Beyond the Measures Using Mobile Air Sensors to Examine Volatile Organic Compounds in Kettleman City Using a Community-Based Participatory Research Approach

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Abstract

California's Kettleman City is surrounded by industries that can emit volatile organic compounds (VOCs) into the air — agriculture, landfills, benzene treatment plants and an aqueduct. VOCs can pose severe environmental threats to residents. This research aims to examine air quality in this disadvantaged unincorporated community and understand the perceptions residents have about their environmental health using a community based participatory approach. To measure air quality, a custom built, micro-gas preconcentrator sampler was used to adsorb VOCs from indoor and outdoor environments throughout Kettleman City. Samples were analyzed via gas chromatography-mass spectrometry to putatively identify the presence of VOCs in the collected samples. Interim chemical analysis revealed potential toluene, xylene, and benzene derivatives in the outdoor air samples and potential tribromomethane in the indoor bathroom air sample. A community environmental health survey was conducted door to door over a two day period. Residents reported a negative relationship with air quality, water quality, and overall environmental health. The combination of qualitative and quantitative findings provides an overall picture of the VOCs present in Kettleman City --- adding to the story of the historical environmental racism experienced by this disadvantaged unincorporated community.

Introduction

Volatile organic compounds (VOCs) are hydrocarbon species present in the atmosphere. Although on a global scale VOC biogenic sources are more abundant than those of anthropogenic sources by approximately a factor of 10, anthropogenic sources of VOCs often dominate in urban areas (*1*). Major anthropogenic sources of VOCs include vehicular exhaust, fuel evaporation, industrial processes, household products, and solvent usage (*2*). Anthropogenic emissions of VOCs include different types of sources, such as: mobile sources, stationary sources, area sources, and point sources (*3*).

Atmospheric levels of VOCs are altered by various, complex, dynamic sink and source processes such as: emissions, chemical reactions, transport, and deposition (*2*). VOCs pose a health concern as a result of their contribution to photochemical smog and the formation of carcinogenic VOCs often generated as industrial chemicals or as byproducts of combustion. Presence and levels of VOCs were studied in Kettleman City due to residential concerns about the possible health effects these chemicals can have in their community.

This research study takes a community- based participatory research (CBPR) approach which requires researchers to acknowledge the inherent power dynamics present between researchers and community members (*4*). In addition, researchers collaborate with community members in choosing the research questions and throughout the research process to better understand their environmental health concerns. CBPR is thought to be a form of anticolonial advocacy scholarship that reverses the normalized roles academic research entails (*5*). Here, it is necessary for communities of the underrepresented and underserved peoples to voice their realities and speak for themselves as experts on daily life in

their communities. Kettleman City is recognized and referenced as an important player and forerunner in the Environmental Justice Movement (*6*). The California Environmental Protection Agency describes the principles of environmental justice as a call for fairness, regardless of race, color, national origin, or income, in the development of laws and regulations, implementation, and enforcement of environmental laws that affect every community's natural surroundings, and the places people live, work, play and learn (*7*). By working together with the community, the research team assessed how to study the environmental pollutants of interest and gather qualitative and quantitative data.

Background

Kettleman City is considered a disadvantaged unincorporated community, meeting the definition of a disproportionately low-income area that is densely settled and not within city limits (*8*). Kettleman City has a long history of environmental injustices and the movement towards environmental justice started in 1988 when a monumental event took place as a result of Chemical Waste Management, Inc.'s proposed installation of a toxic waste incinerator at the landfill situated near Kettleman City. This toxic waste incinerator would not only emit a myriad of VOCs but also other toxic air pollutants. With the construction of the incinerator on a landfill previously located without the residents' knowledge, the community was ready to mobilize against it (see figure 1; *6*). The 1984 *Cerrell Report* was a document created for the California Waste Management Board using California taxpayer dollars to suggest locations where such companies should place their incinerators based on that location's demographics. Suggestions of the locations include communities that are rural, low- income, Catholic, had low educational levels, and were largely employed in resource extractive jobs like mining, timber, or agriculture; communities which would offer the least

resistance to such incinerators (*9*). For most of post-colonial American history, this unjust rationale was used to site industrial facilities and waste plants in low-resistance communities (*10*). Barriers that these communities may experience include: low-income, language-isolation, racism, xenophobia, and low educational attainment.

