Association of major California freight railyards with asthma-related pediatric emergency department hospital visits

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ABSTRACT

Asthma is a major health threat and leading cause of chronic morbidity among children. Air pollutants have been linked to exacerbations and promotion of initial development of asthma. Extensive research already conducted assessing adverse health impacts associated with exposure to pollutants from vehicular traffic. However, little research conducted assessing exposure to pollutants stemming from goods movement industry, such as freight railyards. This study's purpose to assess potential association between residential proximity to major freight railyards and asthma-related emergency room (ER) visits in children. This study included children ≤14 yrs. old, living within 30-mile radius of one of 18 freight railyards in California, and having utilized emergency room services between 2007 and 2009, identified through California Office of Statewide Health Planning and Development (OSHPD) database. Logistic regression modeling with all 18 railyards, and models with top 5 polluting railyards, conducted to assess for potential association between asthma related ER visit (asthma vs. non-asthma visit) and railyard residential proximity. A total 109,645 asthma related ER visits identified, majority among low income, minority populations. Within 18 railyard model, children closest to railyard (0–5 miles) were at significant increased odds (OR = 1.15, 95%CI: 1.10–1.20) for asthma related ER visit and stronger odds observed for 5 top emitting railyards (OR = 1.40, 95%CI: 1.29–1.52). Our findings indicate a strong link between asthma ER visits for children and residential proximity to railyards, especially among low-income and minority communities. There's a critical need to better understand complex health risks for individuals residing in these communities and mitigation efforts for this vulnerable population.

1. Background

Asthma is one of the most prevalent chronic conditions in children today. Impacting approximately 7.1 million children, asthma has become the third leading cause of hospitalization and one of the most common causes of emergency room visits (ALA, 2011). A growing body of scientific studies has identified an association between exposure to transportation-related air pollution with increased respiratory symptoms, asthma related emergency room (ER) visits, and asthma-related hospitalizations (Edwards et al., 1994; Brauer et al., 2007; Chen et al., 2008). The strength of this association is directly related to the increasing proximity to major roadways (McConnell et al., 2006; Brauer et al., 2007; Newcomb and Li, 2008; Andersson et al., 2011). In

addition to exacerbating asthmatic symptoms and increasing the demand for health care services, air pollutants have been identified as promoting the initial development of childhood asthma (McConnell et al., 2010). As of to-date, the majority of the ambient air pollutant research studies have assessed exposure to pollutants stemming from transportation corridors with limit assessment of the goods movement industry (such as freight railyards and railroads), even though it is well established that local residents living near major transportation hubs and corridors are exposed to high levels of airborne pollutants (Sharma, 2006). Thus, there is a critical need for research assessing exposure to pollutants stemming from the goods movement industry, including major freight railyards and railroads.

The State of California may provide a unique setting for assessing

the goods movement industry, as globalization and international trade have dramatically increased, with California becoming a key goods movement and logistics industry economy. The State is a crucial link in the U.S. freight system, with 18 major railyards across the state, each producing tons of diesel emissions per year (CDT, 2018). Millions of cargo containers on trucks as well as diesel-powered locomotives on rails are involved with moving goods to inland ports, and from there they are distributed to the rest of the country. While these transportation corridors have encouraged overall economic growth, the potential exists to adversely impact the health of communities, especially vulnerable populations living in immediate proximity to the goods movement industry. It is known that mostly low income, minority populations live in the areas surrounding the transportation corridors and railyards (Hricko, 2006). While all residents experience the pollution from these sources, young children living in close proximity are at greater risk of developing respiratory health problems. Previous research has identified increased likelihood of adverse respiratory health outcomes of children living and attending school near a major freight railyard (Spencer-Hwang et al., 2015). However, with only limited research assessing impact of freight railyards on the health of children residing in close proximity, there is an urgent need to better understand the potential adverse health outcomes. Thus, the purpose of this research is to assess the potential associations of children's residential proximity to major freight railyards in California with asthma-related emergency room visitations.

