RAPID HEALTH IMPACT ASSESSMENT

The Potential Health Impacts of Incinerators and Power Plant Byproducts on Communities in Brandywine, MD

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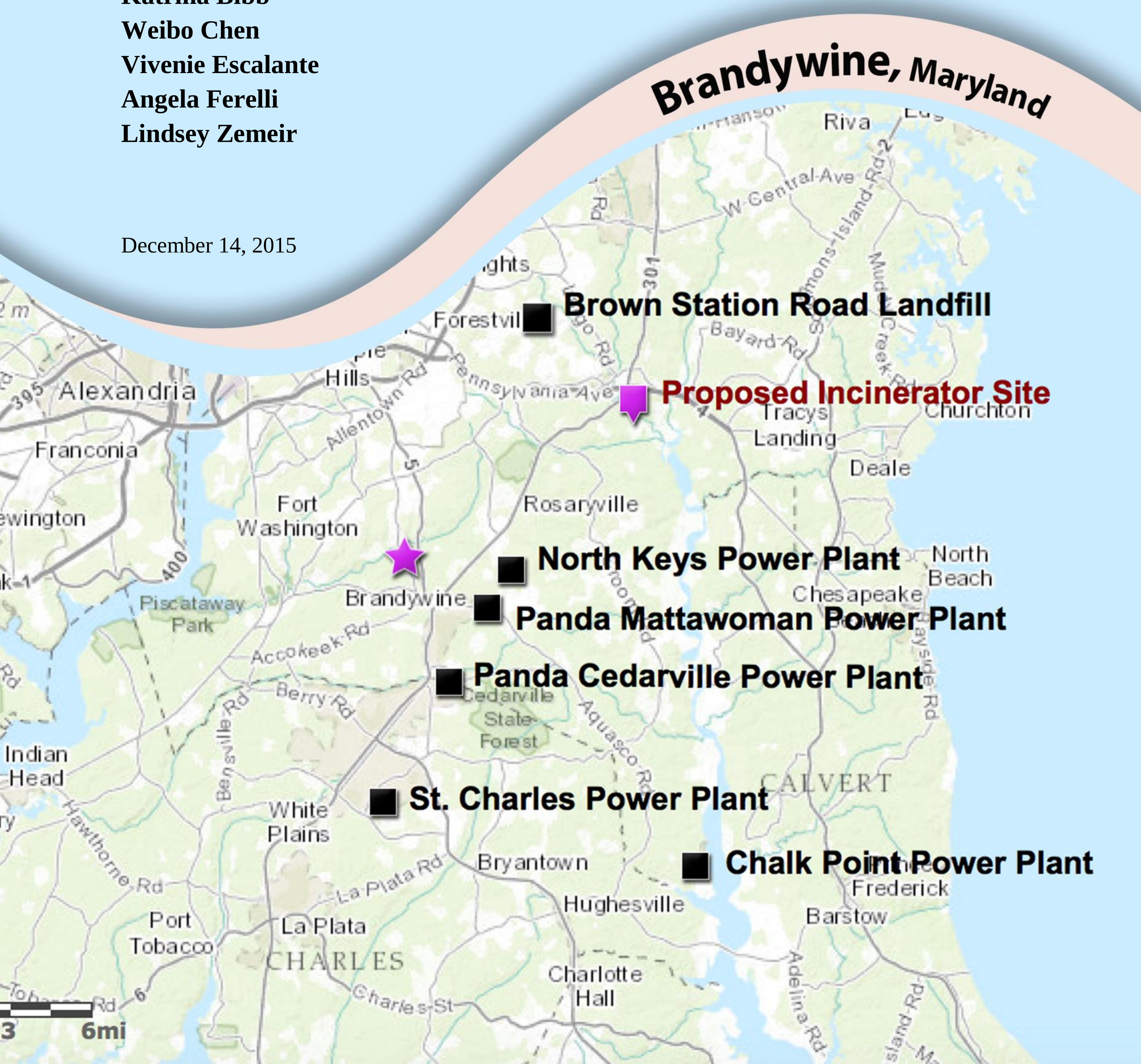


Table of Contents

EXECUTIVE SUMMARY

Background

State and County officials are evaluating a proposed trash incinerator near the Brandywine Community located in Southeast Prince George's Maryland. This community already hosts a gas-fired power plant with two more under construction. Its neighboring communities also hold a power plant with yet another under construction, as well as holding a landfill and a sewage treatment plant with a sewage sludge incinerator. The proposed waste incinerator would replace the landfill which is scheduled to fill up in 2021, with the sewage sludge incinerator site being the most likely location to host the proposed trash incinerator. Community residents are greatly concerned for their health since air and traffic pollution is already heavy in the area.

The purpose of this Rapid Health Impact Assessment (HIA) is to communicate to the population and stakeholders of the Brandywine Community the potential health impacts of adding an incinerator in the community. This HIA would serve as a report that combines a literature review on the potential effects of power plants, landfills, and incinerators on human health, something that is often overlooked when proposing policies and projects. Recommendations and alternatives will also be provided in order to alleviate the detrimental effects on an already overburdened Brandywine Community.

Key Findings

Key findings included in this HIA are as follows:

- Vulnerable Populations in the Brandywine Community:
    - 80% Minority population (compared to 45% in MD)

- Majority attained no more than high school education
- 1/3 of Brandywine population are children (<18 years)
- HRSA designated as a Medically Undeserved area (MUA)

- EJ indices for zip code 20613 report moderate to high percentiles (> 74th) for PM 2.5, ozone, traffic, and superfund site proximity at the state, region, and national level, indicating a high burden disparity of selected environmental pollutants in this area relative to the rest of the nation.
- Air quality data reveals Prince George's county is currently designated non-attainment status for 8-hour ozone levels.
  - PM 2.5 data from Brandywine Maryland were highest at an elementary school site and correlated with diesel traffic counts.
- Gas fired power plants are not a clean energy source. Methane leakage and emissions leading to contamination of water and air has been shown to be an issue in a number of steps in the fracking process. Linkage to occupational health hazards and exasperation of poor air quality have also been established.
- The adverse health outcomes most consistently linked to residential exposure to landfills are adverse birth outcomes and increased cancer risk.
  - Adverse birth outcomes: the most constant findings were low birth weight, small for gestational age, anterior abdominal wall defects (gastroschisis), and increase risk of congenital malformations.
  - Cancer: bladder cancer in both males and females was most frequently noted.
- Individuals who live within close proximity to waste incinerators and who are exposed to toxic emissions from incinerators have a higher risk of the following health outcomes:

  - Decreased pulmonary function
  - Negative birth outcomes (low birth weight, preterm births, and higher infant mortality rates)
  - Various forms of cancer (such as stomach, colon, liver, lung, and bladder cancers, childhood cancers, non-Hodgkin's lymphoma, and soft tissue sarcomas)
  - Higher overall mortality rate, and a build-up of chemicals in the blood system.
- Currently, Prince George's county zoning allows incompatible land uses to be adjacent to one another and setback distances and use of green buffer is inefficient and underutilized
  - To protect overburdened communities, multiple zoning related recommendations can be made that do not include complete re-writing of base zones; mainly, communities can work together with local legislature to install health ordinance overlay zones in residential zones, and establish larger setback distances with more mandatory green space.
  - Goals in changing zone classifications should focus on prohibiting incompatible adjacent land uses and providing designated open space buffer zones around industrial areas with special precaution given to prevailing wind direction.
- Investing in a "zero waste" hierarchy will allow the county to minimize its waste in a sustainable, low emissions manner.
- Promoting the Cumulative Impacts bill can aid in environmental justice and air quality issues.

INTRODUCTION

Health Impact Assessment (HIA) is a systematic process that can be used as a potential tool in assessing the health implications of various decisions. It uses an array of data sources and analytic methods and considers input from stakeholders to determine the potential effects of a proposed policy, plan, program, or project on the health of a population and the distribution of the effects within the population.[1] A rapid HIA is conducted when there is a limited amount of time (weeks to months) and resources. Table 1 lists the 6-step framework that illustrates the HIA process[1]:

Table 1: Six Step Framework of Health Impact Assessment

SCREENING	Determines whether a proposal is likely to have health effects and whether the HIA will provide information useful to the stakeholders and decision-makers.
SCOPING	Establishes the scope of health effects that will be included in the HIA, the populations affected and the methods to be used.
ASSESSMENT	Involves a two-step process that first describes the baseline health status of the affected population and then assesses potential impacts.
RECOMMENDATIONS	Suggest design alternatives that could be implemented to improve health or actions that could be taken to manage the health effects, if any, that are identified.
REPORTING	Documents and presents the findings and recommendations to stakeholders and decision-makers.
MONITORING AND EVALUATION	Are variably grouped and described. Monitoring can include monitoring of the adoption and implementation of HIA recommendations or monitoring of changes in health or health determinants. Evaluation can address the process, impact, or outcomes of an HIA.

SCREENING

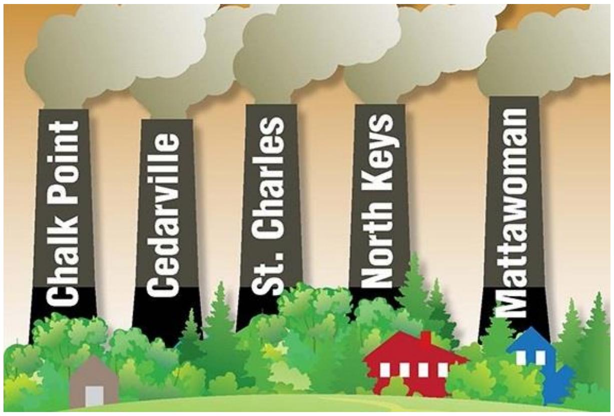


Figure 1: Power Plants

Brandywine, Maryland is already home of one gas-fired power plant with two additional gas-fired power plants under construction. It's neighboring towns also hold a gas-fired power plant with yet another under construction; meaning that in the future, the area will hold five gas-fired power plants (see figure 1). The neighboring town of Upper Marlboro houses two landfills and just southeast of the town, a sewage treatment plant with a sewage sludge incinerator. The sludge incinerator site will also be the likely site of any new trash incinerator the county is proposing, which would replace the landfill that is scheduled to fill up in 2021.

Stakeholder interviews conducted as part of the HIA process discovered that the community is already heavily concerned about the cumulative impacts of the power plants on air pollution as well as the heavy traffic. They feel helpless in stopping these facilities from being constructed in their community, especially since they are under the impression they do not have the support of their elected officials.

"Can tell air quality is bad – Air is hard to breathe, a lot of asthma in area… Woman who grows herbs says that on bad days, plants begin to die. Traffic is horrendous on little road already."

- Stakeholder Interview

"As usual, the county tried to use southern Prince George's County as a dumping ground for facilities that no county residents want in their neighborhood. Even then, our county council member did not side with us or even let us know about it."

- Stakeholder Interview

For these reasons, it was determined that an HIA would benefit the community by imparting information concerning the health impacts of the various power plants in the area, as well as the landfill and proposed incinerator. It would also apprise the community with recommendations and alternatives to the proposed incinerator.

SCOPING

Health Effects Considered

In order to determine which health impacts to evaluate, a research of the literature was conducted. Input was also collected from stakeholders who identified air quality, traffic density and mercury as their main concerns. Potential health effects are divided into the following categories: Power plants, Landfills, and Incinerators.

Affected Populations

In addition to individuals who live near these locally unwanted land uses (LULUs), the HIA sought to further study vulnerable populations which were identified through the literature [2–4] and input from community members. They are as follows:

- Infants and Toddlers (approximate ages 0-3);

- Children (approximate ages 4-11);
- Elderly (65 years and older);
- Pregnant Women;
- Economically Disadvantaged;
- Racial and Ethnic Minorities (ex. African American, Hispanics);
- The Uninsured; and
- People with Chronic Health Conditions (ex. Diabetes, Hypertension, Asthma, Cardiovascular Disease).

As can be seen on Figure 2, community residents are particularly concerned for their children, since their Elementary School and Playground are surrounded by LULUs.

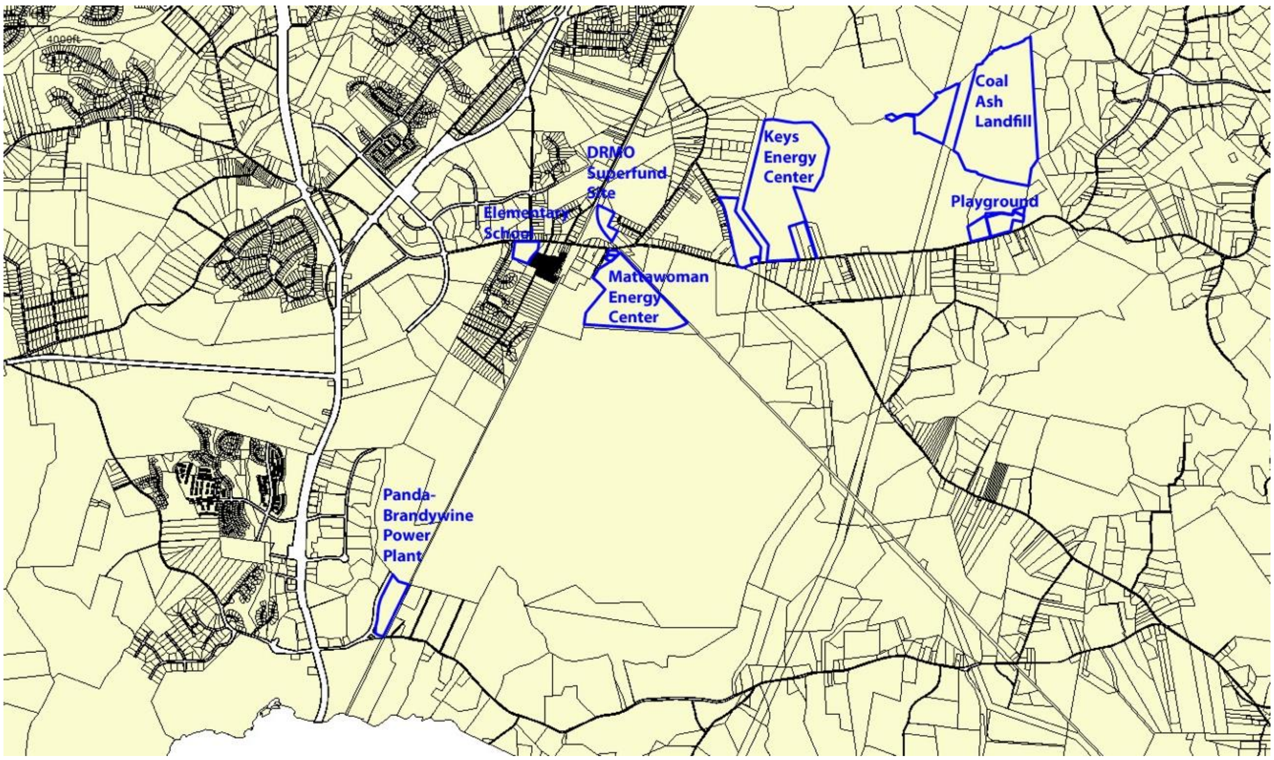


Figure 2

Methods

Methods used to evaluate health impacts on community consisted mainly of a literature review, a summary of available data on the existing baseline conditions at the smallest unit of data available (ex. Census tract or zip code). When unable to do so, county level data was used and when possible, compared to state and nation wide statistics.

