>0.01%</td>
<td>2.19E-05</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Beryllium*</td>
<td>1.31E-04</td>
<td>1.64E-05</td>
<td>1.02E-05</td>
<td>n/a</td>
<td>n/a</td>
<td>7.77E-06</td>
<td>5.00E-04</td>
<td>1.55%</td>
<td>5.20E-07</td>
<td>4.00E-04</td>
<td>0.1%</td>
</tr>
<tr>
<td>Selenium*</td>
<td>1.86E-04</td>
<td>2.34E-05</td>
<td>1.45E-05</td>
<td>n/a</td>
<td>n/a</td>
<td>1.11E-05</td>
<td>2.0</td>
<td>0.001%</td>
<td>7.40E-07</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Vanadium*</td>
<td>1.10E-04</td>
<td>1.38E-05</td>
<td>8.59E-06</td>
<td>n/a</td>
<td>n/a</td>
<td>6.54E-06</td>
<td>0.50</td>
<td>0.001%</td>
<td>4.37E-07</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Notes: * All results for all test runs below detection limit; detection limit based results shown
**: Total 2,3,7,8 tetra dioxin/furan toxic equivalents
A: standard for Chromium CAS No. 7440473 listed
B: standard for Nickel, soluble compounds CAS No. 7440020
n/a: no applicable TAP screening level
Figure 8-1: Location of Unitized Maximum Impacts