2. Materials and methods

2.1. Study population and setting

This study included data from the CA Office of Statewide Health Planning and Development (OSHPD), a database holding anonymous, individual patient level information for all persons with an hospital ER visit in the State of California (OSHPD, 2011). In addition to the cause of the ER visit, the database includes patient level demographic information (i.e. age, sex, race, ethnicity, insurance, residential ZIP code, reason for the emergency room visit). Study subjects included children 0–14 years of age with an ER visit between 2007 and 2009. Only those with a residential ZIP code within a 30-mile radius of one of the 18 railyards in California were included. The final study sample represented 3,892,468 children visits to the ER with 109,645 asthma emergency room visits and 3,782,823 non-asthma related ER visits.

The 18 major California freight railyards included in this study were Barstow, City of Industry, Colton, Commerce, Commerce Eastern, Dolores, Hobart, ICTF, LATC, Oakland, Richmond, Roseville, Mira Loma, San Bernardino, San Diego, Sheila, Stockton, and Watson (Table 1, Fig. 1). The freight railyards were identified through the 2007–2009 Railyard Health Risk Assessments and Mitigation Measures Report carried out by the California Environmental Protection Agency (EPA, 2013). This report described the amount of onsite and offsite pollution by taking into account the specific idling and transit times of locomotives and other transportation means as well as any industry localized around each railyard.

2.2. Health endpoint

The health endpoint of interest for this study was asthma related ER visits provided by the OSHPD database. An asthma related ER visit was identified based on the International Classification of Diseases, 9th revision (ICD-9) codes 493.0–493.9 (CDC, 2002). Asthma related ER visits were compared with all other non-asthma related ER visits.

2.3. Railyard proximity assignment

Using residential ZIP code, proximity to the railyards was assigned using GIS software (ArcGIS version 10, Esri, Redlands, CA). The

Table 1
On- and off-site annual emissions of tons of diesel particulate matter for 18 intermodal California railyards.

Name of railyard	Total onsite emissions (tons of diesel particulate matter)	Total offsite emissions (tons of diesel particulate matter)	Ratio of onsite to offsite	Rank
BNSF San Bernardino	22	11	2	1
BNSF Barstow	27.9	26	1.07	2
UP Stockton	6.9	10	0.69	3
UP ICTF/Dolores	23.7	50	0.47	4
BNSF Watson	1.9	4.6	0.42	5
UP Oakland[a]	11.2	27.6	0.41	6
UP Colton	16.5	43.5	0.38	7
BNSF Stockton	3.6	10	0.36	8
BNSF Richmond	4.7	19.8	0.24	9
UP LATC	7.3	33	0.22	10
BNSF Hobart[b]	23.9	113.4	0.21	11
UP Mira Loma	4.9	30.7	0.16	12
BNSF San Diego	1.7	11.6	0.15	13
UP Commerce[b]	12.1	113.4	0.11	14
BNSF Commerce Eastern[b]	3.1	113.4	0.03	15
BNSF Sheila[b]	2.7	113.4	0.02	16
UP Roseville	25.1	NA	0	
UP City of Industry	10.9	NA	0	

Note: Offsite emissions are measured as non-railyard sources within a 1-mile boundary, unless indicated. Based on data reports obtained from the California Environmental Protection Agency Air Resources Board (EPA, 2013).
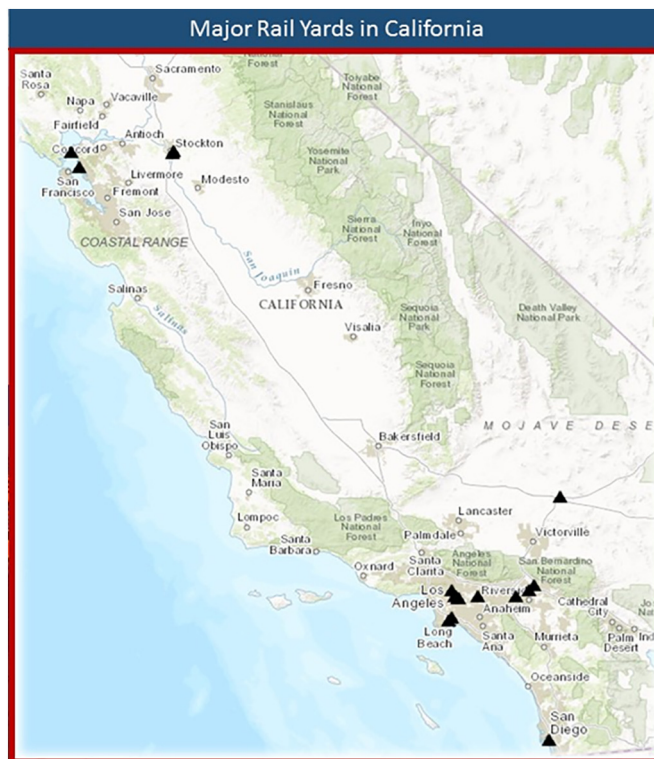[a] Unknown boundary.
[b] 2 mile boundary.

