Title
Size-resolved Particulate Matter Composition And Potential Health Impacts On California’s Inland Empire

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SIZE-RESOLVED PARTICULATE MATTER COMPOSITION AND POTENTIAL HEALTH IMPACTS ON CALIFORNIA'S INLAND EMPIRE

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ABSTRACT

Particulate matter (PM) in areas of high traffic from diesel exhaust particle (DEP) emissions profoundly contributes to healthcare disparities, such as increased rates of asthma and lung cancer, specifically targeting underserved populations. This project studies the impacts of increasing traffic-related particulate air pollutants associated with the growth of large warehouses in underserved communities in the Inland Empire of California, and their potential impact on pulmonary health. Time series of PM concentrations from the Purple Air Real-Time Air Quality Sensor Network were analyzed for the identification of hotspots, which were narrowed to three distinct school sites in the Inland Empire that were near high traffic and in close proximity to logistic centers. Local ambient PM samples of $PM_{2.5}$ to PM_{10}, inhalable particles, were collected using 10-Stage Micro-Orifice Uniform Deposition Impactors (MOUDI, Model 110-NR) for a duration of two weeks at each site during the summer of 2022. Upon collection, extraction followed, consisting of the following methods: sonication and syringe filtration using dichloromethane via dry nitrogen. Samples were then analyzed using gas chromatography/ mass spectrometry (GC/MS) equipped with a nonpolar column (HP-5MS). To determine the trace of DEP emissions, 1-nitropyrene (1-NP) was selected as a marker compound due to its high presence in DEP and its possible carcinogenicity. Results show the presence of 1-NP, with significant amounts ranging from 0.56 µm to 1.8 µm, which provides evidence for the potential health risks posed to local communities. Further investigation is needed for long-term monitoring of PM composition and exposure-associated health outcomes in these underserved communities.

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Introduction

Diesel exhaust from cars is evident everywhere one goes, but what is most common, specifically in disadvantaged communities near schools and our neighborhoods, are warehouses. These warehouses give rise to harmful pollutants that people living in these communities breathe in daily. Particulate matter (PM) consists of a mixture of solid and liquid droplets localized in the air that are inhalable particles composed of different chemicals arising from a variety of emission sources (EPA). PM profoundly contributes to healthcare disparities such as increased rates of asthma and lung cancer, specifically targeting underserved populations. Particulate matter collected from various school sites in the IE near high-traffic areas will be the focus of this assessment. The goal of this study is to uncover the chemical composition of particulate matter and its effects on health. Therefore, the objective of this research is to determine traces of 1-nitropyrene (1-NP) in ambient PM and how they impact asthma or chronic respiratory diseases in these communities. My hypothesis is that high amounts of diesel exhaust particles (DEP) are found in sites near high-traffic areas and warehouses. In this case, schools – experimental sites – near highways, and more warehouses would have more traces of 1-NP. Through this recognition, this research can be used in community advocacy aimed at addressing environmental health disparities.

1.1 Impacts of particulate matter on underserved communities

The Inland Empire is a region inland and adjacent to coastal Southern California that consists of major cities such as San Bernardino, Rancho Cucamonga, Riverside, and Ontario. According to Brady et al. (2021), in a study of the Inland Empire's poverty levels, using 50% of the state's median as a poverty threshold, the IE has a significantly higher poverty rate of 23.5%, whereas the state has a poverty rate of 19.5%. In comparison to the United States as a whole, using the 50% median of the US as a poverty threshold, the IE has a poverty rate of 22.4% and the US has a rate of 18.1%. Therefore, more IE residents lived in poverty from 2016 to 2018. Moreover, based on the Census, 52% of the IE population is Hispanic/Latinx, with 31% of the population being White (Brady et al., 2021). Being that, as the economy is growing, the Inland Empire has a growing number of warehouses that are being built at an increasing rate near neighborhoods with high poverty rates, especially near schools and homes alluding to traffic by heavy-duty vehicles, sacrificing the health of the majority Hispanic and Black populations. According to data collected from the Redford Conservancy at Pitzer College in 2021, the IE has roughly 1 billion square feet of area occupied by warehouses, with a total of 4,300 warehouses developed (SBCounty.gov). The reason for warehouses being built in such areas is the implementation of reductions in labor costs as well as enhancements in product manufacturing and distribution (Yuan 2018). On the other hand, the causes of environmental injustice are the following: local undesirable land use requires places with low rent land, locations with the least political engagement, and biases in zoning regulations (Yuan 2018). These warehouses are primarily found near locations with access to major roads - public transportation. Researchers addressed how warehouse zoning (locations) are more likely to occur in disadvantaged neighborhoods due to better land accessibility, establishing low-wage labor, and community segregation (Yuan 2018).