Kettleman City residents along with the help of Greenpeace fought against this implementation of an incinerator and after rigorous struggles, they successfully prevented the incinerator from being built. From this event, the community group, El Pueblo Para El Aire y Agua Limpia ("People For Clean Air and Water") was founded, which then co-founded Greenaction for Health and Environmental Justice. Both of these community groups are still active today and worked with us throughout this research.

Figure 1. *Local community members protest the Kettleman Hills Waste Facility. By Bradley Angel - Available Online, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=32066583.*

Geography and Surrounding Industries

Kettleman City is located in California's Central Valley between Fresno and Bakersfield. The Central Valley is a flat

region surrounded by the Coast Ranges and Sierra Nevada mountain ranges, giving it a "bathtub" type of topography. This geography affects the sinks available for the emitted air pollutants and renders the Valley a closed system (*6*). In addition to build up of ambient VOCs based on geography, surrounding industries are also important contributors.
Kettleman City is approximately two miles off of the Interstate-5 highway (area source) and approximately three miles away from a Chemical Management Waste landfill (point source). Additionally, Kettleman City is an agricultural region bordered by agriculture on the North, East, and West side. Benzene treatment plants are also present to remove benzene from water before distribution into the public water system. All of the aforementioned emissions sources give rise to VOCs, our chemicals of interest.

Methods

Environmental Health Perceptions

To study residents' environmental health perceptions of Kettleman City, anonymous Community Environmental Health Surveys were conducted. The research team walked to each household (N=300) with surveys on an iPad over a two day period from October 27 to October 28, 2018. Flyers with a URL link to the Qualtrics survey were left at households if no one was available to take the survey at the moment. The survey had both English and Spanish versions available. The survey had a total of 82-items regarding socioeconomic status, pesticide exposure, truck idling, female reproductive health, air quality, water quality, health concerns, and perspectives regarding law enforcement and governing agencies. Additional participant observations were recorded and documented.

Mobile Air Sensors

To study volatile organic compounds, three custom built micro-preconcentrator (μPC) samplers were used to collect data indoors, outdoors, and within a shower. The collected data included parameters such as GPS location and time of data collection, in addition to the adhered VOCs. The air samples were collected by researchers by placing one μPC sampler per site. Figure 2 depicts the μPC samplers that were deployed in this pre-pilot study, indicating it was the first time the μPC samplers were used in the field. The samples were collected on a loaded chip with a sorbent bed shown in Figure 3. The indoor data was collected within a residence and was set on a two hour timer. The indoor conditions during the time of data collection had no surrounding combustion activities at the time and were placed approximately three meters away from the kitchen area. The outdoor data was collected by placement of the sampler in a busy intersection during hot, sunny conditions (>32°C) on a two hour timer. The shower sample was collected by placing the sampler in a shower setting with cold running water for 30 minutes. The air samples were then analyzed using gas chromatography-mass spectrometry (GC/MS). The GC/MS used was a Varion ion trap 3800GC/4000MS.

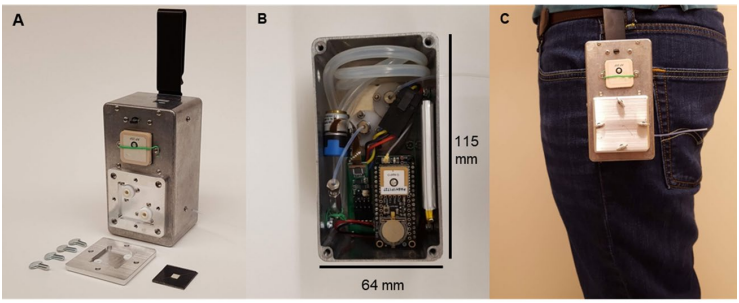

Figure 2 Custom built μPC sampler, which collects VOCs from air. A) Thumbscrews allow users to load chips for multiple VOC collections B) The sampler contains a pump, microcontroller and GPS for sample collection C) The device is mobile and even wearable (*11*).