Stakeholder Interviews

Interviews were conducted through email, phone calls and in-person meetings. Interview questions sought to identify stakeholders view of potential impacts of the power plants already in place and under construction, as well as the proposed incinerator. These potential impacts and alternatives were in turn incorporated into the Assessment and Recommendation sections of the HIA. Stakeholders that were interviewed are as follows:

- Mike Ewall, Founder/Director/President of Energy Justice Network
- Mildred Kriemelmeyer, Prince George's County concerned long-term resident who lives within 5 miles of proposed incinerator site and numerous power plants

Population and Sociodemographic Data Analysis

EJSCREEN tools were used to obtain demographic information for the Brandywine community census tract 20613 zip code. A 5-mile buffer was used around this community, and demographics were retrieved from the 2010 U.S. Census, 2008-2012 American Community Survey, and EPA data for Brandywine.

Baseline Health Data Analysis

The 2014 Prince George's County Health Report, developed by the Prince George's County Health Department, was used to obtain data on the overall health status of Prince George's County, as well as county performance on various health indicators (such as mortality rates, obesity rates, cancer prevalence, and birth outcomes). The 2015 County Health Rankings, a project developed through the collaboration of the Robert Wood Johnson Foundation and the University of Wisconsin Population Health Institute, provided data on Prince George's County health outcome and health indicator rankings, in comparison with other Maryland counties, the state of Maryland, and U.S. benchmarks.

Air Quality Data Analysis

Air Quality index reports were generated from the EPA website for all Maryland counties detailing PM 2.5 levels and ozone. Daily 8-hour ozone and PM 2.5 readings in Prince George's county 2013-2015 were compiled from EPA's AQI plots. Non-attainment counties for criteria air pollutants in Maryland were retrieved. AirBeam technology was also utilized, which measures PM 2.5 concentrations. The AirBeam was used at three locations: Brandywine Elementary School, Cedarville Power Plant, and the most likely site of the proposed incinerator, the sewage treatment plant.

Traffic Density Analysis

EJSCREEN report regarding traffic proximity was created. In addition, ArcGIS Traffic Density Maps were generated utilizing the ArcGIS online database. Traffic counts of diesel trucks were recording in each Airbeam sampling site, and correlated with PM 2.5 data.

Environmental Justice Indices

EJSCREEN Reports and maps were generated for Brandywine, MD zip code 20613 detailing demographic indicators, environmental indicators, and Environmental justice indices.

ASSESSMENT

Population and Sociodemographic Status

The 2010 U.S. Census data[5] for Brandywine (MD) indicates that approximately 80% of the members of this community are part of a minority population, which, according to the EPA demographic indicators provided in the EJSCREEN report, is significantly greater than the average percentage of minority populations for the state of Maryland (45%). 70% of the Brandywine community members identify as African-American, 22% identify as White, and 5% identify as Hispanic (see figure 3).[5] The majority of the population has not attained more than a high school level education, with 30% reporting that they graduated high school, 35% reporting that they attended some college but did not earn a degree, and 34% reporting that they received either an Associate's or Bachelor's Degree (see figure 4).[6] The average income for individuals residing in Brandywine is approximately $38,000.[6] 18% of the community reported a household income of less than $50,000, 15% reported a household income between $50,000 and $75,000, and 68% reported a household income greater than $75,000.[6] While the majority of this population would not be considered "low-income," there are still many members in this community who may have difficulty obtaining health care services and resources due to their income level, and thus may be differentially impacted by this new incinerator. Finally, approximately one-third of the Brandywine population is children (less than 18 years of age), and are considered a vulnerable population, since they are more susceptible to health risks (see figure 5).[6]

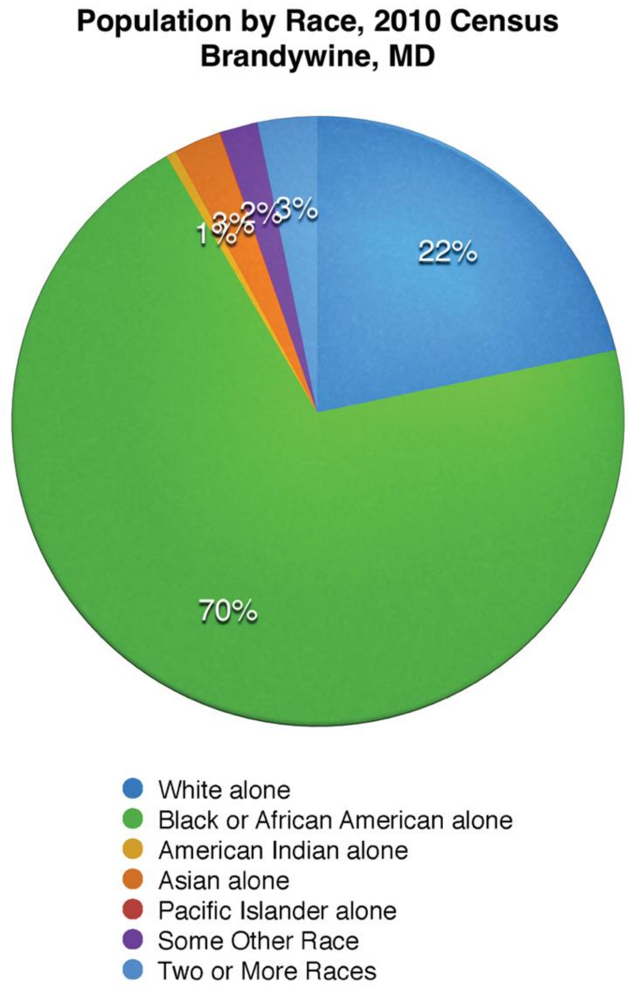

Population by Race, 2010 Census
Brandywine, MD
22%
70%
1%
3%
2%
3%
White alone
Black or African American alone
American Indian alone
Asian alone
Pacific Islander alone
Some Other Race
Two or More Races

Figure 3

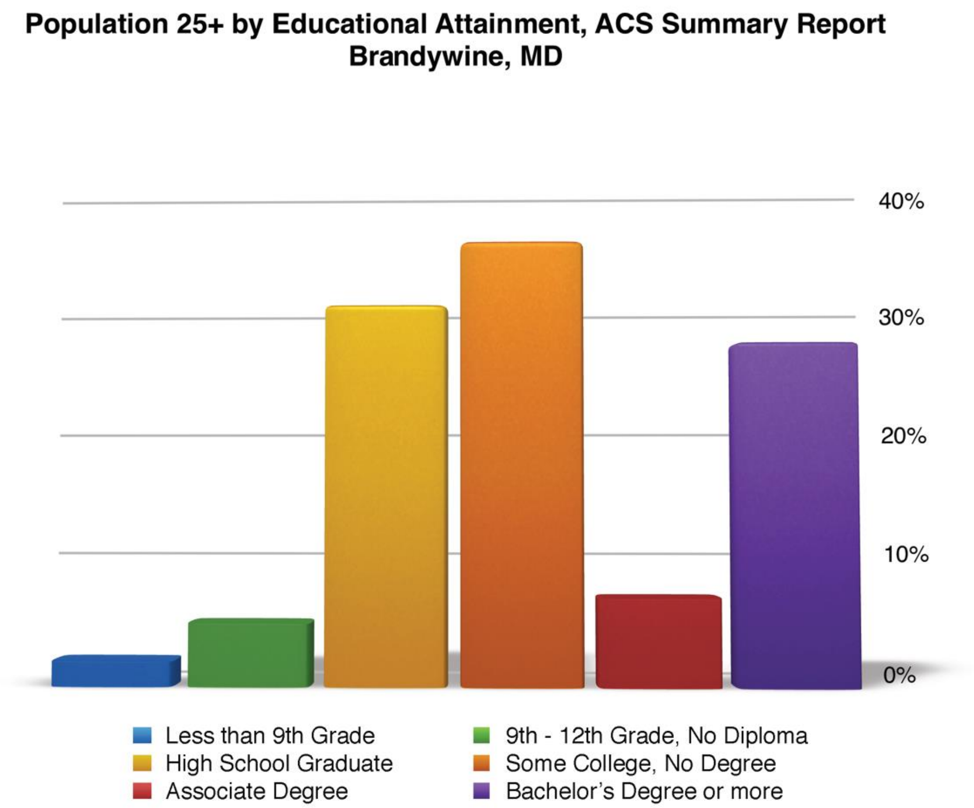


Figure 4

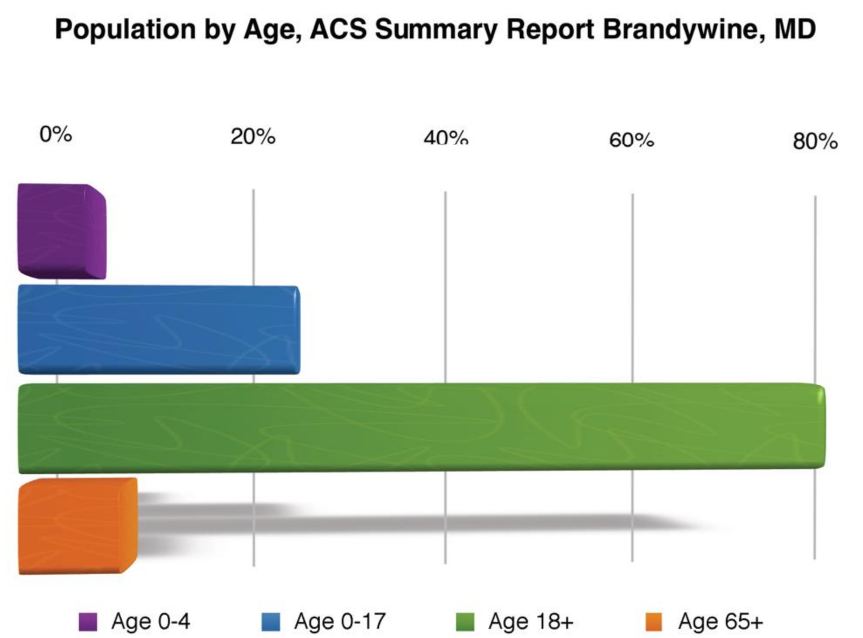


Figure 5

Baseline Health Status of Brandywine, MD

Baseline health data was collected for Prince George's County to determine the current health status of residents and inform our recommendations regarding the health impacts of the incinerator proposed in the Brandywine community. Health data is not available at the zip code level (for Brandywine, specifically), so county-level data is used for this report. Overall, Prince George's County has poorer health outcomes compared to the rest of the Maryland counties and the state, as a whole, and has specific indicators that present concern given the health outcomes related to incinerators. Prince George's County is ranked 16th out of 24 counties in terms of general health outcomes, and is ranked 15th out of 24 counties in regards to health factors (health behaviors, clinical care, social and economic factors, and the physical environment).[7]

County-level data indicates that Prince George's County is ranked 19th in terms of length of life and premature deaths.[7] 13% of individuals in Prince George's County reported having poor or fair health.[7] This county has a higher rate of obesity compared to Maryland as a whole, which represents a significant health threat since many health conditions and chronic diseases are associated with obesity. 34% of Prince George's County residents (compared to 28% of Maryland residents) are obese[7] and 68.2% of residents are either overweight or obese.[8]

Over 60% of deaths in Prince George's County are related to chronic diseases, with 25.6% of deaths related to heart disease, 24.3% related to cancer, and 2.8% related to chronic lower respiratory disease.[8] Prince George's County has a slightly higher number of deaths related to cancer (176.5 deaths per 100,000 persons) compared to the state (170.9 deaths per 100,000 persons). However, there are racial disparities in cancer mortality rates for this county data. Cancer mortality in 2010 for Prince George's County was 163.1 deaths per 100,000 persons for Whites, compared to 187.1 deaths per 100,000 persons for African-Americans.[8] Given that there is a significantly higher proportion of African-Americans than Whites residing in Brandywine, this community may be disproportionately affected by cancer and have poorer baseline health outcomes.

Prince George's County also has poorer outcomes related to low birth weight and infant mortality, compared to Maryland. In 2015, the county had 10.3% of infants with low birth weight, compared to 9.0% of low birth weight infants in Maryland.[7] There are significant county-level racial disparities in terms of birth weight. In 2012, there were 11.9% of low birth weight infants for African-Americans, compared to only 6% for Whites.[8] The infant mortality rate in 2012 was 8.6% for Prince George's County, compared to 6.3% for Maryland, and there were 4 infant deaths for Whites, compared to 69 infant deaths for African-Americans and 26 for Hispanics.[8] Further, 12.7% of births in 2012 in Prince George's County had late prenatal care or no prenatal care at all, which is important to consider for health outcomes related to birth weight and infant mortality.[8]

Individuals in Prince George's County also face issues related to access to health care. In 2015, 16% of Prince George's County residents were uninsured, compared to 12% of Maryland residents.[7] Further, there are fewer primary care physicians in the county, which makes it difficult for residents to receive the health care that they need, and may pose a problem for those individuals who would be impacted by the incinerator. The Health Resources and Services Administration (HRSA) has designated Brandywine, MD as a medically underserved area (MUA), meaning that it has been identified as having too few primary care providers per 1,000 residents, high infant mortality, high poverty, or a high elderly population.[9]

Existing Conditions: Air Quality

Prince George's County Air Quality

The Clean Air Act (CAA) requires the EPA to establish national ambient air quality standards on the most common and widespread pollutants.[10] These standards were set to protect the health of sensitive subpopulations with a margin of safety. This act also requires states to create plans to enforce these standards to minimize pollution existing and future stationary facilities, non-road mobile sources, mobile sources, and area sources.[10]

EPA calculates the Air Quality Index (AQI) for five major air pollutants regulated by the CAA: ground-level ozone, particulate matter (PM 2.5), carbon monoxide, sulfur dioxide, nitrogen dioxide, and lead.[11] Ground-level ozone and PM 2.5 are the two pollutants that pose the greatest threat to human health in Prince George's county (Table 2). A plot of the three years of Prince George's county air measurements show that 8-hour ozone indices were above 50-- indicating moderate or worse air quality- 110 out of 912 total days (12%), with three days in 2015 cited as "unhealthy for sensitive groups" (Figure 6). All daily indices were tested via ANOVA in JMP and determined to be insignificantly different, although 2015 reports a wider range of indices than 2013 or 2014, which could indicate higher levels in certain high risk months, such as summer (supplemental figure 1). PM 2.5 AQI values were classified moderate 257 out of 782 total days (32.8%), with no AQI reaching unhealthy levels (>100) (Figure 7). Together, these data explain why Prince George's county is currently nonattainment status for 8-hour ozone and was recently nonattainment for PM 2.5 (Table 3).