1.2 Current Regulations - Diesel Engines and Warehouses

As of now, regulations are set by the Environmental Protection Agency (EPA) and the California Air Resource Board (CARB) for heavy-duty engines. In 2020, the EPA issued an Advanced Notice of Proposed Rule (ANPR) for the Cleaner Trucks Initiative, which sets new emission standards for nitrogen oxides (NO_x) and other pollutants in heavy-duty engines. They defined heavy – duty vehicles as those with a gross weight of above 8,500 lbs in federal jurisdiction and above 14,000 lbs in California for 1995 model years and later. To add on, standards for vehicle regulations are measured in grams per brake horsepower-hour (g/bhp- hour) (DieselNet 2023), where the Federal Test Procedure beginning for model-year 2027 vehicles in NOx limit is 0.034 g/bhp per hour, whereas for model-year 2024 they were 0.05 g/bhp per hour in comparison to standard PM use for general vehicles of 0.005 g/bhp per hour for these models. Hence, the evolution of emission standards and limits for heavy-duty engines is important to note due to the increase in traffic generated by diesel trucks associated with warehouse operations and highway use. These emissions from diesel engines contribute to the production of ground level ozone and significant pollutants.

Similarly, with the increased development of logistic centers, as of April 2023, Assembly Bill 1000 (AB 1000) has gained momentum as it was heard by the Assembly Local Government Committee but failed to receive the required votes to pass. In brief, Assembly Bill 1000 would prohibit the development or expansion of any warehouse/ logistics center that is within 1,000 feet of sensitive receptors such as homes, schools, and hospitals, including the requirement of zero-emission vehicles, reductions in truck idling, and zero-emission energy operation requirements (California State Assembly Democratic Caucus 2023). As of now, reconsideration of the bill has been granted. While some agree with AB 1000 due to its ban on warehouses and the problems like traffic that are brought forth, others opposed it, saying that the development of these logistic centers provides locals with jobs and creates avenues for the expansion of businesses (Davis 2023). Regardless, this research focuses on the collection of emissions at sites localized near high-traffic areas and in proximity to warehouses in order to assess $PM_{2.5}$ concentrations.

1.3 Experimental target region

In regard to the Inland Empire, this research was based in the County of Riverside. In brief, when defining inhalable particulate matter, three categories are of priority: mass (µg), volume

(m^3), and size (<10 µm or <2.5µm in diameter as in PM_{10} or $PM_{2.5}$). According to County Health Rankings, based on data provided by the EPA in 2019, Riverside in comparison to California and the United States, has had high emissions of air pollution with an average density of 12.7 $\mu g/m^3$ surpassing that of California, which has an average of 7.1 $\mu g/m^3$ and the United States, which has an average of 7.4 $\mu g/m^3$. Notably, the 2023 Annual State of the Air report from the American Lung Association found that the top polluted counties are San Bernardino followed by Riverside County, both receiving a letter grade of F in regard to the overall pollution based on the national standard for annual $PM_{2.5}$ of 12 $\mu g/m^3$. Moreover, based on data collected from the Redford Conservancy at Pitzer College in 2021, the County of San Bernardino has over 3,000 warehouses, with Riverside County having almost 1,000 more. Indeed, the communities in Riverside are exposed to significant environmental and health impacts because of warehouses and, consequently, pollution generated from increased traffic as a result of its continuous investments in logistics infrastructure.

