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Assessment of indoor air quality exposures and impacts on respiratory outcomes in River Rouge and Dearborn, Michigan

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HIGHLIGHTS

- Explored impact of outdoor air quality on IAQ.
- Indoor gaseous and particulate pollutants sampling.
- Average VOC and PM levels exceeded clean background environment.
- Results indicated potential association with exacerbated asthma symptoms.
- PMs are concerning human health issue, including respiratory health.

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ABSTRACT

Ambient air pollution is a public health issue which could potentially exacerbate pre-existing respiratory conditions and contribute to increases in asthma incidence. This study aims to address gaps in understanding how IAQ is impacted by outdoor air quality, which was done by sampling for indoor gaseous and particulate pollutants in residence and facilities near the sources of pollution. The study areas were selected due to non-attainment status with air quality standards, as well as demographic and socio-economic status of those residing in these areas. Samples are obtained from five locations around the study areas. The sampling procedure involves active sampling methodologies for particulate matter (PM) and gases. Average volatile organic compounds (VOC) levels of 2.71 ppm were measured at a location, while the average particulate matter (PM) concentrations in three study locations were; 15,979 pt/cc, 9533 pt/cc, 5267 pt/cc respectively, which exceeded clean background environment level of 500–2000 pt/cc. All locations had average CO concentrations above 0.3 ppm, which is potentially associated with elevated asthma symptoms. Results demonstrated that facilities in the study area have increased levels of indoor air pollutants that potentially increase asthma and respiratory issues. The study concludes that particulate and gaseous pollutant levels in the study areas are a concerning human health issue. The study outcomes have significant implications for air quality exposure modeling and potential exposure mitigation strategies, which are expected to facilitate the implementation of public policies for improved human health conditions.

1. Introduction

Ambient air pollution is an important public health issue in the city of Detroit, Michigan and surrounding suburbs. Of the airborne pollutants, volatile organic compounds (VOCs), particulate matter (PM), and criteria pollutants (nitrogen dioxide - NO_2 and sulfur dioxide - SO_2) have the most significant impact on the health of the residents of Metro Detroit. Globally, urban ambient air pollution approximately leads to over 2 million human fatalities annually (WHO, 2012). The gaseous and particulate pollutant levels found in urban areas of the United States (U.S.), have been associated with several negative health effects including deterioration of pre-existing respiratory conditions, increased risk for cardiovascular disease, and increased cardiopulmonary mortality, and plays a role in retarding normal lung growth in children and is a cause of asthma (Shultz et al. 2005; Pope et al., 2008; Lewis et al., 2013). There has

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been increased interest in the incidence of asthma amongst children and adults living in the cities of River Rouge and Dearborn, Michigan located in Wayne County. River Rouge is located between the Detroit and Rouge Rivers. The city is a source of industrial importance in the area and is home to the DTE Energy's River Rouge Power Plant and is impacted by the neighboring Marathon Oil refinery in Detroit and U.S. Steel located on nearby Zug Island. In 2010, Michigan's Wayne County violated the National Ambient Air Quality Standard (NAAQS) for SO2, set by the U.S. Environmental Protection Agency (EPA) and was subsequently designated as a nonattainment area. In 2012, the Michigan Department of Environmental Quality (MDEQ) identified the largest SO2 sources in the area, citing U.S. Steel and the DTE River Rouge power plant, as large contributors to airborne pollution (MDEQ, 2016).

Dearborn, Michigan is known to have one of the largest Arab American populations in the nation. The area is also the world headquarters of the Ford Motor Company, an automotive manufacturing company. Dearborn is exposed to a variety of potential carbon monoxide (CO), carbon dioxide (CO2), PM, VOC and formaldehyde exposures from sources including metallurgical coke production, iron and steel production, slag processing, oil refining, electric power generation, metals recycling, and incineration facilities (Pancras et al., 2013). These exposures are characteristic across Wayne County and contribute to the increased rates of respiratory issues.

The adverse effects of PM air pollution in urban areas and increased asthma outcomes have been described in extant toxicology studies (Vinzents et al., 2005; Grahame and Schlesinger, 2010). Studies have linked air pollution exposures to increased asthma occurrence in children (Wichmann et al., 2009; Smargiassi et al., 2014). Most air pollution exposure occurs indoors and results from indoor emission sources, low ventilation rates, and the length of time spent indoors, particularly in homes (Chin et al., 2014). These indoor concentrations can be linked to outdoor levels. High air pollution levels in cities located in Wayne County are due to evaporative emissions and vehicle exhaust, particularly in high traffic urban areas (Bereznicki et al., 2012). Residents of urban areas typically spend more of their time indoors, hence IAQ conditions are probably more indicative of pollution exposure levels affecting human health than outdoor measures. However, the limitations of previous studies indicate a need for the proposed studies because there is inadequate epidemiological evidence to establish the relationship between IAQ and asthma incidence, especially in Wayne County. There is a need to characterize indoor air pollutant exposures in Wayne County in relation to the incidence of asthma amongst residents in the area. This can be accomplished by sampling for airborne contaminants inside of facilities located near the sites of air pollution creation. Addressing the indoor airborne pollution exposure is of fundamental importance when assessing the health outcome of asthma incidence amongst residents in the area of interest.