County	# Days with AQI	Number of Days when Air Quality was... Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy	AQI Statistics Maximum	90th Percentile	Median	Number of Days when AQI Pollutant was... CO	NO2	O3	SO2	PM2.5	PM10
Anne Arundel County, MD	242	204	37	1	.	.	101	57	40	.	.	206	.	36	.
Baltimore County, MD	304	234	65	5	.	.	119	68	40.5	.	30	242	1	31	.
Calvert County, MD	209	180	29	.	.	.	77	54	40	.	.	209	.	.	.
Carroll County, MD	215	189	26	.	.	.	100	51	39	.	.	215	.	.	.
Cecil County, MD	302	209	91	1	1	.	161	65	42	.	.	147	.	155	.
Charles County, MD	215	181	33	1	.	.	104	54	39	.	.	215	.	.	.
Dorchester County, MD	304	245	59	.	.	.	71	55	40	.	.	212	.	92	.
Frederick County, MD	215	191	23	1	.	.	101	51	41	.	.	215	.	.	.
Garrett County, MD	304	276	28	.	.	.	84	50	39.5	.	.	242	1	61	.
Harford County, MD	304	225	76	3	.	.	132	66	42	.	.	189	.	115	.
Howard County, MD	274	213	61	.	.	.	92	60	36	1	118	.	.	155	.
Kent County, MD	291	222	69	.	.	.	93	61	42	.	.	152	.	139	.
Montgomery County, MD	294	213	78	3	.	.	119	63	43	.	.	149	.	145	.
Prince George's County, MD	304	179	122	3	.	.	132	67	47	.	.	149	.	155	.
Washington County, MD	294	203	91	.	.	.	94	65	43	.	.	138	.	156	.
Baltimore (City), MD	304	194	108	2	.	.	116	67	45	.	22	122	.	160	.

Table 2: 2015 air quality index data for Maryland counties. Note that Prince George's county had 304 reportable days of air quality monitoring, out of which 149 days saw 8-hour ozone as the main pollutant detected, and 155 days with PM 2.5 as the main pollutant. Table generated from http://www3.epa.gov/airdata/ad_rep_aqi.html

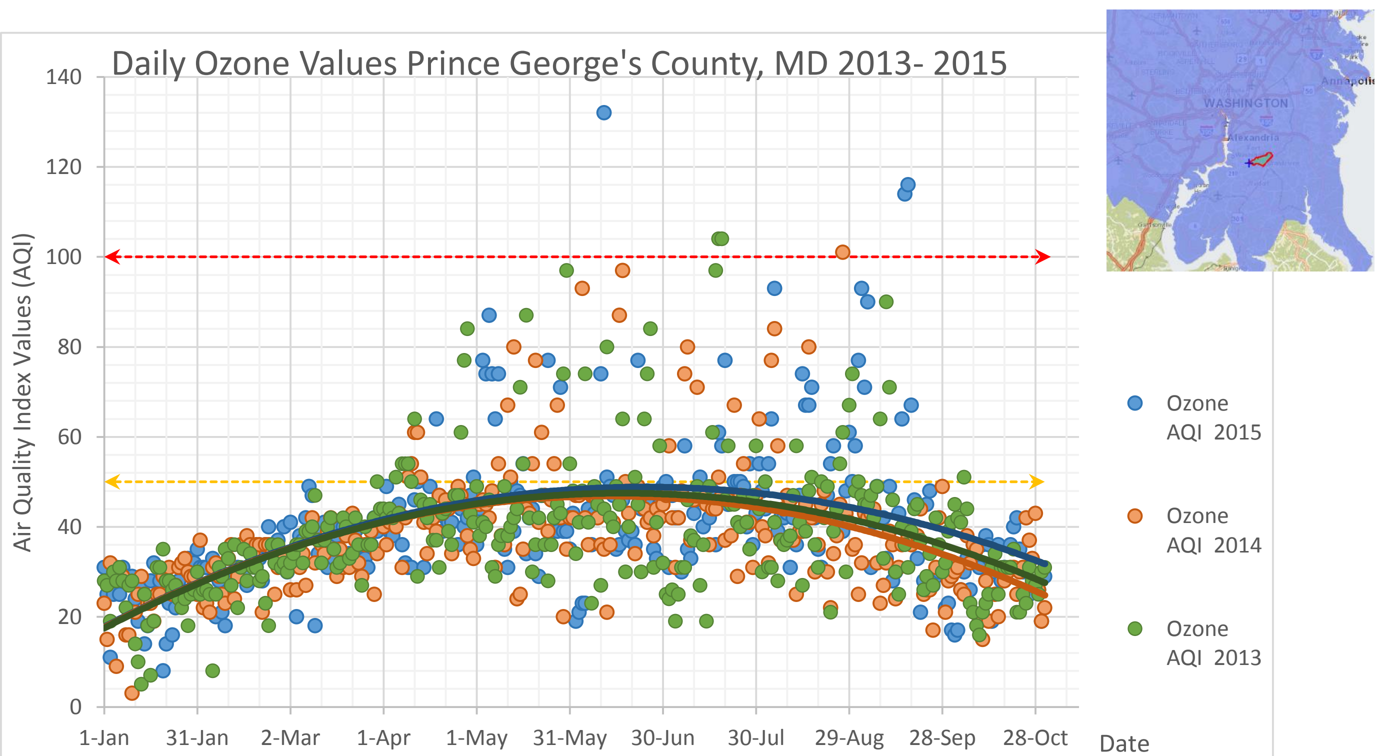


Figure 6: Daily 8-hour ozone readings in Prince George's county 2013-2015 1 January – 28 October. Trendlines (Blue: 2015, Orange: 2014, Green: 2013) are second order polynomial to account for seasonal variability in ozone. Data points above red dashed arrow indicate unhealthy ozone days for sensitive populations. Note that 2015 shows higher on average ozone reading than 2013 or 2014. Map in top right denotes Brandywine MD zip code 20613 in relation to EPA designated 8-hour ozone non-attainment. Data adapted from http://www3.epa.gov/airquality/airdata/ad_viz_plotaqi.html

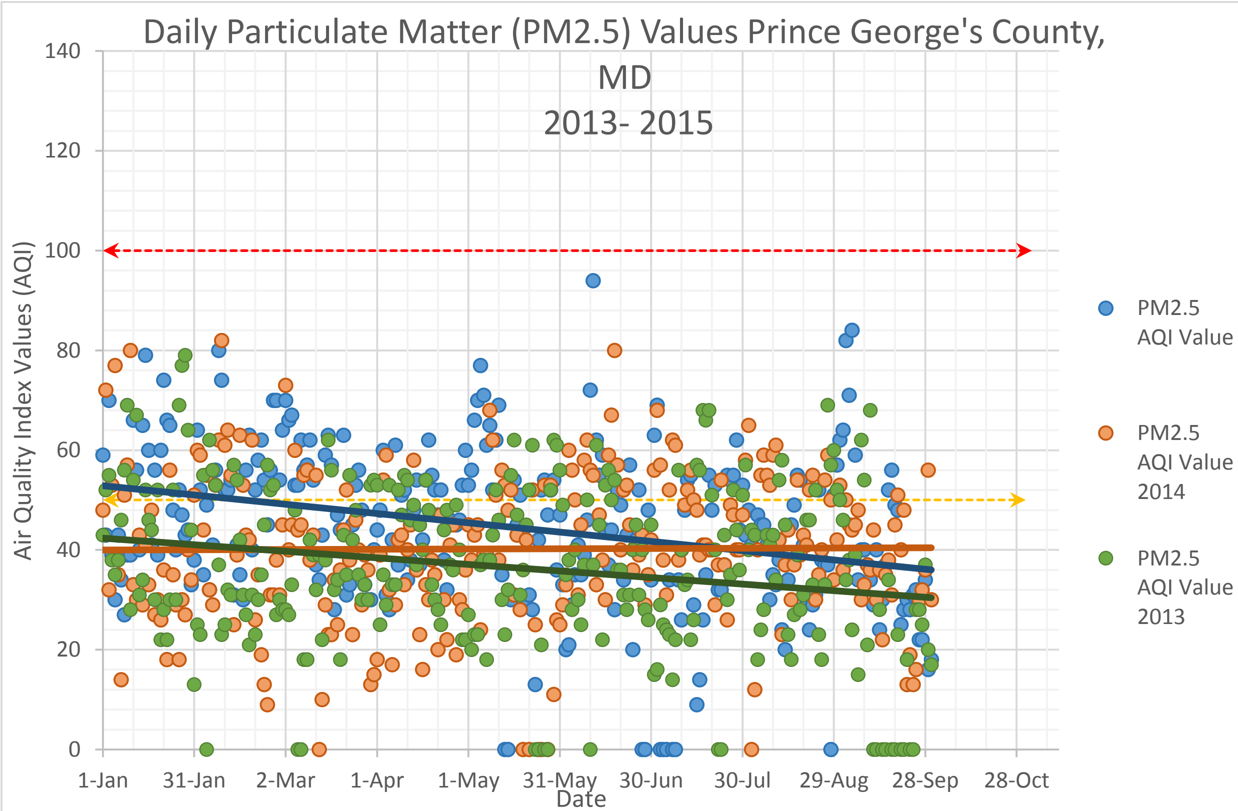


Figure 7: Daily PM 2.5 readings in Prince George's county 2013-2015 1 January – 28 September. Data points above yellow dashed arrow indicate moderate PM 2.5 pollution days/. Trendlines (Blue: 2015, Orange: 2014, Green: 2013) indicate no increasing trend in daily PM 2.5. Data adapted from http://www3.epa.gov/airquality/airdata/ad_viz_plotaqi.html

Table 3: History of Prince George's (PG) County nonattainment (highlighted) for various criteria air pollutants relative to other MD counties.

County	Pollutant	Nonattainment in Year													Redesignation to maintenance	Classification
MARYLAND		>2004	2004	2005	2006	2007	2008	2009	2010	2011*	2012	2013	2014	2015		
Anne Arundel	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Moderate
Anne Arundel	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			12/16/2014	Moderate
Baltimore (City)	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Moderate
Baltimore (City)	Carbon Monoxide (1971)	-													12/15/1995	Moderate
Baltimore (City)	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			12/16/2014	Moderate
Baltimore	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Moderate
Baltimore	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			12/16/2014	Moderate
Calvert	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Marginal
Carroll	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Moderate
Carroll	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			12/16/2014	Moderate
Cecil	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Marginal
Charles	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Marginal
Charles	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			11/5/2014	Moderate
Frederick	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Marginal
Frederick	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			11/5/2014	Moderate
Harford	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Moderate
Harford	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			12/16/2014	Moderate
Howard	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Moderate
Howard	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			12/16/2014	Moderate
Montgomery	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Marginal
Montgomery	Carbon Monoxide (1971)	-													3/15/1996	Moderate
Montgomery	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			11/5/2014	Moderate
Prince George's	8-Hr Ozone (2008)	-	-	-	-	-	-	-	-	-	-	-	-	-	/ /	Marginal
Prince George's	Carbon Monoxide (1971)	-													3/15/1996	Moderate
Prince George's	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			11/5/2014	Moderate
Washington	PM-2.5 (1997)			-	-	-	-	-	-	-	-	-			12/16/2014	Moderate

Red squares denote years in non-attainment status. Note that PG county is currently under marginal nonattainment for 8-hour ozone. Table generated at http://www.epa.gov/airquality/greenbk/anayo_md.html

Traffic Data and Airbeam PM 2.5 Collection in Brandywine, Maryland

Investigation of community air monitoring at three sites revealed average levels of 22.5ug/m ^{3} PM 2.5 with an average peak reading of 37.5 ug/m^3 around Brandywine elementary school— 8 – 9 ug/m^3 above other sites tested (Table 4). Traffic counts of diesel trucks were conducted in each area simultaneously to air data collected and is shown in Table 5. When assessed for correlation, 85% of the data can be explained by a linear trend line, meaning there may be a significant positive relationship between particulate matter and diesel trucks (Figure 8). Multiple studies have correlated diesel traffic with PM 2.5.[12,13] While these data presented should be viewed as preliminary, more research is warranted in Brandywine area to obtain reproducible results of diesel traffic contributions to particulate matter. Taken together with data gathered indirectly (Figure 9 , Figure 7,) it is clearly demonstrated that Brandywine is burdened with heavily trafficked roadways and experiences "moderate" PM 2.5 AQI values regularly. Installing new infrastructure would further exacerbate Prince George's county air quality issues and is therefore not recommended.

Table 4: Airbeam Air Monitoring Data 11-06-2015 (in ug/m^3)

Time Stamp	Facility	Katrina	Vivenie	Overall Average
9:25-9:40 am	Brandywine elementary school average	23	22	22.5
	Brandywine elementary school peak	**37**	38	37.5
10:10-10:25 am	Panda Brandywine power plant average	14	15	14.5
	Panda Brandywine power plant peak	19	22	20.5
10:55-11:10 am	Proposed incinerator site average	12	15	13.5
	Proposed incinerator site peak	19	22	20.5

Table 5: Diesel Truck Counts in 15 min interval

Facility	Number of diesel trucks	Diesel trucks per minute
Brandywine elementary school	19	1.27
Panda Brandywine power plant	11	0.73
Proposed incinerator site	4	0.27

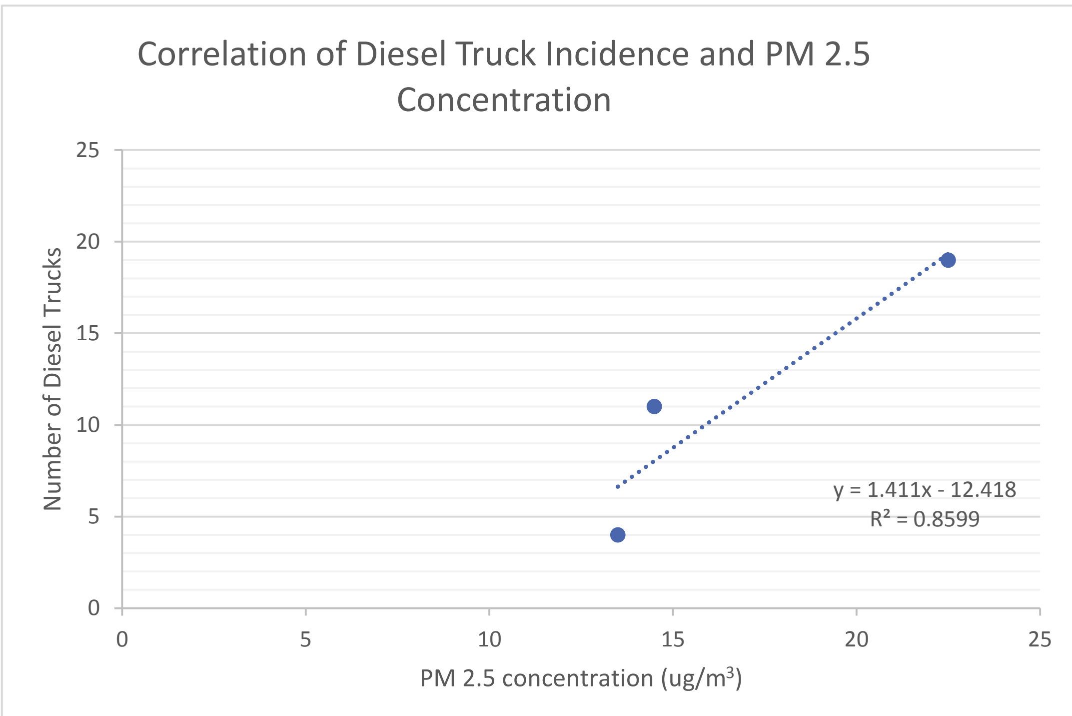


Figure 8: Correlation of diesel truck count and PM 2.5 concentrations in three areas of concern in Brandywine, MD.