1.4 Composition of diesel exhaust

Diesel exhaust (DE) comes from diesel fuels from sources of emissions like trains, trucks, ports, and overall heavily traveled roads, which are most likely found in populated areas. DE is a mixture of hydrocarbons composed of carbon particles, organic compounds such as gaseous pollutants, and oxides of nitrogen. To explain the process of emissions, the internal combustion process of these engines produces water and carbon dioxide, whereas the incomplete combustion of diesel fuel - under high temperature and pressure – entails combustion reactions with the engines lubricating oil, oil additives, and other non-hydrocarbon chemicals such as fuel additives, contributing to pollutant emissions (W. Addy Majewski, 2023). Therefore, when the emissions of NO_x react with other atmospheric chemicals, they form $PM_{2.5}$ and ozone. In California, medium- and heavy-duty (M/HD) vehicles emit over 47.9 million metric tons of greenhouse gases annually, responsible for 62 percent of nitrogen oxide and 56 percent of particulate matter from on-road vehicles (Robo et al., 2022). It has been noted by the California Air Resource Board that more than 90% of DEP is less than 1 μm in diameter and contains more than 40 carcinogenic substances, including polycyclic aromatic hydrocarbons (PAHs). Specifically, 1-NP is known to be the most abundant nitroarene in diesel exhaust emissions. Due to their proximity to transportation infrastructure, emissions from M/HD vehicles produce disproportionate amounts of air pollution. In cause, leading to exacerbating health concerns in those adjacent communities with developed warehouses. Agencies, such as the International Agency for Research on Cancer (IARC), have identified diesel engine exhaust as a carcinogen that is linked to the risk of lung cancer in humans. Similarly, the National Institute for Occupational Safety and Health (NIOSH) noted diesel exhaust as a potential occupational carcinogen. Thus, it is important to note the respiratory effects that result from diesel particulate matter.

1.5 1-Nitropyrene as marker for diesel exhaust particles

This research will focus on amounts of 1-NP as a surrogate measurement of DEP from monitoring sites. As previously mentioned, DE is a complex mixture composed of PAHs and nitro-substituted PAHs (nitro-PAHs), specifically 1-NP, which is generated from incomplete combustion. Researchers found that this nonpolar compound is the most abundant nitro-PAHs in air particulate and diesel particulate standard reference materials (SRMs) (Bamford et al., 2003). As a result, 1-NP is the ‘marker’ of nitroPAH. To explain, occurring in the combustion chamber of a diesel engine, the chemical mechanism of formation of 1-NP is due to the addition of nitrogen oxide (NO) or nitrogen dioxide (NO_2) to PAH free radicals (Schuetzle et al., 1983). Populations can be exposed to 1-nitropyrene via inhalation of ambient air, ingestion, and dermal contact (PubChem). As of now, there are no cancer studies reported in humans, but based on epidemiological studies on F344/N rats, when exposed, there were significant accumulations of 1-nitropyrene found in the lungs and other organs, leading to reports on genetic toxicity causing tumors at different tissue sites via different exposure routes (Chan 1996). The reason for 1-NP's genotoxic effects is due to its DNA-binding metabolite. 1-NP is metabolized by loss of the N-hydroxyl group, or O-acetylation, followed by removal of acetate, which creates a nitrenium ion that reacts with deoxyguanosine to create the DNA adduct (National Toxicology Program (NTP), Department of Health and Human Services, 2021). Based on epidemical studies, 1-nitropyrene formed DNA adducts in bacteria and mammalian cells, including human cells, causing morphological transformations and malignant tumors and displaying genotoxic effects (NTP 2021). Thus, this compound has a reasonably anticipated role as a human carcinogenic agent.

1.6 Defining particulate matter and its effects

In this study, PM refers to 'airborne particulates' categorized based on sizes, PM_{10} and $PM_{2.5}$. Here, diameter size is correlated with posing health risks. To further explain, when referring to size, particulate matter can be compared to a strand of hair that is 50 to 70 microns in diameter, whereas $PM_{2.5}$ is a much smaller, finer size considered inhalable particles, such as metals, air particles, and organic compounds (EPA). Particles of 2.5 microns have greater effects when compared to PM_{10} due to particle deposition occurring in the human lung, airways, and other tissues. Considering the upper airway passages include the nose, mouth, and pharynx down to the larynx, then the lower airway passages begin at the larynx down the trachea and extend to the alveoli, known as the small air sacs, and to the ends of the bronchial tree (Canadian Centre for Occupational Health and Safety (CCOHS) 2018). Thus, upon exposure to these airborne particles, how the particulates are deposited in the lungs depends on the size, shape, and density of the substance. According to research, the major mechanisms of particle deposition are trans-synaptic, impaction sedimentation, and systematic circulation, where PM_{10+} is trans-synaptic as it travels via blood circulation, $PM_{2.5-10}$ is known to be impaction and sedimentation, as its movement of transport is to regions of the alveoli (Brownian diffusion), and $PM_{2.5}$ and other ultrafine particles consists of systemic circulation (pulmonary circulation), as PM can be translocated via the blood and deposited in the liver, spleen, or brain (Li et al., 2018).