Fig. 1. Geographical location of the 18 major goods movement railyards across the state of California.

centroid of each ZIP code was measured to assign distance to the nearest rail yard. Two-thirds of all ER visits (N = 3,892,468) in the database originated in ZIP codes within 30 miles of a California railyard and were included. Based on the average size of California ZIP codes,

Table 2

Demographic profiles of emergency room patients with asthma living within a 30 mile radius from one of the 18 California railyards.

Characteristics	Total	≤ 5 miles	5.01–10 miles	10.01–15 miles	15.01–20 miles	20.01–25 miles	25.01–30 miles
	N = 109,645	n = 35,780	n = 32,105	n = 14,736	n = 12,385	n = 8417	n = 6222
	(100.0%)	(32.6%)	(29.3%)	(13.4%)	(11.3%)	(7.7%)	(5.7%)
Age at ER visit							
Under 1 year	5981 (5.5)	2194 (6.1)	1720 (5.3)	750 (5.1)	656 (5.3)	349 (4.2)	312 (5.0)
1–4 years	42,628 (38.9)	14,122 (39.5)	12,375 (38.6)	5693 (38.6)	4827 (39.0)	3, 236 (38.4)	2375 (38.2)
5–9 years	37,254 (33.9)	12,004 (33.5)	11,095 (34.6)	5031 (34.2)	4176 (33.7)	2900 (34.5)	2048 (32.9)
10–14 years	23,782 (21.7)	7460 (20.9)	6915 (21.5)	3262 (22.1)	2726 (22.0)	1932 (22.9)	1487 (23.9)
Race[a]							
White	43,346 (39.5)	11,834 (33.1)	11,299 (35.2)	6582 (44.7)	6045 (48.8)	4225 (50.2)	3361 (54.0)
Black	399 (0.4)	145 (0.4)	135 (0.4)	53 (0.4)	21 (0.2)	26 (0.3)	19 (0.3)
Asian	3688 (3.4)	786 (2.2)	973 (3.0)	817 (5.5)	574 (4.6)	361 (4.3)	177 (2.8)
Native American	22,320 (20.4)	7932(22.2)	8440 (26.3)	2130 (14.5)	1707 (13.8)	1000 (11.9)	1111 (17.9)
Native Hawaiian	469 (0.4)	99 (0.3)	74 (0.2)	69 (0.5)	102 (0.8)	54 (0.6)	71 (1.1)
Other	28,093 (25.6)	12,229 (34.2)	7455 (23.2)	2971 (20.2)	2631 (21.2)	1921 (22.8)	886 (14.2)
Ethnicity[a]							
Non-Hispanic	47,820 (43.6)	19,684 (55.0)	12,437 (38.7)	5496 (37.3)	5396 (43.6)	3058 (36.3)	1749 (28.1)
Hispanic	46,791 (42.7)	12,295 (34.4)	14,741 (45.9)	6568 (44.6)	5258 (42.5)	4249 (50.5)	3680 (59.1)
Health insurance[a]							
Medicaid	49,444 (45.1)	18,479 (51.7)	14,120 (44.0)	5913 (40.1)	5129 (41.4)	3279 (39.0)	2524 (40.6)
Self-pay	9756 (8.9)	3917 (11.0)	2784 (8.7)	1079 (7.3)	913 (8.8)	576 (6.4)	487 (7.8)
Managed care	45,399 (41.4)	11,562 (32.3)	13,601 (42.4)	7077 (48.0)	5817(7.4)	4265 (50.7)	3077 (49.5)
Other	5028 (4.6)	1815 (5.1)	1597 (5.0)	664 (4.5)	523 (4.2)	296 (3.5)	133 (2.1)
Gender[a]							
Female	37,093 (33.8)	12,107 (33.8)	10,845 (33.8)	4877 (33.1)	4251 (34.3)	2886 (34.3)	2127 (34.2)
Male	70,797 (64.6)	23,177 (64.8)	20,663 (64.4)	9591 (65.1)	7984 (65.5)	5390 (64.0)	3992 (64.2)

[a] The sum of some columns does not add up to 100% due to missing values.

and as the distance variable was not linearly distributed, we created six 5-mile residential railyard proximity categories which included: 0- < 5, 5- < 10, 10- < 15, 15- < 20, 20- < 25, and 25- < 30 miles, to assign each study subject to the nearest major railyard.