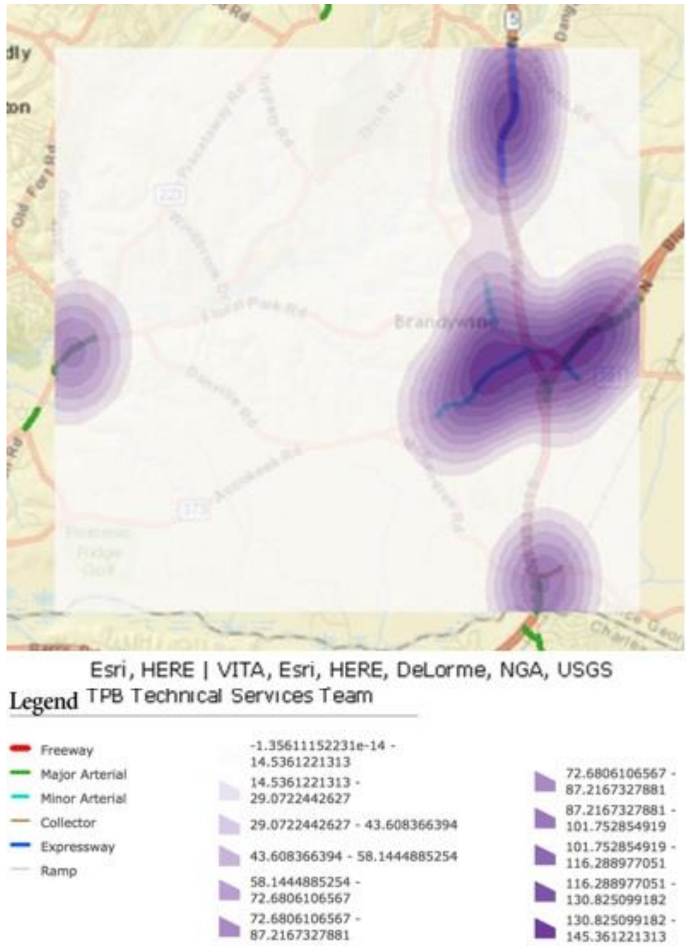


Figure 9: ArcGIS Traffic Counts – Annual Average Density Brandywine, MD

Prince George's County nonattainment

The status of nonattainment carries stipulations to minimize pollution and improve air quality in the designated area by placing restrictions on growth of certain land uses. States with nonattainment areas classified as "moderate" or higher must develop state implementation plans (SIPs) showing how the areas will meet these standards.[14] In areas of nonattainment, permits must be obtained for new "major source" infrastructure (emitting > 100 tons/ yr of any one pollutant) to ensure the source will employ pollution offsets and reflect lowest achievable emissions.[14] There are multiple environmental justice issues associated with nonattainment status of ozone and other maintenance criteria air pollutants in this area. Firstly, minorities are over represented in nonattainment areas.[15] Secondly, some government programs provide tax credits and incentives for major source polluters under the guise of "renewable energy" to obtain permits for building in otherwise burdened areas.[16] For these reasons, nonattainment areas can be targeted for continual siting of unwanted land uses with no strict regulation enforcement to mitigate the issue.

Environmental Justice Indices in Brandywine, MD

The EJSCREEN tool quantifies an environmental justice (EJ) index for a census block group by weighing a demographic index, the average of percent low income and percent minority, with environmental indicators for an area.[17] Environmental indicators quantify both potential and actual sources of exposure to selected environmental pollutants, mainly particulate matter (PM 2.5), Ozone, traffic proximity, lead paint, proximity to risk management plan sites (RMP), hazardous waste management facilities (TSDF), superfund sites (NPL), and direct water discharge sites.[17] The EJ index is calculated as follows:

$$\begin{gathered} EJ\ Index = \\ (\ Environmental\ Indicator)\ X \\ (Demographic\ Index\ for\ Block\ Group - Demographic\ Index\ for\ US)\ X \\ (Population\ count\ for\ Block\ Group) \end{gathered}$$

The EJSCREEN tool then assigns a percentile rank in comparison of the selected environmental factor to the rest of the state, region, and country.[17] In this calculation, the largest drivers of the index are the demographic index for a block group compared to that of the US. Therefore, a large demographic index for minority and low income populations compared to a small demographic index for the US will drive a higher EJ index independent of environmental indicator. Demographic indicators for the selected 20613 zip code indicate above 78th percentile (region, state, country) in minority population, and low in both low income and less than HS education level. These data are taken to mean that the area described is a mid- to upper middle class, educated, diverse demographic (Figure 10, supplemental table 1). Environmental indicators for the area report above the 50th percentile for ozone, traffic, and superfund site proximity at the state, region, and national level meaning zip code 20613 has a moderate to high risk of potential and/or actual exposure to these selected environmental pollutants (figure 11, supplemental table 1). Finally, EJ indices for zip code 20613 report moderate to high percentiles (> 74th) for PM 2.5, ozone, traffic, and superfund site proximity at the state, region, and national level (figure 12, supplemental table 1). This indicates a high burden disparity of selected environmental pollutants in this area relative to the rest of the nation.

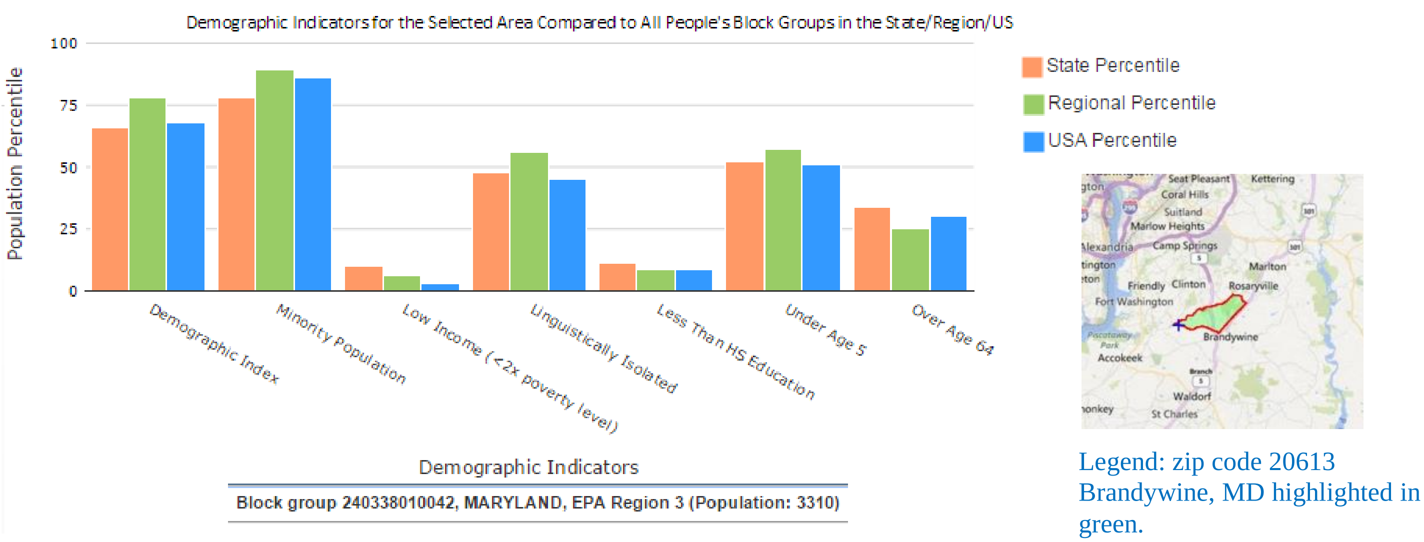


Figure 10: Demographic indicators for the selected Brandywine region zip code 20613. Note that the demographic index is high due to high percentile of minority population relative to state, region, and country. Figure generated at http://ejscreen.epa.gov/mapper/

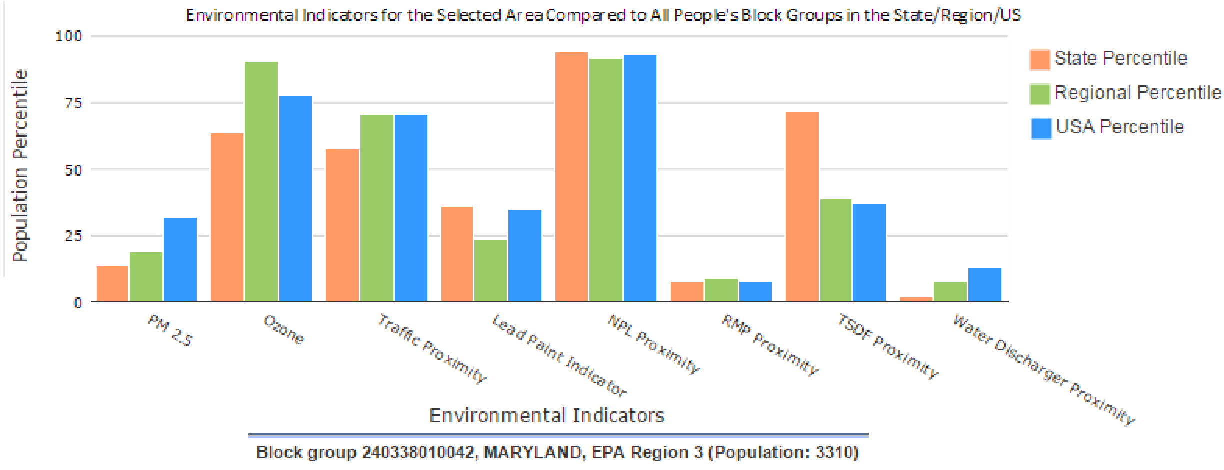


Figure 11: Environmental indicators for the selected Brandywine zip code 20613. Note that this area is above the 50th percentile for ozone, traffic, and superfund site proximity at the state, region, and national level. Figure generated at http://ejscreen.epa.gov/mapper/

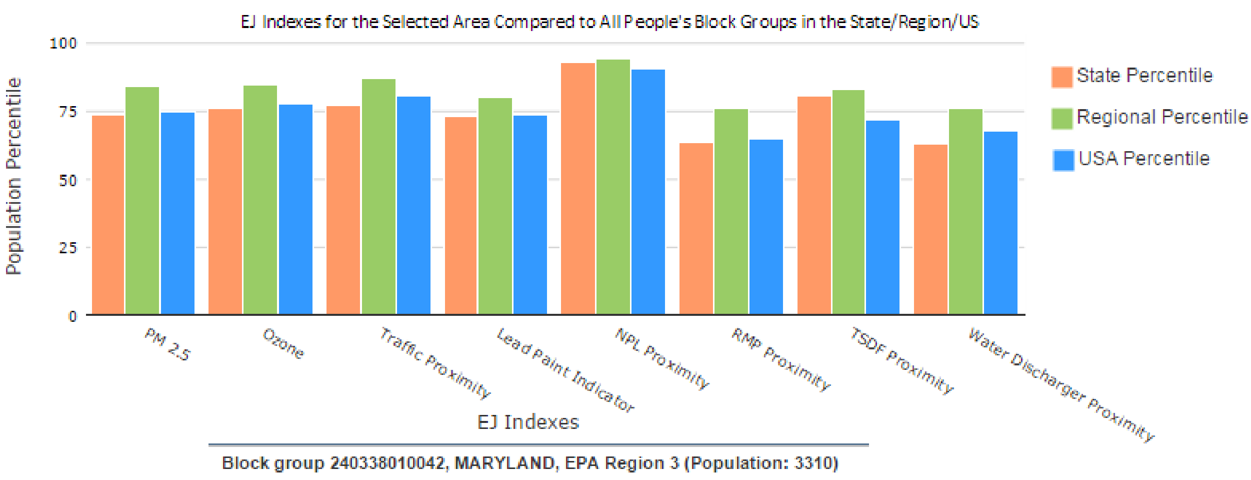


Figure 12: EJ indices for the selected Brandywine zip code 20613. Note that this area is 74th percentile or above for PM 2.5, ozone, traffic, and superfund site proximity at the state, region, and national level. Figure generated at http://ejscreen.epa.gov/mapper/

Power Plants

Pollutants

Coal continues to be the largest energy source used for energy production in the United States, emitting roughly 50% of mercury emissions, 60% of arsenic, 60% of sulfur dioxide (SO_2) emissions and 13% of various nitric oxide (NO_x) emissions into the environment.[18] Although the closest coal power plant (Chalk Point) is 15 miles from the community, gas fired power plants continue to contribute to the environmental injustice in Brandywine. Natural gas fired power plants emit about 50 to 60 percent less carbon dioxide emissions than coal fired plants, but the toxicological effects of the drilling and extraction process pose unseen health risks to the environment and humans.[19]

The primary component of natural gas in the United States is methane, which is highly flammable and released into the atmosphere upon burning natural gas for electricity. Natural gas leaks are also said to be "the largest anthropogenic source of the greenhouse gas methane (CH4) in the U.S".[20] Greenhouse gasses such as carbon dioxide are also released, further contributing to our ever growing climate conundrum. Nitric oxides are released as well and react with volatile organic compounds along with heat, sunlight and other power plant, landfill or incinerator byproducts such as sulfur dioxide, producing ground level ozone and particulate matter ($PM_{2.5}$). High levels of natural gas inhalation can also be toxic. Occupational health hazards of drilling and extracting natural gas expose workers to hydrogen sulfide, silica, noise pollution, diesel PM, temperature extremes, natural occurring radioactive material (NORM) and a number of other hazardous chemicals.[21]

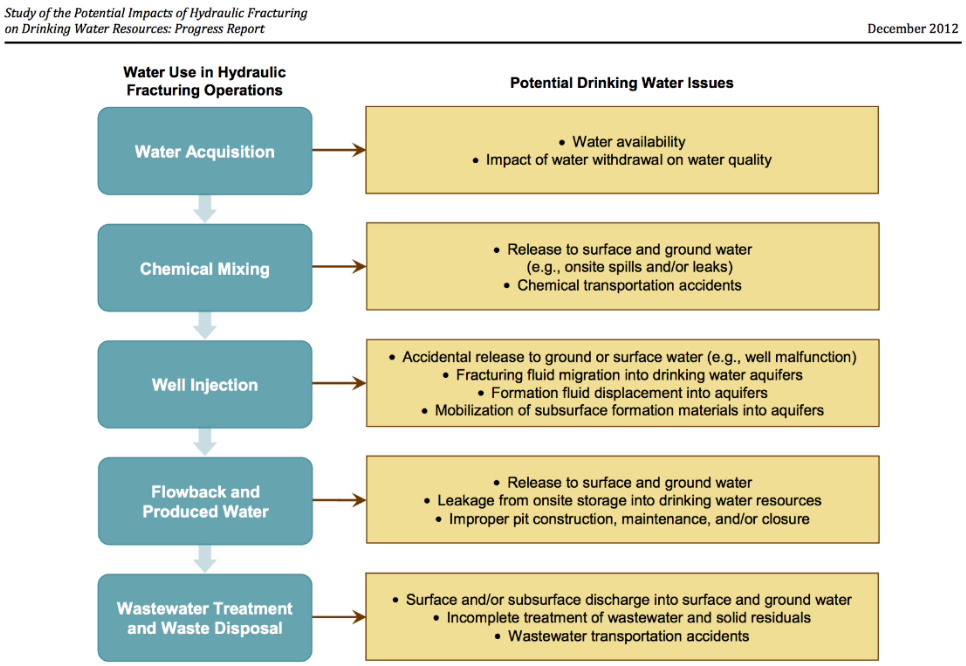


Figure 13: Potential drinking water issues associated with each stage of the hydraulic water cycle. The potential issues help to define the fundamental research questions. Figure reprinted from the Study Plan (US EPA, 2011e).