Epidemiological studies indicate a correlation between $PM_{2.5}$ and respiratory diseases due to an increase in the incidence and mortality of respiratory infections. Given that $PM_{2.5}$ is a small particle size, it can cause deep lung penetration and deposit at terminal bronchioles or enter via blood circulation and have adverse systemic effects on body organs. In a study by Li et al. (2017) in China, they studied the effects of pollution on outpatient visits for acute respiratory outcomes, and they found that upon exposure to $PM_{2.5,}$ it was positively correlated with outpatient visits for upper respiratory tract infection, acute bronchitis, community-acquired pneumonia, and acute exacerbation of bronchiectasis. Another study also reported that $PM_{2.5}$ was significantly associated with an increase in hospital emergency room visits specifically for upper respiratory tract infection, lower respiratory tract infections, and acute exacerbations of chronic obstructive pulmonary disease (Xu et al. 2016). Moreover, a study conducted by the CDC and Prevention's National Environmental Public Health Tracking Program collected information from 17 states and found that ozone and $PM_{2.5}$ are associated with respiratory emergency department visits among all age groups, with some variations across ages, disease outcome, and pollutant source (Strosnider 2019). Provided that, such studies signify that $PM_{2.5}$ exposure is related to increased susceptibility to a variety of respiratory infections, either lower or upper respiratory infections, which in turn can potentially contribute to the development of long-term diseases such as asthma.

To add on, *in vitro* studies suggest that exposure to $PM_{2.5}$ affects the respiratory host defense. In a study by Rivas-Santiago et al. (2015) on PM-exposed alveolar epithelial cells (A549 cells), they found a downregulation in the ability of the A549 cell line to express the antimicrobial peptides human defensin 2 and defensin 3 (HBD-2 and HBD-3), overall enhancing the development of TB – tuberculosis infection. In a similar manner, Mushtaq et al. (2011) found that in A549 cells exposed to urban $PM_{2.5}$, it increased adhesion of bacterial pneumonia to the human epithelial airway cells via oxidative stress and platelet-activating factor receptor, which are responsible for pro-inflammatory responses. In the final analysis, these studies are indicative that $PM_{2.5}$ compromises the epithelial host defense functions in the airways, promoting infections. Due to the increased levels of inflammatory factors and the enhancement of bacterial infections associated with PM exposure, asthmatic symptoms such as wheezing become evident (Otero et al., 2013). At the present time, in these underserved communities, health disparities are seen corresponding to increases in asthma rates and respiratory illnesses (such as lung cancer, chronic obstructive pulmonary disease (COPD), cystic fibrosis, premature death, worsened mental health and cognitive function, etc.).

Methods

In determining fieldwork locations, the websites of PurpleAir's Community Sensor Map and Google Maps were used to narrow hotspots based on US EPA $PM_{2.5}$ real-time series sensors in the IE region and warehouse locations, specifically Riverside County, during the summer of 2022. Due to set-up limitations at warehouse sites, regions containing an AQI over 90 were chosen. Based on accessibility, three distinct, populated schools were chosen for setup: Rubidoux High School, Jurupa Valley High School, and UC Riverside. All schools shared commonalities in regards to their locations: near high-traffic freeways – in this case, all near the 60-Freeway - and logistic centers within proximity, with Jurupa Valley High School being surrounded by the most warehouses and UC-Riverside as the control site.