2.4. Potential confounding variables

1) *Individual patient level.* In addition to the ER visit information, the OSPHD 2011 database provided individual, patient level information on a number of potential confounders including: age (under 1 year; 1–4 yrs.; 5–9 yrs.; and 10–14 yrs.), sex (male/female), race (White, Black, Asian, Native American, Native Hawaiian and Other), insurance type (Medicaid, self-pay, managed care and other) and ethnicity (Hispanic/non-Hispanic).

2) *Census derived neighborhood characteristics.* The 2010 Census database provide social-ecological level potential confounders including: English proficiency (yes/no), household heating source (coal/non-coal), household income, and acquisition of smoking products (yes/no), with the individual variable assigned to each subject based on their residential ZIP code.

3) *Air pollution indices.* Air pollution data obtained from the Aerometric Information Retrieval Systems (AIRS) is collected and maintained by the U.S. EPA. Including air quality statistics for O_3 (ppm) and $PM_{2.5}$ (ug/m^3), collected over the national EPA ambient monitoring network from 1999 to 2009. Air pollution indices were calculated for each site throughout the study area and interpolated to geographic centroids based on residential ZIP code. We developed multiple air quality indicators for the criteria pollutants in order to characterize patterns of spatial and temporal variation in air pollution levels. Additionally, the EPA Toxic Release Inventory (TRI) 2014 database was utilized (EPA, 2016) to provide data on release of chemicals.

4) *Traffic related air pollution exposures.* The California Department of Transportation (CalTrans, 2008) database was used to model proximity to major roadways as a proxy for residential exposure and school exposure to traffic emissions. Distance from the subjects'

residence to nearest major roads (freeway, highway, and arterials) was estimated through GIS mapping methods described previously; this data was used to adjust for potential confounding by nearby vehicle traffic (McConnell et al., 2006; Newcomb and Li, 2008; Wilhelm et al., 2008; Rioux et al., 2010). Residential proximity to the nearest major road was categorized as ≤ 100, 100–200 m, > 200–300 m, and > 300 m.

2.5. Statistical analysis

Descriptive demographic variables were assessed and compared by residential railyard proximity (i.e. 0- < 5, 5- < 10, 10- < 15, 15–20, 20–25 miles) using chi-square and *t*-tests. The potential association between residential railyard proximity and asthma related ER visit (dependent variable) was assessed using logistic regression models which allowed the calculation of odds ratios (OR) and 95% confidence intervals (95% CI). Asthma ER visits were analyzed as a dichotomous event (1 = asthma related visit, 0 = non-asthma related visit). Based on previous work described by Szklo and Nieto's modifications to Hill's Guidelines to adequately adjust for potential confounders we ran the base model plus four additional models with different sets of potential confounders to explore distance from the railyard with ED visits for asthma (Szklo M., Nieto J., 2012). The first model explored the crude base model by railyard proximity. In the second model, we then added individual level variables (age category, sex, race, ethnicity, insurance status) to the crude model to assess the impact of individual confounders on the potential association between railyard proximity and asthma related ER visit. In the third model, we explored the crude base model plus outdoor pollutant variables (ZIP code residential density, road proximity, TRI, ozone, and $PM_{2.5}$). Model four explored the crude model plus the social ecological level variables (ZIP code area, English proficiency, health source, household income and acquisition of smoking products). The fifth and final full regression model included all potential confounders: the crude base model, age, gender, race, ethnicity, health insurance, median household income, residential density by

ZIP code, major road proximity, TRI, Ozone, $PM_{2.5}$, ZIP code surface area, English proficiency, indoor heat source, and acquisition of smoking products. Residential proximity within 25.1 to 30 miles from a railyard was utilized as the reference category. Assumptions were assessed and met for logistic regression modeling. An additional sensitivity analysis was conducted with inclusion of only study subjects within 30 miles of one of the top five most polluting railyards (n = 343,042). All analyses were conducted utilizing SAS version 9.4 (SAS Institute, Cary, NC).