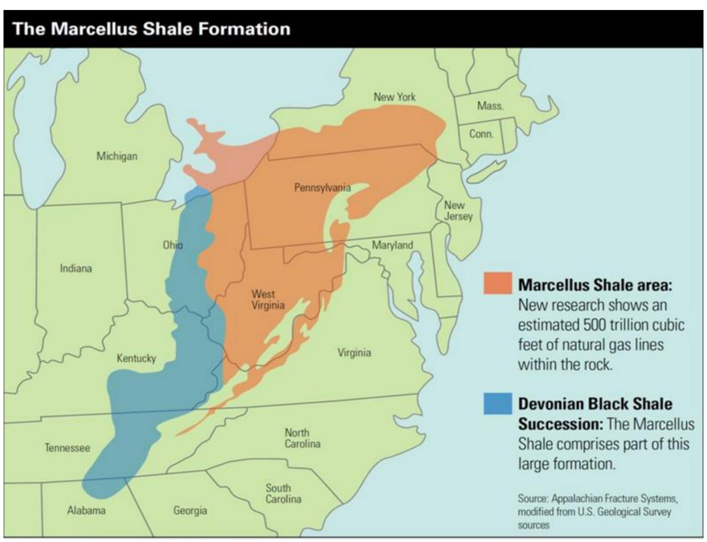
Health Effects

Natural gas is dangerous due to its colorless and odorless properties, however, in residential usage such as stoves and central air, companies add an odor as a safety precaution.[22] Methane contaminated water from natural gas leakage threatens a variety of (residential) water sources and ecosystems living along the pipes of natural gas power plants, which extend for over 100 miles. In a study which measured methane leakage from 19 locations in DC, 12 were found to be potentially explosive in manholes, creating a dangerous environment for individuals living nearby.[20]

Air pollution from gas power plant processes including nitric oxides, VOCs and PM cause nasal passage complications (loss of smell, irritation, nosebleeds), respiratory irritation, painful joints, sinus issues, dermal irritation, neurological (headaches) and eye burning all deteriorate the health of those living near gas facilities. Stress was a commonly recorded symptom of those living near the Marcellus Shale Formation.[23] In over 30% of samples collected from 11 sites nationwide, crystalline silica levels which if inhaled cause silicosis, an incurable lung disease, exceeded NIOSH exposure limit by tenfold, therefore leaving workers still unprotected. Collectively, 25% of chemicals associated with drilling are carcinogenic, over 35% effect the endocrine system and up to 50% of them affect the nervous, immune, cardiovascular and renal systems.[24]

Global effects affecting health

As methane is continuously trapping heat in the atmosphere, 25 times more efficiently than carbon dioxide, our climate warms and more disaster ensues. This increase in temperature creates a domino effect of repercussions across the globe making environments irregular for wildlife, increasing global catastrophes such as "induced seismic events", hurricane and mass flooding, in turn, creating more opportunity for diarrheal diseases in places such as Africa.[24,25] Air quality if also directly affected by increasing temperatures. As temperatures increase, quality decreases, exacerbating human and environmental health.



Limitations and Gaps in Research

Of the 52 members of the Pennsylvania Governor's Marcellus Shale Advisory Commission, the Maryland Marcellus Shale Safe Drilling Initiative Advisory Commission, and SEAB Natural Gas Subcommittee, no individuals with health expertise were found in order to make legitimate claims to oppose drilling. Regardless, over 60% of those involved in the public health hearing held by the SEAB Natural Gas Subcommittee opposed natural drilling due to health issues.[26] Aside from the lack of legitimately educated advisors, limited data is available to extensively assess the toxicological effects of natural gas drilling due to the fact that this "deep fracking" process is less than 20 years old.[24]

Landfill

Landfilling represents the largest route for the disposal of waste throughout Europe and North America.[27] Within the landfill a complex sequence of chemical and biological processes produces liquid and gaseous emissions from the parent waste. In older landfills, contaminants may be leached from the solid waste by water producing contamination of surface and groundwater.[28] Modern landfill designs incorporate leachate containment, using geomembranes and low porosity materials such as bentonite.[28] Leachate chemistry is highly variable but contains large amounts of organic matter, ammonia-nitrogen, heavy metals, and chlorinated organic compounds and inorganic salts.[29] Heavy metals found in leachate include zinc, copper, cadmium, lead, nickel, chromium and mercury.[28]

Much organic waste is converted to gaseous products, termed 'landfill gas' (LFG) which typically contains approximately 45% to 60% methane (CH_4), 40% to 60% carbon dioxide (CO_2), and less than 1% of trace gases such as hydrogen sulfide (H_2S).[30] Many trace concentrations of nitrogen, oxygen, ammonia, sulfides, hydrogen, carbon monoxide, and nonmethane organic compounds (NMOCs) such as trichloroethylene, benzene, and vinyl chloride are also observed in landfill gas.[30]

Each landfill site is unique with respect to age, quantity and type of waste contained, local meteorology, hydrogeology and engineering control of leachate and landfill gas.[28]

Emissions and Exposure

The reporting of annual emission from most landfills is necessary under section 111 of the Clean Air Act (42 U.S.C. § 7411), as amended. Landfills are the third largest anthropogenic source of CH_4 emissions in the United States (114.6 MMT CO2 Eq.), accounting for 18.0 percent of total CH_4 emissions in 2013.[31] It is important to remember, that monitoring data taken at landfills do not necessarily reflect the levels of contamination to which people may be exposed. Nonetheless, these data usually offer some insight into either general air quality, landfill gas migration, or possible health hazards.[30]

A number of potential exposure pathways can contribute to the exposure of people to contaminants from landfills. Airborne exposure may lead to inhalation of LFG or emissions from LFG flares and/or particulate matter.[28] Particles less than 10 micrometers in diameter (PM_{10}) pose a health concern because they can be inhaled, and accumulate in the respiratory system.[32]

Water-related human exposures may occur through direct ingestion, dermal contact or by consumption of produce irrigated (and/or manufactured with) contaminated water.[33] Public water supplies are under water quality regulations so if it were affected by leachate chemicals, this would be quickly identified by routine monitoring. Private water supplies, such as wells, are more susceptible, since they are not routinely monitored.

Another potential human exposure pathway is contaminated soils through atmospheric deposition of landfill emissions. Exposure of children to contaminated soils is of particular concern since young children are known to ingest greater quantities of soil and dust particles than adults through inadvertent ingestion of dust adhering to their hands.[28] Daily soil ingestion estimates for children between the ages of 1 and 4 residing at a superfund site found that mean soil ingestion estimates were 45mg day^{-1} for 50% of children.[34]

Brown Station Road Sanitary Landfill

The Brown Station Road Sanitary (BSR) Landfill located approximately 2.5 northwest of Upper Marlboro, Maryland began operation in the late 1960s, and municipal solid waste has been accepted at the landfill to this present day; it is divided into two primary areas. Area A, approximately 150 acres, is further sub-divided into areas A1 and A2 and operated between 1968 and 1992. Area B, approximately 140 acres, is currently active and has been in operation since 1992. Landfill gas is currently collected from the landfill and used to fuel boilers at the Prince George's County Correctional Center located approximately two miles away. Collected gas in excess of the Correctional Center's needs is burned in the flares.[35]

In the early to mid-1990s, offsite LFG migration was discovered at the BSR Landfill adjacent to Area A2 (an unlined area), along Brown Station Road. The area of concern measured about 1,000 feet, and adjacent to this area on the other (south) side of Brown Station Road were several private homes and nearby marshlands.[36] The Western Branch of the Patuxent River also runs on the north-northeast boundary of the landfill property, and is a large surface water body.[35] Increased methane concentrations were found by temporary probes installed between the nearby marshlands and landfill site (see figure 14). It took 10 years and several methods of containment, for the Prince George's Department to report that the migration was now under control and in regulatory compliance.[36] Studies have shown that landfill gas will continue to be generated for periods of between 15 and 30 years after final deposition of the waste, depending on waste and site characteristics.[27]

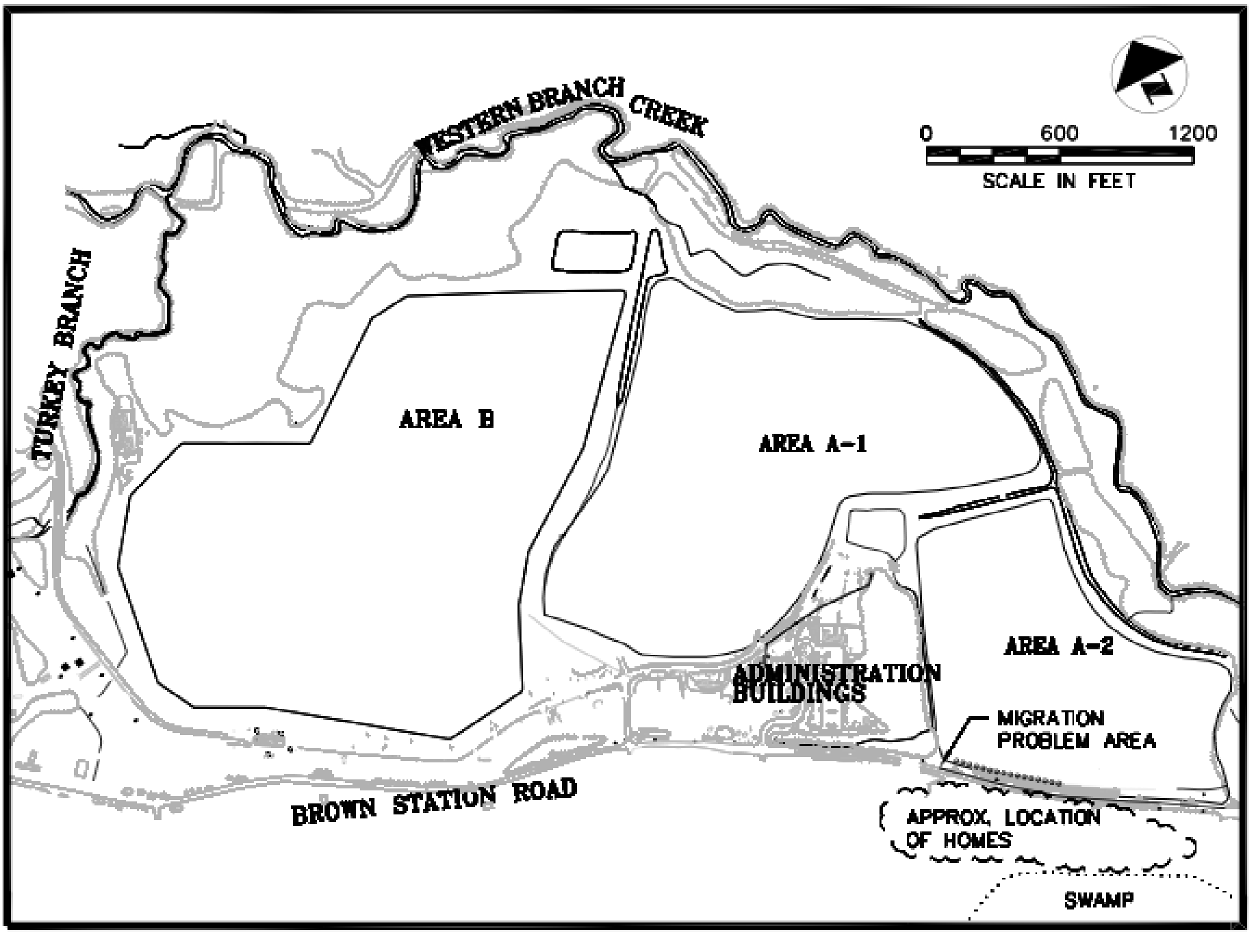


Figure 14: Brown Station Road Sanitary Landfill Offsite Landfill Gas Migration

Potential health effects

In the United States, results of public health assessments conducted at 167 waste sites during 1993 to 1995 showed that about 1.5 million people had been exposed to site-specific contaminants,[28,37] and that approximately 2 million persons live within a 1-mile radius of the nearly 1300 hazardous-waste sites on the National Priorities List (NPL).[38]

At 10% or more of the sites that had either completed or potentially completed exposure pathways, 56 substances were identified. Of these, 19 are either known or anticipated human carcinogens, and 9 are associated with reproductive or endocrine-disrupting effects, [28,37] but some health effects are known to be synergistic and the potential importance of additive effects of chemical mixtures is highlighted both by in-vitro experimentation and evidence from animals.[28] Still, the scientific basis for identifying synergism and associated health impacts has yet to be established.

It is no wonder then, that this has generated concerns about health effects associated with exposure to substances from landfill sites. This led the Agency for Toxic Substances and Disease Registry (ATSDR), as part of its federally legislated mandate, to develop a list of seven priority health conditions (PHCs) associated with hazardous waste sites: these are birth defects and reproductive disorders, cancers (selected sites), immune function disorders, kidney dysfunction, liver dysfunction, lung and respiratory diseases, and neurotoxic disorders.[38]

Vulnerability of children and pregnant women is a principal consideration when considering health effects. Children are uniquely vulnerable to environmental toxicants since pound for pound of body weight, they drink more water, eat more food, and breathe more air than adults. Children in the first 6 months of life drink seven times as much water as the average American adult.[39] This implies that children will have substantially greater exposures than adults to any toxicants that are present in water, food, or air. Two additional characteristics of children further amplify their exposures: their hand-to-mouth behavior, and playing close to the ground. Children's metabolic pathways, especially in the first months after birth, are immature. Their ability to metabolize, detoxify, and excrete toxicants is also different from that of adults.[28,39]

The fetus is also known to be at elevated risk from exposure to toxicants at certain key stages: in the period three to seven weeks post conception, toxic exposures can produce major structural defects such as cardiac abnormalities and neural tube defects.[28,40] Toxic effects in later periods in pregnancy are more characteristic of a different spectrum of disorders: these include low birth weight and functional disorders.[41]

Epidemiological studies of health effects

The epidemiological evidence of health effects associated with exposure from landfill sites has been the purview of several studies. [42-53] These studies are divided into adverse birth outcomes and cancer risk.