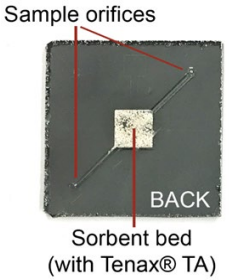

Figure 3 The µPC sampler (above) passes air samples through these custom chips, which are packed with a chemical sorbent. The sorbent adsorbs VOCs from the air and is returned to the lab for chemical analysis via GC-MS (*12*)

Results

The Household Community Environmental Health Survey received an 11% response rate (N=31).

Demographics

Of the people that responded, 64% identified as female and the remaining 36% identified as male. 57% of participants have resided in Kettleman City for over 12 years, 14% have lived in Kettleman City for 6-12 years, 21% for less than six years, and 7% for less than a year. 55% of participants either work or live with a household member that works in agriculture. Out of those that responded to the survey question (n=28), 35% had no children under the age of 18 years residing there, 18% had one, 25% had two, 21% had three minors or more. Out of the 31 contributors, roughly 55% chose to take the survey in English. However, 74% of participants' households primarily speak Spanish in their household while the remaining 26% primarily speak English.

Environmental Health Concerns

When asked about the level of environmental pollution in their neighborhood, 84% of those who responded (N=31) answered

somewhat high, high, or very high while 16% responded somewhat low or low. Participants were then asked to identify the most concerning environmental health problems in their community using a list of 13 choices. Of those who responded (n=22), the most frequently reported problems included asthma (19%), valley fever (12%), birth defects (11%), respiratory illnesses (11%), and cancers (11%). Of least concern was neurological disorders (3%), development disorders (1%), and injuries or accidents (1%). For the following question (n=27), 55% of participants reported having observed a truck idling in their community, 19% answered that they had not seen a truck idling in their community, and 13% were unsure. When asked if there are time limits to truck idling, 10% responded yes, 57% responded no, and 30% responded that they did not know.

Gas Chromatography- Mass Spectrometry

The GC/MS chromatogram depicted in Figure 4, together with the instrument's library, showed that toluene, xylene, and benzoyl chloride were possibly present in the outdoor sample. The indoor sample contained possible toluene and benzoyl chloride. Tribromomethane was possibly detected in the shower sample. Caveat: This pre-pilot data collection and small sample size provide putative identifications only.

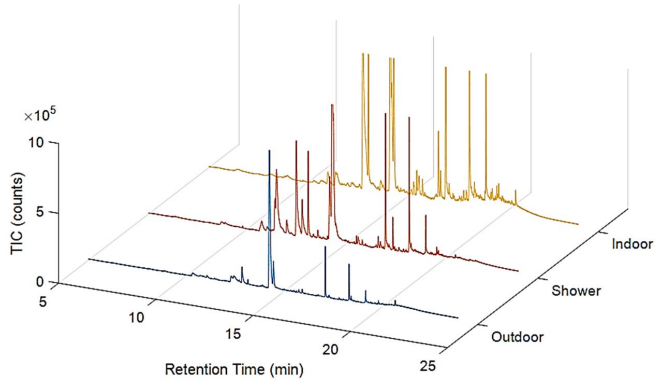

Figure 4 GC/MS chromatogram TIC (counts) vs Retention Time (min)-- unpublished result. Comparison of data collected from three locations within Kettleman City.

Discussion

The Community Environmental Health Survey was used to get a baseline understanding of the emission sources of VOCs and residential perceptions of environmental health. Out of the provided options of environmental health concerns, air quality-related ailments were among the most concerning for residents. Although possible identifications of the VOCs present in Kettleman City were provided by the GC/MS data, we cannot state whether these airborne chemicals are at toxic levels without quantification of VOC concentrations-- a critical step in predicting their environmental and health impacts. However, based on the putative identifications of the air samples, the GC/MS identified possible benzoyl chloride present in both outdoor and indoor environmental samples. No atmospheric reactions are known to produce benzoyl chloride. Thus, if benzoyl chloride were present both in indoor and outdoor environments, it would be due to industrial emissions. Once released to the atmosphere, benzoyl chloride can react with hydroxyl radicals or photolyze. However, benzoyl chloride exists as a fuming liquid and can volatilize from dry soil. Benzoyl chloride's shortest lifetime has been determined to happen via hydrolysis, thus making rain a possible major sink for the possible omnipresent compound in Kettleman City (*13*).