3. Results

A total of 3,892,468 ER visits were identified within a 30-mile radius from one of the 18 railyards and among those 109,645 were asthma related and 3,782,823 were non-asthma related ER visits (Table 2). The region closest to the railyard (within 0–5 miles) is comprised of primarily children within the 1–4-year-old age group (40.8%), with a greater proportion identified as a non-white minority racial group (50.4%) and with Medicaid insurance (51.2%), a proxy measure for income. Moving further away from the railyard to zone 6 (25.1–30 miles) there is an increase in the percentage the white racial group (63.2%) with a decreasing percentage of those with Medicaid insurance (39.3%).

For the 109,645 asthma related cases, the majority were among ethnic or racial minorities (70.4%), children in the 1–4-year-old age category (38.9%) and with Medicaid insurance (45.1%). In assessing asthma related visits and railyard proximity, it is observed that more than half of the asthma related ER visits (n = 67,885; 61.9%) were among the study population living within 10 miles of the nearest major railyard. Within the 10 mile radius the majority of the ER visits were among ethnic or racial minorities (72.8%), children in the 1–4 years old age category (39.0%) and with Medicaid insurance (48.0%). Within the region closest to the railyard (< 5 miles), the majority of asthma ER visits were among ethnic or racial minorities (71.6%), children in the 1–4-year-old age group (39.5%) and with Medicaid insurance (51.6%). Fig. 2 depicts asthma-related ER visits by race/ethnicity and railyard proximity.

Within the 18 railyard regression analyses, the crude model generally exhibits a linear trend with significantly increasing odds of visiting the ER for an asthma related reason with increasing proximity to the nearest major railyard (Table 3). There is a 24% increase in the odds of visiting the ER for an asthma related reason when moving from the 15- < 20 mile distance to the railyard category to the 5- < 10 mile distance category (OR = 1.05 and 1.29, respectively). There is a slight

decrease in odds moving from the 5- < 10 mile distance category to the 0- < 5 mile category (1.24, 95% CI: 1.21–1.27). The fully adjusted, 18 railyard model shows a linear trend of increasing odds for asthma related visit with increasing proximity to the railyard; indeed, the locations farthest from the railyard for models 3–5 consistently indicate significantly lower odds for asthma related ER visits. The greatest odds in adjusted models were observed among the final, fully adjusted model among those living within 5- < 10 miles of the railyard (OR = 1.18, 95% CI: 1.13–1.23).

Much stronger associations were found among the models depicting the top 5 polluting railyards. The strongest association was observed within the fully adjusted model for the category within 5- < 10 miles of the railyard (OR = 1.47; 95% CI: 1.35–1.60). There was a 25% increase in odds of asthma related ER visit between the 18 to the 5 railyard models for subjects observed living in the closest proximity to one of the top 5 most emitting railyards. There is also a large increase in odds (25%) from the 15- < 20 mile distance group moving closer to the railyard within 5- < 10 miles, which also happens to be the category with the highest odds observed for visiting the ER for an asthma related reason.

4. Discussion

A growing body of evidence indicates that traffic emissions and diesel exhaust are associated with increased risk of adverse respiratory health outcomes in children, such as reduced lung function, airway inflammation, wheezing-sounding breathing, coughing, exacerbation of asthmatic symptoms, development of asthma, increased medication use, ER treatment and hospitalizations (Kim et al., 2004; Gauderman et al., 2007; Holguin et al., 2007; McConnell et al., 2010). Moreover, recent evidence has pointed to the additional role of railyard related emissions, impacting children already affected by background pollution (Spencer-Hwang et al., 2015). Our study set out to investigate if our findings from the San Bernardino railyard study were similar to findings observed for freight railyards in general. To explore this, we studied all 18 intermodal railyards in California as well as the five most polluting ones among them. In sum, we found a strong relationship between the likelihood of a child visiting the ER for an asthmatic condition and increasing residential proximity to one of the 18 major railyards in our study. More importantly, these findings were maintained after fully controlling for possible confounders, further supporting the identified relationship that proximity to major railyard adversely affects children's health.