Adverse Birth Outcomes

Tables 6a and 6b provide a review of epidemiological studies done on adverse birth outcomes, the health outcomes most consistently linked to landfills. Table 6a consists of single-site epidemiological studies which attempt to determine whether there is an increased incidence of health effects in people living near a specific landfill site. Table 6b consists of multi-site studies which compare the frequencies of symptoms among people living near sets of landfill sites with the frequencies among the general population. These same criteria will be applied to cancer studies, which are discussed next.

Table 6a: Single-Site Studies of Adverse Birth Outcomes associated with landfill sites

Landfill Site	Primary Exposure Route	Definition of Exposed Population	Study Period	Principal Findings
Lipari landfill, New Jersey[42]	Leachate contamination of two nearby streams and a lake	Mother's residence in radius of <1 mile from Landfill site	1961-1985	Term births (37-44 weeks gestation) to parents living closest to the landfill had a statistically **lower average birth weight** (192 g) and a statistically higher proportion of **low birth weight** [odds ratio (OR) = 5.1; 95% confidence interval (CI), 2.1-12.3] than the control population. Infants had twice the risk of **prematurity** (OR = 2.1; 95% CI, 1.0-4.4) than the control population.
Nant-y-Gwyddon landfill, Wales[43]	Landfill gas	Less than 2 miles from Landfill site	1983-1996	The rate of **congenital malformation** in the five exposed wards was **3.6 times** than in the unexposed wards (2.3 to 5.7, P<0.001). The incidence of anterior abdominal wall defects (**gastroschisis**) was unusually high compared with the rest of England and Wales.
Municipal solid waste landfill site, Montreal, Quebec[44]	Landfill gas	Perimeter of <3 miles	1979-1989	**Low birth weight** was significantly elevated in the exposure zone (adjusted OR = 1.20; 1107 exposed cases; 95% CI, 1.04-1.39). **Small for gestational age** excess risk observed (adjusted OR = 1.09; 951 exposed cases; 95% CI, 0.96-1.24)
BKK landfill, Los Angeles, CA[45]	Airborne Exposure: Vinyl Chloride	Census block groups falling within three miles of landfill property line	1978-1986	**Reduction** in **mean gestational age** by 1.8 days and 59.0 gram **reduction** in **mean birth weight**.

Table 6b: Multi-Site Studies of Adverse Birth Outcomes associated with landfill sites

Authors	Study Parameters	Definition of Exposed Population	Study Period	Principal Findings
Dolk et al.[46]	21 landfill sites in 5 European Countries	Maternal residence within 5 miles of landfill site	1982-1993	***33% Increase in Risk:*** Residence within 2 miles of a landfill site associated with non-chromosomal congenital anomalies: **neural tube defects** (OR 1.86; 95% CI, 1.24-2.79), **malformation** of the **cardiac septa** (OR 1.49; 95% CI, 1.09-2.04), and **abnormalities of the great arteries** and **veins** (OR 1.81; 95% CI, 1.02-3.20) ***Borderline Significance****:* **Tracheo-oesophageal anomalies** (OR 2.25; 95% CI, 0.96-5.26), **hypospadias** (OR 1.96; 95% CI, 0.98-3.92), and **gastroschisis** (OR 3.19; 95% CI, 0.95-10.77). Noted consistent decrease in risk with distance away from sites.
Elliot et al.[47,48]	9,565 landfill sites in England, Wales and Scotland	Radius of <2 miles proximity of landfill	1983-1998	***Excess Risks:*** **Neural tube defects** (RR = 1.05; 95% CI, 1.01-1.09), **cardiovascular defects** (RR = 0.96; 95% CI, 0.93-0.99), **hypospadias** and **epispadias** (RR = 1.07; 95% CI, 1.04-1.10), and **abdominal wall defects** (RR = 1.08; 95% CI, 1.01-1.15) ***Excess Risks:*** **Low birth weight** (RR = 1.05; 95% CI, 1.05-1.06) and **very low birth weight** (RR = 1.04; 95% CI, 1.03-1.05)
Palmer et al.[49]	24 landfill sites in Wales	Maternal residence <2 miles from landfill site	1983-2000	The ratio of observed to expected (O/E) rates of **congenital anomalies** before landfills opened was 0.87 (95% CI, 0.75-1.00), and this increased to 1.21 (95% CI, 1.04-1.40) after opening, resulting in a standardized RR of 1.39 (95% CI, 1.12-1.72) 1998-2000 showed a RR of 1.04 (95% CI, 0.88-1.21) for **congenital malformations**.
Vrijheid et al.[50]	23 landfill sites in 5 European countries	Maternal residence within 2 miles of landfill site	1982-1993	***41% Higher Risk:*** **Chromosomal anomalies** in people who lived <2 miles from site than those who lived further away (OR 1.41; 95% CI, 1.00-1.99)

Cancer Risk

Several studies have raised concerns on the potential links between increased risks of several cancers and landfill sites. Several cancers such as bladder, pancreas, liver, and leukemia have been implicated, although no consistent pattern has emerged. Tables 7a and 7b list the various epidemiological studies conducted on risks of cancer associated with landfills.

Table 7a: Cancer Incidence associated with landfill sites

Single-Site Studies	Primary Exposure Route	Definition of Exposed Population	Study Period	Principal Findings
Waste disposal site, Northwestern Illinois[51]	Drinking water from wells contaminated with VOCs	Residence in town using water from contaminated wells	1978-1985	Standardized incidence ratios for **bladder cancer** were significantly elevated in males (1.7) and females (2.6).
Miron Quarry municipal solid waste, Montreal, Quebec[52,53]	Landfill gas into ambient air and soil	Zip code areas containing and bordering site (less than 3 miles from perimeter of site)	1979-1985[52]	Males in exposure zone nearest to site: **Elevated risks** were found for **cancers** of the **pancreas** (adjusted OR = 1.4; 95% CI, 0.8, 2.6); **liver** (OR = 1.8; 95% CI, 0.8, 4.3); and **prostate** (OR = 1.5; 95% CI, 1.0, 2.1). Males in sub-exposure zone downwind from site: **High risk** also found for **pancreatic cancer** (OR = 1.7; 95% CI, 0.9, 3.5) and **non-Hodgkin's lymphomas** (OR = 1.5; 95% CI, 0.8, 2.6).
			1981-1988[53]	Males in exposure zone nearest to site: **Elevated risks** were found for **cancers** of the **stomach** [Relative Risk (RR) = 1.3; 95% CI, 1.0-1.5); **liver and intrahepatic bile ducts** (RR = 1.3; 95% CI, 0.9-1.8); and **trachea, bronchus,** and **lung** (RR = 1.1; 95% CI, 1.0-1.2). **Prostate cancer** was also elevated (RR = 1.2; 95% CI, 1.0-1.4). Among women, rates of **stomach cancer** (RR = 1.2; 95% CI, 0.9-1.5) and **cervix uteri cancer** were elevated (RR = 1.2; 95% CI, 1.0-1.5)

Table 7b: Multi-Site Studies of Cancer Incidence associated with landfill sites

Authors	Study Parameters	Definition of Exposed Population	Study Period	Principal Findings
Lewis-Michl et al.[54]	38 landfill sites in New York, USA	Residence within buffer zones of 250 ft., 500 ft. and 1,000 ft. of landfill site boundary	1980-1989	***Statistically significant:*** Elevated risks for **female bladder cancer** (OR = 4.08) and **female leukemia** (OR = 4.76). **Cancer risk** was **four times greater** for both **female bladder cancer** and **leukemia.**

Limitations and Data Gaps

A common problem in epidemiological studies of landfill sites, whether it be single or multiple sites, is that information regarding potential human exposure from landfill sites is lacking. Although a substantial number of studies have been conducted on risks to human health from landfill sites, very few landfills have been evaluated with respect to both the types of chemicals they contain and the extent to which they may be releasing chemicals.

Besides being hindered by insufficient exposure data, the study of landfill exposures is complicated by the fact that if residential communities are being exposed to chemicals from landfill sites, it will generally be to low doses of mixtures of chemicals over long periods of time. Association with such low-level environmental exposure are by their nature difficult to establish.

Other limitations include study design, such as small sample size in single-site studies, which may have resulted in insufficient statistical power to detect small differences. Also, certain cancer studies may have been conducted during an inadequate period of time, not allowing enough time for the disease to manifest itself in the exposed population.

Incinerator

Pollutants

Municipal Solid Waste Incineration (MSWI) is an integrated waste management system in which the incinerator is the main part.[55] Incineration is the process of combusting the waste under high temperature.[56] This process has several advantages: mass waste volume reduction by approximately 70%-90%,[57,58] effective sanitary process of disposing hazardous wastes such as toxins and pathogens in medical wastes.[56] Moreover, in modern designs, Incinerators also possess features like energy recovering and producing ability, which is known as waste-to-energy process,[59] and some of the bottom leftovers can be reutilized.[55] For these reasons, MSWI has been considered and accepted as a favorable method of waste management for decades.

However, MSWI is also notoriously known for its contribution in releasing wide variety of toxic chemical byproducts, including polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and heavy metals.[60] This fact urges regulation in minimizing the health impacts of MSWI brings to the environment and human.

Generally, despite specific wastes which are treated in specific procedures, typical residues of MSWI by grate combustion are: 1. Bottom ash, 2. Grate siftings, 3. Boiler and economizer ash, 4. Fly ash, 5. Air pollution control (APC) residues.[55] The amount of each residue produced at an incinerator depends on several factors. In Table 8,[57] the estimated amounts of typical MSWI residues produced are presented; in Table 9,[55] the content of different heavy metal which consists of various contaminants in the residues from waste combustion is listed.

Table 8: Typical amounts of residues produced per metric ton of waste incinerated

Type of Reside	Typical amounts produced (kg/ton of feed waste)
Bottom ash	250-420
Grate siftings	5
Boiler ash	2-12
Economizer ash	No data (small)
Fly ash	10-30
Acid gas scrubbing residues	
- Dry process	20-50
- Semidry process	15-40
- Wet process	1-3

Table 9: Ranges of total content of elements in MSWI residues (from IAWG, 1997)

	Concentration (mg/kg)			
Element	Bottom Ash	Fly Ash	Dry/semi-dry APC residues	Wet APC residues
Al	22,000-73,000	49,000-90,000	12,000-83,000	21,000-39,000
As	0.1-190	37-320	18-530	41-210
Ba	400-3,000	330-3,100	51-14,000	55-1,600
Ca	370-123,000	74,000-130,000	110,000-350,000	87,000-200,000
Cd	0.3-70	50-450	140-300	150-1,400
Cl	800-4,200	29,000-210,000	62,000-380,000	17,000-51,000
Cr	23-3,200	140-1,100	73-570	80-560
Cu	190-8,200	600-3,200	16-1,700	440-2,400
Fe	4,100-150,000	12,000-44,000	2,600-71,000	20,000-97,000
Hg	0.02-8	0.7-30	0.1-51	2.2-2,300
K	750-16,000	22,000-62,000	5,900-40,000	810-8,600
Mg	400-26,000	11,000-19,000	5100-14,000	19,000-170,000
Mn	80-2,400	800-1,900	200-900	5,000-12,000
Mo	2-280	15-150	9-29	2-44
Na	2,800-42,000	15,000-57,000	7,600-29,000	720-3,400
Ni	7-4,200	60-260	19-710	20-310
Pb	100-13,700	5,300-26,000	2,500-10,000	3,300-22,000
S	1,000-5,000	11,000-45,000	1,400-25,000	2,700-6,000
Sb	10-430	260-1,100	300-1,100	80-200
Si	91,000-308,000	95,000-210,000	36,000-120,000	78,000
V	20-120	29-150	8-62	25-86
Zn	610-7,800	9,000-70,000	7,000-20,000	8,100-53,000

Exposure and health outcomes have been studied for some of these airborne pollutants, however there have been very limited studies on the health outcomes associated with specific toxins emitted from incinerators such as dioxins, furans, and other metals.[61] This section will provide an overview of the health outcomes associated with exposure to waste incinerators, including outcomes related to pulmonary function, reproductive health, cancer risk, mortality, and build-up of chemicals in the blood system. These health outcomes are associated with the collective list of toxins and byproducts emitted from incinerators.

Pulmonary Function

Multiple studies have examined the association between exposure to waste incinerator emissions and pulmonary function, and have determined that individuals residing in communities within close proximity to incinerators have poorer overall respiratory function. Exposure to PM and NO_2, in particular, have been associated with significantly poorer pulmonary function,[62] and long-term exposure to airborne particles, NO_2, SO_2, and CO are associated with an increased risk of developing bronchitis and a loss of life expectancy.[63] Nitrogen and SO_2 have also been associated with short-term respiratory effects.[63] Further, most of the heavy metals emitted from incinerators have been linked to kidney disease, respiratory disease, cardiovascular damage, blood effects, and neurotoxicity.[63] In a study comparing the pulmonary function of residents living in three communities with incinerators to those individuals living in three nearby communities without incinerators, researchers found that residents in incinerator communities had slight decreases in Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV), and Forced Expiratory Flow (FEF).[62] As the distance between residences and the incinerator increased, individuals had small increases in pulmonary function.[62] Further, individuals performed lung function (spirometric) tests once per year for three years, and researchers discovered that individuals living in communities with the incinerators had statistically significant poorer Forced Vital Capacities (FVC) compared to residents in communities without the incinerators.[62] Increases in exposure within the community, as measured by the incinerator exposure index, were linked to a significant decrease in the FEV and FVC values for residents in two of the incinerator communities (compared to comparison communities).[62] Vulnerable individuals with existing respiratory conditions (in this study, individuals with hay fever) in one of the incinerator communities were found to have significantly poorer pulmonary outcomes when compared to individuals without hay fever.[62] Other vulnerable populations include children living near incinerators. Another study found that schools closer to municipal waste incinerators had an increased prevalence of wheezing and headaches in the children attending those schools.[64] Incinerator employees who are regularly exposed to incinerator emissions had significant decreases in several pulmonary parameters and had more respiratory problems (even after adjusting for lifestyle factors, such as tobacco consumption).[64]

Reproductive Health

There are many reproductive health effects and birth outcomes that have been linked to exposure to emissions from waste incinerators. Hu and Shy[61] reviewed previous literature on health effects of incineration and found that there was an increased frequency of twinning in areas at risk for exposure to pollutants and toxic emissions from incinerators. It has been speculated that polychlorinated hydrocarbons, which are a byproduct of chemical incineration, may be related to twinning.[61] Another review of epidemiological studies found that individuals exposed to emissions from incinerators had an increased risk of infants being born with lethal congenital anomalies (particularly spina bifida and heart defects), even after adjusting for social class, year of birth, birth order, and multiple births.[64] As distance from the incinerators increased, there was also a significant decline in risk for infant deaths alone and infant deaths associated with these congenital anomalies.[64] Another study examining the relationship between maternal exposure to incinerator emissions and frequency of preterm births found that exposure to pollutants released from incinerators was associated with more severe preterm births (infants born before 32 weeks of gestation).[65] Further, exposure to particulate matter and gaseous pollutants may be associated with low birth weight and newborns with a weight in the lowest tenth percentile for a particular gestational week.[65]