Toluene was also present in both outdoor and indoor environments. Toluene is a component of gasoline among other solvents and is found in cigarette smoke. Together with xylene and benzene (BTX), the mixture is used as an additive for gasoline (*14*). Once in the atmosphere, toluene can be degraded photochemically by hydroxyl radicals. The variability of sources for this chemical reflects the possible presence of it in both outdoor and indoor environments.

Xylene was found to be possibly present in the outdoor sample and not the indoor sample. Xylenes include various isomers and can be emitted to the air with automobile exhaust, paints, coatings, and adhesives (*15*). Xylene is also a combustion byproduct emitted from gas engines, diesel engines and burning of wood. Once in the atmosphere, xylene can react with hydroxyl radicals or be removed from the air via wet deposition (*16*). Since xylene was identified only in the outdoor sample, likely sources in Kettleman City are environmental from fuel combustion and exhaust.

Lastly, tribromomethane or bromoform is a byproduct of water disinfection (*17*). The cold shower sample provided a peak for bromoform in the chromatogram picture in Figure 4. Cold water was selected primarily to reduce the cost for the resident and also to reduce the amount of volatiles present during the sample collection. Tribromomethane is mostly degraded in the atmosphere by hydroxyl radicals and is not susceptible to photolysis (*17*).

Reflecting on the survey responses, residents reported encountering the emission of air pollutants through the survey responses. An emission source to highlight is truck idling, which can be responsible for the putative findings of xylene and toluene. Additionally, VOC concentrations indoors are affected by ventilation. Many residents expressed keeping windows and doors closed for most of the day in order to keep out harmful volatile compounds and few participants mentioned having an air filter within the home. These observations indicate a possibility of higher than usual VOC concentrations within households. The benefit of using the μPC samplers was their small size. This method was not only appropriate since it included a Tenax® sorbent bed for the collection of VOCs but its mobility made the collection process simple (18).

A limitation for this study was low participants for surveys. In part, this was due to the mistrust that some residents have towards researchers from an institution. An additional limitation was the distance between researchers and the community leading to a partnership with few face-to-face interactions. However, a benefit from using CBPR were the interactions between researchers and community members that were eager to participate. The community members that were interested in the study provided guidance and knowledge to the researchers during the study. The use of the CBPR method was of great importance to this interdisciplinary study and allowed for the research to be problem-based instead of discipline driven, a comprehensive approach to complex problems (*19*). Together, qualitative and quantitative results revealed the presence of VOC emissions in the community as identified by residents and gas chromatography. Not surprisingly, residents hold negative perceptions of their environmental health in Kettleman City. More representative VOC data collection is necessary to more confidently identify and quantify the VOCs present and exposed to residents in this environmentally disadvantaged community in California's Central Valley.

Conclusion

When discussing environmental pollution and the effects of air quality, the demographics of the locations with these emissions sources and the experiences of fence-line communities near these sources are oftentimes disregarded. This lack of awareness regarding the experiences that people face as a result of environmental injustices creates a knowledge gap in the general populace and slows down the process for creating policies to combat these point-source contributors to environmental pollution at the core. By including CBPR methods into scientific studies, scientists humanize the data and are better able to effectively communicate the urgency to either

finding alternatives to existing practices or discontinuing them entirely. By intertwining environmental justice with environmental science, a myriad of solutions may arise. Considering that this research focuses on environmental health, future research should include studying ground-level ozone levels, quantification of nitrous oxides, analysis of the air filters some residents have within the residence, water quality, and biological studies of levels of toxicity. Future studies for this project on air quality include, quantification of VOCs, as well as pesticide drift and particulate matter. In addition, our study will include interviews with Kettleman City residents that will be recorded and transcribed.

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