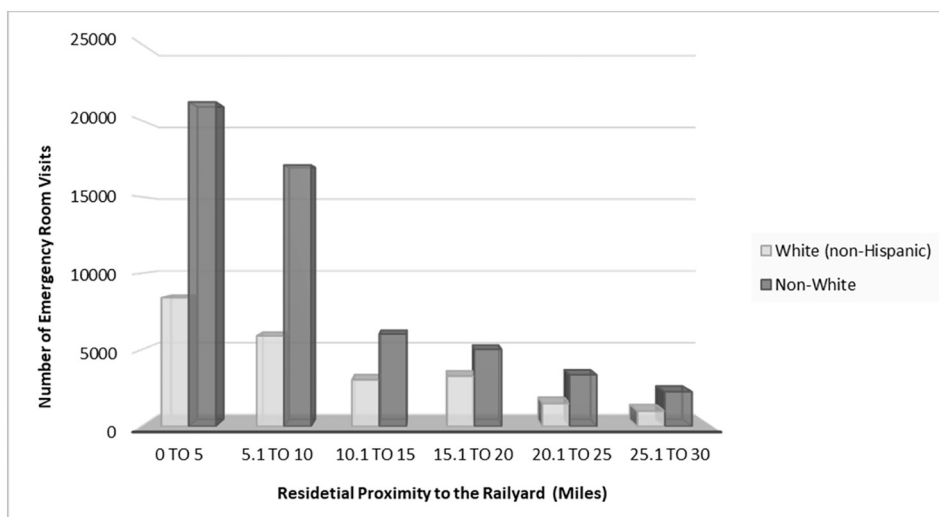Interestingly, our findings may have identified a potentially unique

Fig. 2. Distribution of the asthmatic ER related admissions by race/ethnicity and railyard proximity.

Table 3

Odds ratio estimates for visiting emergency room for asthma by increasing residential proximity to the railyards in California.

Model	Distance category	18 Railyard model			Top 5 polluting railyard model		
		Point estimate	95% confidence limits		Point estimate	95% confidence limits	
CRUDE[a]	Distance 1: ≤5 miles	1.24	1.21	1.27	1.28	1.22	1.35
	2: 5.01–10 miles	1.29	1.25	1.32	1.29	1.22	1.35
	3: 10.01–15 miles	1.11	1.08	1.15	0.94	0.88	1.00
	4: 15.01–20 miles	1.05	1.02	1.08	1.00	0.92	1.08
	5: 20.01–25 miles	1.00	0.96	1.03	0.83	0.78	0.87
CRUDE + Individual Level[b]	Distance 1: ≤5 miles	1.23	1.19	1.27	1.31	1.24	1.38
	2: 5.01–10 miles	1.22	1.19	1.26	1.35	1.28	1.43
	3: 10.01–15 miles	1.14	1.10	1.18	1.10	1.02	1.18
	4: 15.01–20 miles	1.09	1.05	1.13	1.15	1.06	1.25
	5: 20.01–25 miles	1.02	0.98	1.06	0.96	0.90	1.02
CRUDE + Outdoor/Pollution Level[c]	Distance 1: ≤5 miles	1.26	1.21	1.31	1.43	1.32	1.54
	2: 5.01–10 miles	1.35	1.30	1.40	1.44	1.33	1.56
	3: 10.01–15 miles	1.15	1.11	1.20	1.03	0.95	1.13
	4: 15.01–20 miles	1.07	1.03	1.11	1.03	0.94	1.13
	5: 20.01–25 miles	0.94	0.91	0.98	0.88	0.77	0.90
CRUDE + Social/Ecological Level[d]	Distance 1: ≤5 miles	1.13	1.09	1.16	1.16	1.10	1.23
	2: 5.01–10 miles	1.16	1.13	1.20	1.18	1.11	1.25
	3: 10.01–15 miles	1.03	1.00	1.06	0.86	0.80	0.93
	4: 15.01–20 miles	1.02	0.99	1.05	0.98	0.90	1.06
	5: 20.01–25 miles	0.95	0.92	0.98	0.83	0.78	0.88
CRUDE + ALL Levels[e]	Distance 1: ≤5 miles	1.15	1.10	1.20	1.40	1.29	1.52
	2: 5.01–10 miles	1.18	1.13	1.23	1.47	1.35	1.60
	3: 10.01–15 miles	1.08	1.04	1.13	1.15	1.03	1.28
	4: 15.01–20 miles	1.03	1.00	1.08	1.22	1.10	1.36
	5: 20.01–25 miles	0.94	0.90	0.98	1.02	0.94	1.12