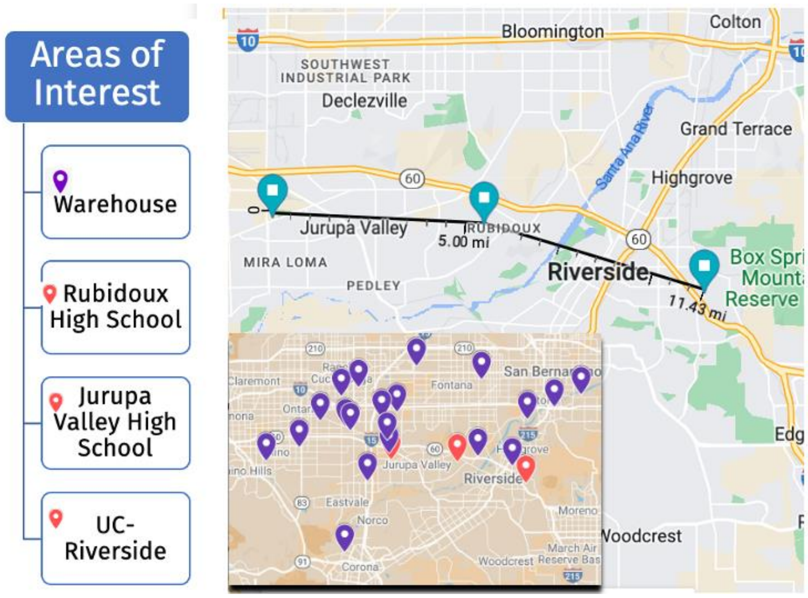

Figure 1. Map of Target Locations in Riverside County: Google Maps were used to map the three sites: Rubidoux High School, Jurupa Valley High School, and UC-Riverside, all along the I-60 freeway. In a close-up image, the sites can be depicted by red markers, and all surrounding warehouses are tagged with a purple marker. Most warehouse sites are located near Jurupa Valley High School.

2.1 Filter collection

At all three sites, the Micro-Orifice Uniform Deposition Impactors™ (MOUDI) Model 110-NR was used at each site for the duration of two weeks during the summer of 2022 for PM data collection. The purpose of using this device was for size-resolved aerosol sampling and collection. The collection of particles on this device is via a nozzle driven by a 30 liter-per-minute (LPM) pump, which deposits particles onto stages based on PM cut-point diameters. The MOUDI™ used contains 11-stages with the following size intervals and stage cut sizes: 0.056, 0.1, 0.18, 0.32, 0.56, 1.0, 1.8, 3.2, 5.6, 10, and 18 µm. Before each MOUDI setup at the sites, the MOUDI was cleaned and placed on aluminum foil substrates at each stage, where PM would be deposited. The placement of the MOUDI was outdoors for all three locations but varied in position due to school ground limitations. Due to having only one particle collection device, the MOUDI was placed first at Rubidoux High School, then at Jurupa Valley High School, and finally at UC-Riverside (Geology Building).

2.2 Extraction process

Following the two weeks of collection at each site, MOUDI aluminum foil substrates were taken out and placed in vial containers with 20 mL of dichloromethane (DCM), a nonpolar solvent used for the extraction of PM on aluminum foil substrates. Once the eleven aluminum foil substrates collected were each placed in a vial, representative of each MOUDI stage, each of the vials was then placed in an ultrasonic bath and sonicated for 30 minutes in order to agitate particles for extraction. After sonication, each vial underwent syringe filtration which consisted of using an Agilent Captive Econofilter of 0.2 μm pore size and a syringe. The purpose of adding a filtration step by syringe filters was due to the aluminum debris that was contained in the vial with the DCM as a result of sonication. Thus, in order to decrease contaminants in these samples, all sonicated vials were filtered using syringe filtration and their liquids were transferred onto new vials. After undergoing syringe filtration, each vial was then placed under nitrogen drying for a duration of approximately two hours to concentrate the sample extracts. Once nitrogen drying was completed for all eleven vials, the remaining liquid samples, which appeared clear in color, was transferred onto 2 mL autosampler vials. Each site had eleven vials, representative of each MOUDI stage. A total of thirty-three vials were obtained.