Cancer Risk

Exposure to toxins released from incinerators has also been linked to an increased risk for multiple forms of cancer. In a review of epidemiologic studies, Hu and Shy[61] found that as distance from incinerators increased, there was a statistically significant decline in risk for all cancers, including stomach, colorectal and lung cancers. After adjusting for various factors such as age, smoking habits, exposure to occupational carcinogens, and air particulate levels, proximity and exposure to incinerator pollutants was also linked to lung cancer (with a 6.7 fold increased risk for those living near incinerators).[61] Another study examining communities living near an incinerator also found an overall increased risk for all cancers, including stomach, colon, liver, lung[64] and bladder cancer[63] for those living in closer proximity to the incinerator, as well as an increased risk for childhood cancers.[63] Individuals living in areas with the highest dioxin concentrations had a 2.3 fold increased risk of developing lymphomas, compared to individuals living in low dioxin concentration areas.[64] Finally, exposure to dioxins emitted from incinerators has been linked to an increased risk for non-Hodgkin's lymphoma and soft tissue sarcomas.[66] Individuals employed at incinerators, who are regularly exposed to high levels of incinerator emissions, also have an increased risk for gastric cancer.[64]

Increased Mortality Risk

In individuals subjected to regular (and close) exposure to incinerator emissions, such as individuals working in the incinerators, there is an increased risk for mortality from multiple causes. While individuals in the Brandywine community may not be living within such close proximity to the incinerator and may not be exposed to such high doses of the incinerator emissions, it is still important to consider these health outcomes. Incinerator employees employed at the incinerator for at least one year had increased rates of lung cancer, esophageal cancer, and ischemic heart disease, compared to national rates, and had a significant increase in death from ischemic heart disease (among those employed for more than thirty years) and gastric cancer (compared to the regional population).[61] Incinerator workers also had a higher prevalence of hypertension, compared to the US population.[61]

Build-up of Chemicals in Blood System

Exposure to incinerator emissions is also associated with a build-up of chemicals in the blood system. Residents living in close proximity to an incinerator were found to have increased body levels of heavy metals, particularly hair mercury levels,[61] and organic chemicals.[66] Incinerator employees who are subjected to high levels of incinerator emissions have been shown to have higher urinary arsenic, tetrachlorophenol, hydroxypyrene and 2, 4, 5-trichlorophenol levels, significantly higher mean blood lead levels, significantly higher blood levels of toluene and Cadmium, and higher body levels of some organic compounds and heavy metals.[61] Incinerator employees also had higher blood concentrations of dioxins.[64]

Limitations and Data Gaps

While there is currently a large body of literature addressing the health outcomes associated with exposure to toxins released from incinerators, there are still many gaps in the data and potential directions for future research. Most of these studies on health outcomes have addressed short-term health outcomes associated with shorter periods of toxic exposure. While many of the participants in these studies may have been residing in communities within close proximity to an incinerator, these studies did not follow the participants over time to determine long-term health outcomes. The studies examined health indicators, such as respiratory function, during a pre-determined period of time. The only studies that have examined long-term health outcomes have followed individuals who were employed at the incinerators. This research provided data on cancer or mortality, however this data might not be generalizable to other populations since incinerator employers typically have significantly higher exposure to incinerator toxins than individuals residing in the nearby communities. Thus, future research should follow residents in communities near incinerators over a longer period of time to examine long-term health outcomes associated with incinerator pollutants. Similarly, future research could examine dosage effect for individuals residing in communities near incinerators. Participants could be grouped based on how long they have resided in the community, to determine whether duration of exposure is associated with poorer health outcomes. Finally, while there is data on many types of health outcomes, including cancer, mortality, reproductive and birth outcomes, respiratory outcomes, and blood levels of certain chemicals, there are still other health conditions that have not yet been examined. A possible direction for research would be to determine whether individuals residing in communities near incinerators have a higher risk of developing certain auto-immune conditions or health conditions related to consistently high levels of stress (as would be likely for those living in such toxic environments).

RECOMMENDATIONS

Zoning in Prince George's County

One way to effectively and sustainably protect communities from hazardous land uses is to modify the county's zoning code. Even with the rise of effective social justice and equity groups, zoning remains an environmental justice issue today. This is due the historic development and use of the zoning system. Having zone classifications of land use inherently protects the integrity of certain areas and excludes undesirable uses within those areas.[67] Often, this leads to disproportionate siting of multi-family and high density housing adjacent to unwanted land uses.[68] Furthermore, case studies have demonstrated disparate enforcing of zoning regulations in these areas—which are often high minority and low income, with respect to actions such as inspection of environmental permits and penalties under hazardous waste laws.[68] Unfortunately, these issues continue to burden communities partly because county zoning regulations are often grossly out of date. Prince George's county is undertaking a zoning re-write to bring the county regulations up to the twenty first century. This change in legislature presents an opportunity for community action groups in Brandywine, MD, as there is now a platform on which to propose salutogenic modifications in zoning such as re-structuring setback distances, restricting adjacent incompatible land uses, and installing a health ordinance overlay zone in overburdened communities.

Current Zoning Regulations

There are few requirements in the Prince George's county code of zoning regulations considering industrial and residential uses. Of primary issue, the current zoning standard allows for incompatible land use between some industrial and residential zones.[69] This means that residential and even educational areas, such as elementary schools, can reside next to industrial zones, as seen in Brandywine, MD (see figure 15). Furthermore, the code prohibits dwellings to be erected within industrial zones, but allows residential and educational space erected before reclassification of the zone to remain.[69] This signifies a critical public health risk, and it is recommended that the county work with communities and industries in these zones to re-locate and/or minimize adverse health effects. With respect to adjacent incompatible land use, the code mandates that light to moderate industrial uses must conform to the setback distances provided in the landscaping manual and the infrastructure must include 10% green space.[69] On industrial and other denoted "high impact" zones adjacent to non-compatible uses such as residential, landscaping is employed to "form a visual and physical separation, mitigate undesirable impacts, such as noise, smell, storage facilities, dust, fumes, vibration, litter, vehicle exhaust, and lighting."[70] While this is a good foundation for a buffer zone regulation, the attention to human public health is lacking and must be revised. In practice, high impact uses are required to have a minimum building setback distance of 60 feet with landscaping on at least 50 feet.[70] However, the landscaping code makes it clear that existing and developed sites not in conformance with regulations therein are not required to conform to new setback distances.[70] It is advisable that the county planning office research scientific evidence supporting the setback distances as is, and propose that these distances be increased with additional "green buffer" implementation. Furthermore, it is recommended that the county evaluate current infrastructure at a high public health risk and revise rules which exempt developed high impact uses from conforming to buffer zone regulation.

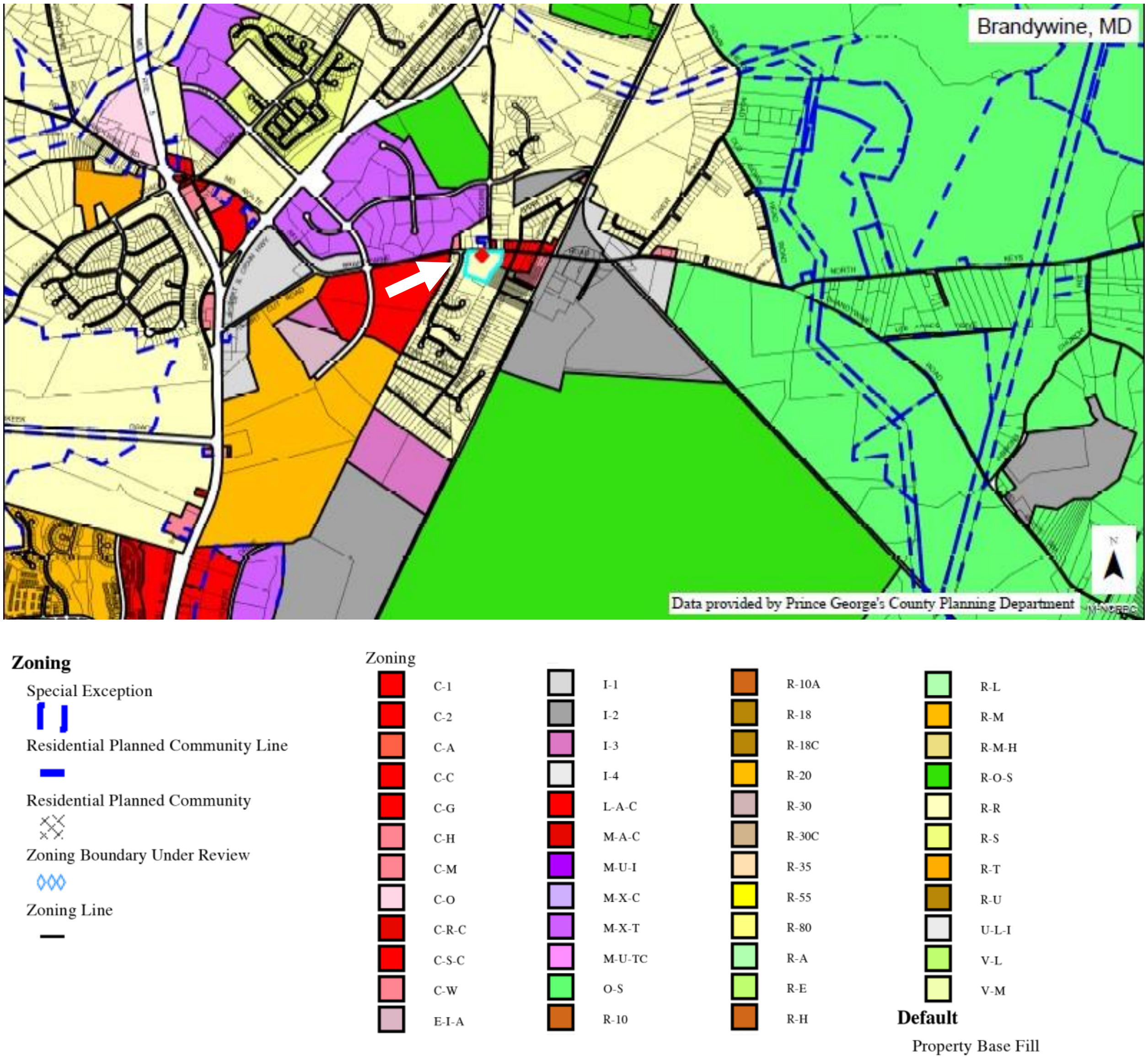


Figure 15: Current zoning schematic in Brandywine Maryland, with Brandywine elementary school highlighted in white. Note that there are multiple base zone categories for similar use and that open space is not on all four sites on industrial area.

Proposed Modifications in Zoning to Promote Salutogenesis

Some modifications that promote health in the county do not require heavy modification to existing regulation. For example, to protect the integrity of residential areas from street derived nuisances, Prince George's county landscape manual requires buffering of residential development from streets to reduce any "adverse effects" to the development.[70] This perspective should be employed for elementary schools and other areas that concentrate vulnerable populations. There have been multiple studies on the efficacy of "green buffers" or trees in urban settings to capture particulate matter.[71–73] One study in Beijing, China reported the American sycamore, Chinese cork oak, and the Paper birch tree showed highest accumulation of PM 2.5.[72] Similarly, a study in Sydney, Australia reported a significant negative correlation in PM 2.5 levels with percent greenspace in similar topographic urban areas.[71] This modification would not require substantial changes in zoning regulations, would promote environmental and public health, and add to the aesthetics of communities.

Ultimately, it is recommended that Prince George's county make substantial modifications to current zoning regulations that not only protect overburdened communities, but promote overall county health. Recommendations focus on employment of more efficient buffers, eliminating incompatible adjacent land uses, and coordinating with the EPA to install health ordinances for criteria air pollutants from both point and mobile sources. The Prince George's county zoning re-write endeavors to address in part this outstanding environmental justice issue. The re-write intends to consolidate many superfluous zoning designations the county already has, promote mixed use zones with highly sustainable economic development potential, and protect and enhance residential zones from incompatible adjacent uses.[74] This re-write is currently in phase one of development, so it presents a unique opportunity to county outreach groups to get involved as proponents of zoning justice. A community-local government task force should be created within the county to focus on this issue as the zoning re-write continues, following framework of the joint task force for the Andrew's air force base.[75] Any new zoning codes should exclude industrial zoning category to be used within mixed zones, as is currently seen in light industrial (U-L-I) and planned communities (R-P-C).[69] Industrial zoning should be sited next to open space areas O-S or other designated green space areas.[68] Prevailing winds should be considered when siting industrial zones in this county, and residential/ educational zones should be modified accordingly as to minimize air pollution flow in to populated areas. "Green buffers" should be employed wherever possible, and scientific evidence for minimum setback distances to protect public health must be re-assessed and implemented in new zoning codes.

If areas cannot be re-zoned, implementing overlay zones with health ordinances can protect public health and air quality. Overlay zones are used to provide additional regulations in a specific area over multiple base zones without having to manipulate underlying base zones. Municipalities have the ability to employ health ordinance requirements or stricter pollution requirements over commercial and residential areas high risk for adverse effects from industrial zones. For example, in 2009 Cincinnati, city council passed an "environmental justice ordinance" that would require expansion or construction of hazardous waste and air pollution point sources to perform a risk analysis and demonstrate operations will not cause a "cumulative, material adverse impact" on the community.[76] Furthermore, initiatives to encourage cooperative land use planning between industrial use and the surrounding community could be made, focusing on ways to reduce the operational impacts of industrial use on adjacent land.[75] This could be accomplished in part by citing the proposed cumulative impacts bill and installing a health ordinance in burdened communities.

Alternative Waste Measures: Anaerobic Digestion

One attractive alternative energy generation source to the incinerator is the installment of an anaerobic digestion system in Brandywine, MD and the adoption of a "zero-waste hierarchy" scheme throughout Prince George's county (Figure 16). Currently in the United States more than 181.4 million metric tons of municipal solid wastes (MSW) are produced annually containing up to 60% organic material.[77] Anaerobic digestion, which converts the organic portion of this waste into energy (Figure 17), can minimize the product digestate that must be treated downstream and can have largely positive environmental and cost impacts, by minimizing landfill use and producing methane biogas.