The aim of this study is to focus on those individuals that may be affected by air quality issues in Wayne County, Michigan, leading to health conditions such as asthma. In Detroit, asthma hospitalizations rates for children are over three times the statewide average. There are approximately 5.1 asthma hospitalizations per 1000 Detroit residents, and 33.6 asthma emergency department visits per 1000 children (younger than 18 years) (Lemke et al., 2014). Additionally, the prevalence of asthma in Detroit adults is 29% higher than in Michigan as a whole (Deguire et al., 2016). It is hypothesized that the levels of air pollutants affect residents in industrialized areas. A critical examination of existing literature aims to support this hypothesis.

1.1. Air pollutants and asthma

Studies have shown that a variety of pollutants in urban air mixtures, contribute to asthma morbidity and mortality, such as PM, CO, NO_2, SO_2, ozone (O_3), and particulate species like organic and inorganic carbons, sulfate, nitrate and metals (Wagner et al., 2012; Olawoyin, 2013). A longitudinal cohort study of asthmatic children in metro Detroit found that the level of air pollutants in the area adversely affects lung function of susceptible asthmatic children. Participants were predominantly African Americans from low-income families, of which greater than 75% had persistent asthma (Lewis et al., 2005). $PM_{2.5}$ and 8-hr O_3 concentrations measured in Detroit were close to or above NAAQS standards, whereas levels of PM_{10} met current standards. The findings strongly suggested, in both single- and two-pollutant regression models, that these levels of air pollutants were associated with adverse effects on pulmonary function for those at-risk children with asthma.

Another study investigated ambient air quality and its association with acute asthma events among people, aged in 5–89 years, between Detroit, Michigan and Windsor, Ontario, Canada. Acute asthma events were calculated using emergency room visits and hospitalizations and standardized to overall age and gender distributions of the populations. It was found that the air quality variations were related to adverse respiratory evens for both Detroit and Windsor (Lemke et al., 2014). These studies suggest that pollutants could be contributing or worsening both childhood and adult asthma in those residing in the Detroit, Michigan area.

1.2. Air pollution in Wayne County

The EPA establishes NAAQS for fine particulate matter ($PM_{2.5}$) to protect the public from the adverse health impacts of $PM_{2.5}$. Wayne County is designated as a nonattainment area for both the annual and 24-hr standard because air pollution levels persistently exceed the NAAQS of 15 $\mu g/m^3$ annually and 24-h concentrations of 35 $\mu g/m^3$ (Duvall et al., 2012; MDEQ, 2017). Wayne County's air quality is influenced by industries such as; motor vehicle factories, refineries, power plants, and metalworking plants (Zhou et al., 2011). Air pollution source impacts were examined using receptor modeling of daily $PM_{2.5}$ measurements, collected at residential outdoor locations in Detroit during the summer and the winter. Sources of $PM_{2.5}$ in order of contribution were motor vehicles (24–36% by mass), sulfate or coal combustion (17–35%), secondary nitrate (16–37%) and organic matter (17–21%). Road dust, steel manufacturing, and mixed industrial sources accounted for less than 11% by mass (Duvall et al., 2012). Another study explored the association between PM and adverse health effects in Detroit. It was found that The $PM_{2.5}$ components and gaseous pollutants associated with mortality in Detroit were linked with warm season secondary aerosols and traffic markers (Zhou et al., 2011).

Building factors influence the concentration and composition of $PM_{2.5}$ indoors. Loss mechanisms can be outdoor air infiltration through the building envelope, deposition to indoor surfaces, and particle removal via filtration. Particles can also undergo chemical reactions indoors which can lead to a loss or a gain. Variability in building characteristics and occupant activities can also lead to variability in concentration of $PM_{2.5}$. Due to these numerous factors; some buildings may have similar concentrations as those found outside (Logue et al., 2015). Majority of the air pollutants may accumulate indoors, depending on the functionality of the heating, ventilation air conditioning (HVAC) system. Outdoor contaminants may enter a building through the HVAC system, which may then be recirculated. If the building is not properly ventilated to allow for exhaust ventilation, this could potentially result to adverse human health effects (WHO, 2014). The effectiveness of indoor air distribution considers the air distribution in a space or room but not of the effectiveness of the outdoor air transportation from the ducts