2.3 GC/MS analysis

Given that for this study our diesel exhaust target marker is 1-NP, a HP-5MS capillary GC column used on the GC/MS. DCM was included a solvent blank in the analysis. According to the Certificate of Analysis on Standard Reference Material 1650 for Diesel Particulate Matter, the National Institute of Standards and Technology (NIST) noted 1-nitropyrene with a mass fraction of 18400 µg/kg as the most abundant nitro-PAH. Therefore, based on calculations, our instrument needed 500 parts per million (ppm; ng/µL) to detect our target compound, so the stock solution consisted of 2.9 mg of 1-NP and 5.8 mL of DCM. To construct the calibration curve, we performed serial dilutions and obtained concentrations of 0.5, 5, 50, 250, and 500 ppm. This calibration curve's equation was then used to compute the sample's concentrations at various stages. According to the NIST library, five peaks are major peaks found within the mass spectrum identification of 1-NP. Therefore, the method for the GC/MS was based on selective ion monitoring with the search of five peaks: *m/z* 100, *m/z* 201, *m/z* 217, *m/z* 247, and *m/z* 248. In particular, the molecular ion of *m/z* 247 was used as our target when integrating for abundance since the average molar mass of 1-NP is 247.25 g/mol. For all eleven stages of the MOUDI at all three sites, the abundance was found via integration of the produced spectra from the GC/MS, and then calculations for concentration (ppm) was obtained using the 1-nitropyrene calibration curve equation.

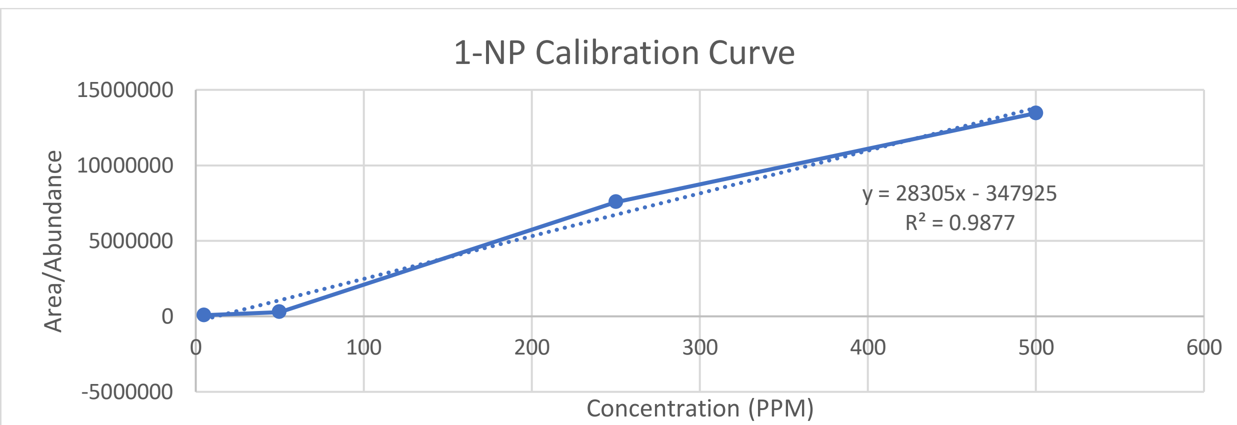

Figure 2. 1-Nitropyrene Calibration Curve

Results and Discussion

In examining the results, Figure 3a demonstrates the amounts of 1-NP that are present at each cut-point stage of the MOUDI, indicating traces greater than PM_{10} and less than $PM_{2.5}$ found at the school sites in varying amounts. At the first site, Rubidoux High School, the lowest PM obtained was 12.84 ppm at Stage 2 with particles of 0.18 μm in diameter, whereas the stage with the highest traces of PM was Stage 5 with 13.97 ppm with particles of 1 μm in diameter. At the second site, Jurupa Valley High School had traces of 1-nitropyrene with concentrations ranging from approximately 20 ppm to 39 ppm. The stage with the highest traces of 1-NP was Stage 1, containing a concentration of 39.59 ppm with particles of 0.1 μm in diameter. At the third site, UC-Riverside, Stage 5 has the highest traces of 1-NP, with a concentration of 26.45 ppm and containing particles of 1μm in diameter. When comparing all three sites (Figure 3b), it is evident that Jurupa Valley High School surpassed both Rubidoux High School and UC-Riverside (our control) in the amount of 1-NP present. Considering Stage 10 of the MOUDI contains particles with the greatest length in diameter size of 18 μm and ends at the base, and Stage 0 contains particles of 0.056 μm in diameter, our data indicates that particles less than 2.5 μm in diameter length were obtained. Thus, all sites contained 1-NP traces in $PM_{2.5}$.