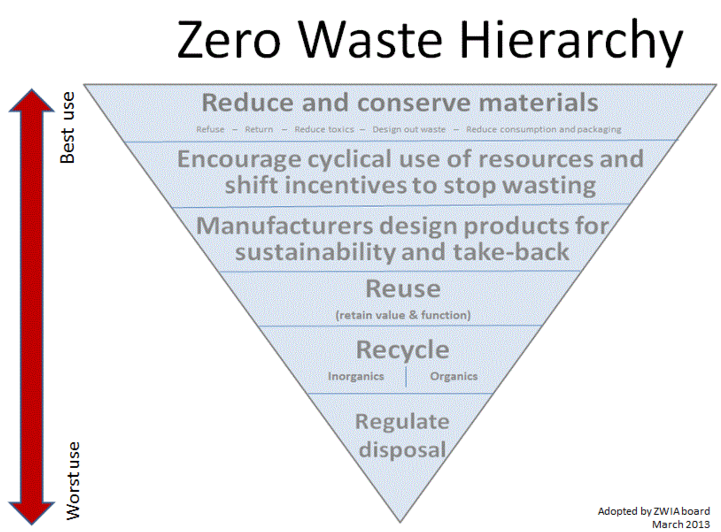


Figure 16: Zero waste hierarchy system adopted by Zero waste Europe to which anaerobic digestion plays a part in "recycle." http://www.zerowasteeurope.eu/

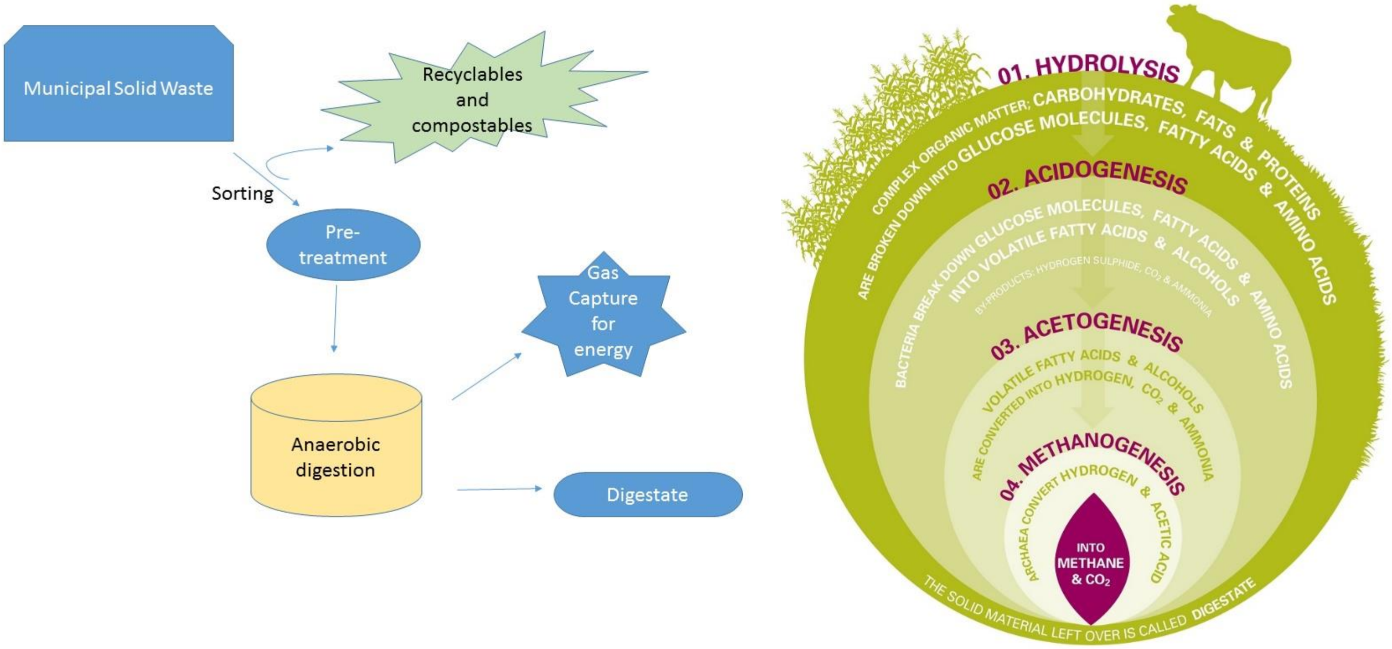


Figure 17: Left – proposed schematic of handling MSW through the AD process and main products. Right- The four main processing in anaerobic digestion to convert complex sugars, proteins, and fats into methane, carbon dioxide, and water. http://adbioresources.org/about-ad/what-is-ad/

Environmental impact of Municipal Solid Waste (MSW) Anaerobic Digesters

Studies on the environmental impacts and benefit of anaerobic digesting (AD) schemes have found that compared with landfills, anaerobic digestion has a smaller environmental impact in all areas tested; eutrophication, ozone layer depletion, human toxicity, and marine ecotoxicity, with the most improvement on impact from food waste.[78] If not favorable as a stand-alone waste treatment, the use of anaerobic digestion as pretreatment for un-digestible toxic heavy metals has been shown to be beneficial in stabilizing them as sludge for ultimate disposal, therefore depleting toxic fraction in landfills.[77]

Cost-Benefit and Potential Viability of Anaerobic Digesters

As capital and operation cost is concerned, a study by the government of Alberta, Canada estimated that the return on investment of anaerobic digesters can range from 5 to 16 years, and can be greatly influenced by the presence of government policy and incentives for green energy production and waste reduction.[79] Furthermore, the California Integrated Waste Management board reported decreasing operations cost as anaerobic digester size increased.[80]

Public policies used for incentivizing commercial development of AD can be roughly divided into two groups: policies which restrict competing technologies' usage, and policies promoting namely AD technologies for waste disposal and biofuel production.[81] Increased tipping fees for MSW collectors, development of new more efficient systems of separate waste collection, tax breaks for businesses and individuals for separate waste collection, as well as education about the importance of waste reduction will ensure AD facilities are provided with high quality source material and increase the rate of return on investment.

Furthermore, stakeholders can minimize initial financial burdens by making use of existing facilities. In a study of 25 California landfills with gas collection, it was estimated that twice as much methane is lost through landfill emissions as is captured as biogas.[80] It was then determined economically attractive for landfills to install sorting stations for isolating the most biodegradable portion of the MSW stream and undergo AD in a standalone unit. Additionally, siting AD facilities at landfills reduces the transportation needed for the non-digestible portion of MSW and may not require additional permits.[80] As an alternative, some landfill cells can be modified to operate as leach-bed batch reactors, which speeds up methane production and allows for higher methane capture rates than simple landfills.[80] This has not been a common practice in Europe primarily because of regulatory restrictions on landfilling of organics. Such restrictions do not exist in the

U.S., making it an attractive stepping stone to employment of full-scale AD of MSW, especially if the landfill site also composts organics.[80]

Anaerobic digestion can also utilize the generation of natural gas as a key to economic stability, however the production of usable gas is highly dependent on the stability of the system and demand of source material.[81] Therefore, tax incentives for citizens and discouraging the use of “throw-away” facilities can greatly influence productivity of anaerobic digestion.

Problems and Solutions of Operating and Maintaining AD

Inhibitory substances very common in municipal waste are often found to be the leading cause of anaerobic reactor upset and failure since they are present in substantial concentrations in wastewaters and sludges.[77] Inhibitory substances include high concentrations of ammonia, sulfur containing compounds, light ions (Na+, K+, Cl-) and heavy metals (Fe, Cd, Ni, Cu), all of which are found in high quantities of municipal waste and waste water.[77] It has been suggested that co-digestion with other waste, adaptation of microorganisms to inhibitory substances, and incorporation of methods to remove or counteract toxicants before anaerobic digestion can significantly improve the waste treatment efficiency.[82] To ensure proper stable function of an anaerobic digester, the addition of bulk polar organic material (yard waste, food waste) and flocculation techniques can remove and reduce these inhibitors.[77] To prevent unfavorable products from entering the AD, source, on-site recycling, and improved refuse-handling equipment can result in the production of more organic-rich and less biotoxic waste.[77] Furthermore, the addition of carbon rich sources like sewage sludge or animal manure can help stabilize the microbial community in anaerobic digestion, and is recommended for prolonged treatment of MSW.[77] These techniques, while effective, contribute to the AD overall capacity and operation costs.[77,82]

In spite of these solutions, poor operational stability is the number one cause preventing anaerobic digestion from being widely commercialized.[77,83] Common problems for preventing implementation and prolonged success of anaerobic digestion systems include siting and permissions issue, odor complaints, and maintaining product flow and demand.[79,83] For these reasons incentives like landfill taxes, landfill bans, consumer education, and the movement towards a zero waste hierarchy by utilizing separate collection systems for organic waste are essential elements of successful public policy that will promote the use of anaerobic digestion in Prince George's county.

Cumulative Impacts Bill - Protecting Air Quality in Overburdened Communities

Due to the highly overburdened nature of the Brandywine, Maryland community with environmental and socioeconomic stressors, citing that the proposed infrastructure would violate the proposed cumulative impacts bill may be an attractive option. The Senate Bill 706/House Bill 1210 "Environment - Permit Determinations - Cumulative Impact Assessments" was presented in February of 2014. The bill called Maryland Department of Environment (MDE) to analyze the potential impacts on the environment and human populations of a proposed industrial permit. The bill would mandate a cumulative impact assessment before determining permit application fates of new industrial facilities. The bill also called MDE to act on the assessment's findings and instill policies to limit the permit's impact along with officially including the cumulative impact assessment's findings within the permit final determination in certain cases to adopt regulations necessary to execute this bill. The limitation of this bill, however, was that it only included the non-incorporated area of Cedar Heights, Maryland, which is just northeast of Washington, D.C., about 23 miles away from Brandywine. Though it initially passed in the Senate, its cross file, House Bill 1210 introduced by Delegate Swain-Prince George's, and the original legislation Senate Bill 706 were not passed by the House. Although the Maryland Association of Counties (MACo) recognized the importance of considering disparate communities when approving environmental permits, they opposed both bills due to the unforeseeable definitive scientific outcomes and cost.[84–86]

Unyielding, Senator Joanne Benson (Prince George's) brought Senate Bill 693[87] "Environment – Ambient Air Quality Control - Cumulative Air Impact Analysis" to legislatures in February of this year (2015) which aimed to address air quality among various overburdened areas in Maryland. It clarified immediate area distances as the 1.5 mile radius of the new source if considered a major source, and 0.75 mile radius if considered a non-major source. A major source is defined by the Code of Maryland Regulations (COMAR) as a stationary industrial source or group which emits 10 or more tons of a single hazardous air pollutant or over 25 tons of a combination of hazardous pollutants. The EPA also considers major sources as an industrial source which emits over 100 tons of any one air pollutant. Furthermore, for nonattainment areas, such as Prince George's county, major sources are defined as those which emit or have the potential to emit at least 25 tons of VOC or NO_x. This bill also specified protected communities by zip codes that contain any of the following: economically disadvantaged populations (i.e. Medicaid or supplemental food program enrollment above median zip codes within state), populations with life expectancies below median of all zip codes within state, and low birth weight infant percentage above median for zip codes within state. Additionally, protected communities would also be determined based on negative health outcomes of pollution and miscellaneous stressors. Along with protected communities, vulnerable populations within: 0.25 miles of a recreational center, school, elderly care facility, childcare facility or other department recognized groups who could be negatively impacted, for a non-major source, and 1 mile for major sources of the aforementioned facilities and groups would also need to be considered prior to construction. Following these identifications, the bill proposes that the Department does not issue air quality permits to the applicant until an analysis of cumulative air impact has been executed an “air quality sampling plan” has been created.

The Cumulative Air Impact Bill requires cumulative impact analysis for air permits issued for new industrial facilities. This bill would ensure that the state considers the cumulative health impacts of existing facilities in a community. As part of the process of issuing a new air permit, sampling is required of recognized pollutants of concern-- especially those which exceed the Clean Air Act’s major source threshold. The bill calls for air quality samples for a minimum of 12 consecutive months prior to the construction of the source if the major source surpasses the emission threshold for $PM_{2.5}$, SO_2, NO_x, and VOCs. It would categorize the degree of impact (none, some or significant) alongside how the applicant would establish mitigation of toxicity. If there is some impact, best available control technology would need to be implemented and if there is a significant impact, denial of the permit may ensue. This bill is currently in the Maryland Senate.

The main goals of both bills mentioned are to address and minimize the detrimental health impacts of incinerators, landfills, transfer facilities, and hazardous waste factories among other related infrastructures within underserved and overburdened areas of Maryland.[87]

The Cumulative Air Impact Bill sanctions precisely what is compiled in this Rapid Health Impact Assessment while simultaneously supporting a wealth of research presented herein. Dissemination of this assessment is vital for communities such as Brandywine for considering the accumulation of health deteriorating infrastructures in certain zip codes which already house above median negative health outcomes and are environmentally burdened by unsatisfactory baseline air quality. It is of primary recommendation by this HIA that legislatures seriously consider the Cumulative Air Impact Bill in order to improve the health of these overburdened and underserved communities in Maryland which house many vulnerable subgroups.

Other Successful Health Impact Assessments

The Cumulative Impact Bill was modeled after other successful cumulative health impact and environmental justice programs implemented by a number of other states including: California, Minnesota, Connecticut and New Jersey.[88] These states have each produced a number of successful HIA's also. California contributions include; San Francisco city planning and use of a traffic mapping tool, identifying and minimizing exposures of air pollutants due to traffic, and heat wave preparedness. New York has also gained publicity with their successful HIAs; assessing air pollution and public health, public health responses to climate change, and informing local laws in order to reduce health problems caused by air pollution.[89] Additionally, a number of successful HIAs have been conducted in Maryland; health impacts of fracking in western Maryland[90] , with a 2015 law placed into effect for a two year moratorium on fracking permits until October of 2017, assessing health and equity in Lexington Market,[89,91] and zoning for a Healthy Baltimore: an HIA of the Baltimore Comprehensive Zoning Code Rewrite.[92]

The common theme in all of these successful HIA's is the identification of vulnerable and underserved populations along with environmentally and point source derived disproportionate health risks. Innovative mapping tools have become one of the best inventions in this century to combat these disparities by illustrating patterns between pollutants and negative health outcomes, which in turn, helps to decrease the impact of pollutants and disparities while cultivating relationships between public health experts and lawmakers to help prevent future public health issues. It is recommended that a full HIA be conducted on this matter, with dynamic community engagement with local government in order to establish higher, sustainable standards of public health in Brandywine, MD and elsewhere.

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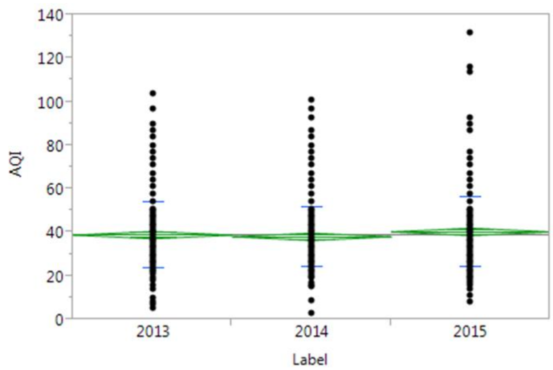
SUPPLEMENTAL DATA

Supplemental figure 1: ANOVA of daily ozone indices 2013-2015



Supplemental table 1- see attached file