Site Data based on PPM and Stage Cut Size

	Site	RHS	JVHS	UCR
Stage	**Cut-Point Size, μm**	**PPM**	**PPM**	**PPM**
0	**0.056**	12.96	25.26	13.97
1	**0.1**	13.10	39.59	14.91
2	**0.18**	12.84	20.60	14.78
3	**0.32**	13.26	20.53	15.07
4	**0.56**	13.21	20.51	14.45
5	**1**	13.97	21.51	26.45
6	**1.8**	13.75	22.53	14.17
7	**3.2**	13.41	26.41	13.86
8	**5.6**	13.64	26.43	14.06
9	**10**	13.11	24.85	15.09
10	**18**	13.03	25.17	14.65

Figure 3a. Rubidoux High School, Jurupa Valley High School, and UCR PM Data

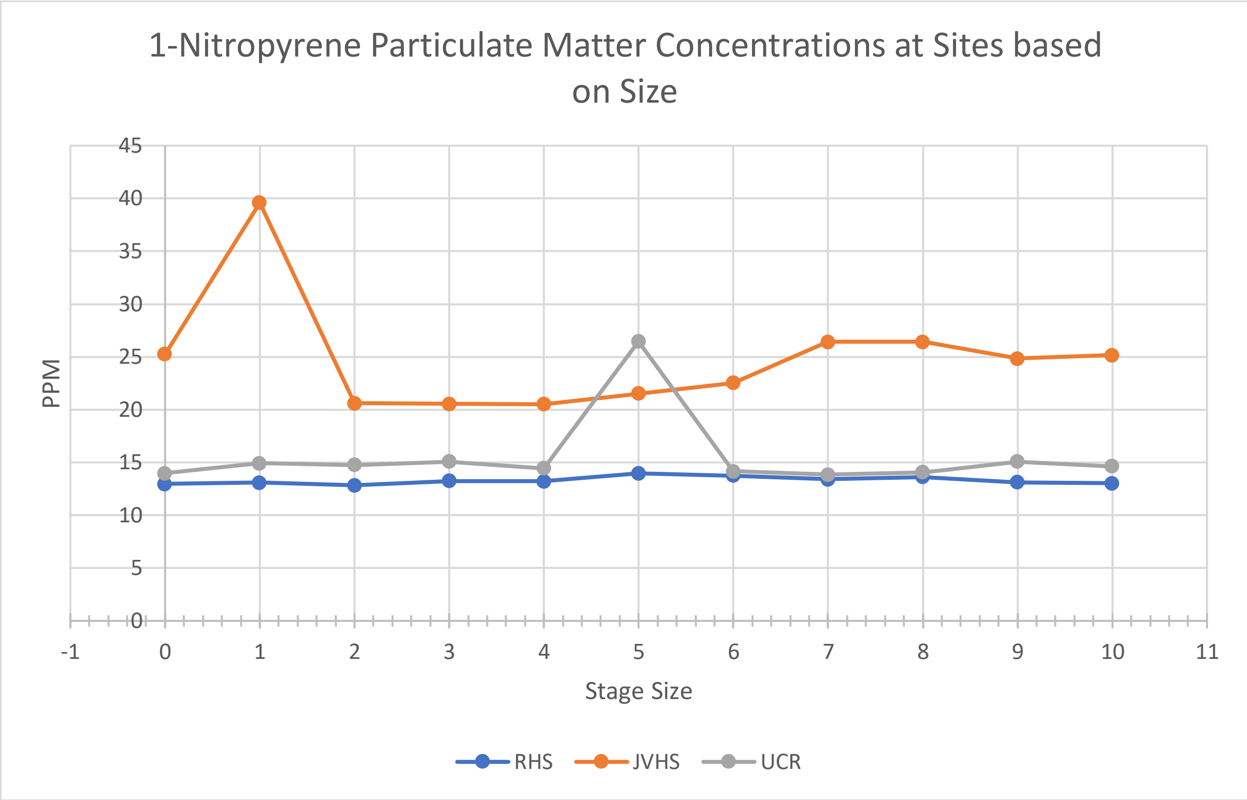

Figure 3b. PM Size Visualization Among Sites: The MOUDI contained 11 cut-point-sized stages, with Stage 0 at the base and Stage 11 at the start (top of MOUDI), respectively, 0.056, 0.1, 0.18, 0.32, 0.56, 1.0, 1.8, 3.2, 5.6, 10, and 18 µm. JVHS exceeded both UCR and RHS with traces over 20 ppm of 1-nitropyrene. All stages at all sites contained $PM_{2.5}$.

Potential limitations

All things considered, the specific environmental hazards posed by specific warehouses are uncertain because there are no monitors by the EPA or local governments tracking the emissions near these warehouses since most sensors are dispersed throughout regions. For this reason, the purpose of this study was to investigate the traces of diesel exhaust emissions, specifically using 1-NP as a marker. However, limitations to this study should be noted. First, traces of 1-NP were studied in a populated environment rather than from a direct warehouse source. Due to having no access to these nearby warehouses, it was not possible to set up our experiment there. Given that the MOUDI was placed in schools, it should also be noted that only one trial was possible at each site, providing limited data for statistical analysis. However, despite having access to display the MOUDI outside on school grounds, there were restrictions as to where the MOUDI could be placed since it did require a source of power and had to be in a secure place due to weather conditions and having students on campus grounds. Thus, due to the placement of the MOUDI on such grounds, the ambient air that was being absorbed, in some cases, was not at similar altitudes of collection, which could have played a factor in our data collection and impacted our results. However, despite the limitations discussed, our results still demonstrated that amounts of $PM_{2.5}$ and ultrafine particles are found in ambient air, specifically abundant in 1-NP, which is a known carcinogen to humans. In addition, this study found that aluminum debris after sonication (during filtration process) coming from the filters placed on each of the MOUDI stages may have affected GC/MS analysis. As of now, results support that 1-NP exists in sizes below $PM_{2.5}$, which may deposit at different lung depths.

Conclusions and Implications

The results of this study suggest that 1-NP is abundant near high-traffic regions, which are composed of warehouses. Also, based on size separation, 1-NP is present in sizes less than 1 μm, being in the range of $PM_{2.5}$ which is inhalable. Therefore, based on this size, we can determine the depositional area and its effect on the community's lungs, given that research indicates that $PM_{2.5}$ deposits in the lower airway. Literature suggests its potential to penetrate alveolar regions and/or other organs (liver, brain, etc.). Short-term exposure can affect the cardiovascular and respiratory systems, leading to incidences of pulmonary disease, respiratory infections, asthma, and stroke. Ultimately, long-term effects indicate increased risks of lung cancer and asthma, and most importantly, the development of infections in children. Provided that this study took place at school sites in underserved communities, our populations at risk are majority Hispanic, and the warehouse distribution is concentrated near these impoverished neighborhoods and schools, creating an influx of high traffic. This high traffic is caused by incoming and departing medium- and heavy-duty (M/HD) vehicles, whose emissions contain 1-NP and contribute to the poor air quality in these residential areas. All things considered, the specific environmental hazards posed by specific warehouses are uncertain because there are no monitors by the EPA or local governments tracking the emissions near these warehouses since most sensors are dispersed throughout regions.

It is important to note that long-term monitoring of PM composition, degradation, and exposure-associated health outcomes in these communities is needed to evaluate the levels of toxicity to humans and bring exposure towards tackling environmental justice. That said, further analysis regarding 1-NP toxicity is required to investigate the potential interactions between size-fractioned products and their accumulation in airway tissues, as well as their effect on lung cells and/or the epithelial barrier. All in all, prospective human studies - larger studies - would be more effective if exposure assessments to PM could be considered for source-specific $PM_{2.5}$ pollutants in order to evaluate the impact of air quality on health. Similar to studies investigating the associations between $PM_{2.5}$ exposure and infections based on hospital visits (Li et al., 2017; Xu et al., 2016; Strosnider et al., 2019), analyzing the numbers of logistic centers dispersed and distributed in the admits region would expose the impact of warehouse developments.

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