[a] CRUDE: Distance Category + Railyard.
[b] CRUDE + Individual Level: Crude + Age Category + Sex + Race + Ethnicity + Insurance Status.
[c] CRUDE + Outdoor/Pollution Level: Crude + Zipcode Residential Density + Road Proximity + TRI (Toxic Release Inventory) + Ozone + $PM_{2.5}$.
[d] CRUDE + Social/Ecological Level: Crude + Zipcode Surface Area + English Proficiency + Heat Source + Household Income + Acquisition of Smoking Products.
[e] CRUDE + ALL Levels: Crude + Individual + Outdoor/Pollution + Social/Ecological.

distribution pattern of pollutants emitted from freight railyards. Emission studies of pollutants from vehicular traffic tend to identify that those in closest proximity experience the greatest pollutant exposure and subsequently are at greatest risk. Our findings indicate that the pattern of exposure and associated adverse health risks may not be as straightforward as that identified for vehicular emission exposure, but more a hybrid exposure from a stationary industry source combined with exposure from moving sources. There may be a number of contributing factors promoting the potential wider distribution of the emitted pollutants which influence subsequent adverse health outcomes. One of the contributing factors for the potentially differing distribution pattern may in part be the size of the diesel related particulates. Due to their size (majority less than $PM_{2.5}$), these particulates behave similarly to buoyant plumes emissions of stationary industry while still retaining some mobile source characteristics; buoyant plumes are lighter than air due to their lower density and higher temperature which in turn influences their dispersion since it can be affected by wind interactions, allowing them to travel further before concentrating to then dissipate. Plus, the physical design of the railyards themselves, with wide open ceiling space completely surrounded by high walls contributes to the "funneling" of pollutants up into the wind currents which may then be carried further than pollutants that are emitted close to the ground as is the case from vehicular traffic. It has been shown that the diesel engines emit large quantities of fine particulate matter ($PM_{2.5}$), PAHs, volatile organic carbons (VOCs), carbon dioxide (CO_2), carbon monoxide (CO) as well as nitrogen oxides (NO_x). Diesel exhaust also contains other carcinogens including benzene (C_6H_6), formaldehyde (CH_2O) and arsenic (As). Studies of vehicular traffic have identified secondary species that do not follow same distribution patterns as their precursor pollutants from vehicular emissions (Canagaratna et al., 2010). Thus, the possibility exists that the types of particles emitted from freight railyard may behave quite differently from pollutants emitted from vehicular traffic.

Living in a railyard community may increase the need for medical services which many families already find difficult or impossible to access. Growing evidence indicates that in California, a higher percentage of young children who are from minority, or low-income families live near transportation corridors and hubs (Hricko, 2006). Our results indicate that minority and low-income children between the ages of 1 and 4 living near a major freight railyard are more likely to visit ER for asthma related reasons. Indeed, neighborhood level conditions have a strong impact on individual health status including morbidity and mortality (Sampson et al., 1997; Cubbin et al., 2000; Schulz et al., 2000). Intrauterine development through the first 5 years of life has been described as a critical time period for growth and development at risk to stresses and environmental exposures. Clearly our findings are concerning, as our results indicate that the population living in closest proximity to the freight railyards and most likely to use emergency room services for asthma are children < 4 years in age; the group with increased vulnerability to stresses and environmental exposures.

In addition to adversely impacting the physical health of children, air pollutants may also hinder academic achievement, as asthma is one of the leading causes for most missed school days for children (Moorman et al., 2012). Most likely the number of children going to the ER for urgent care is significantly less than the number of children who miss school for asthma related reasons, which aligns with a growing body of evidence that has identified an association between outdoor air pollutants and school absenteeism (Ransom and Pope 3rd, 1992; Gilliland et al., 2001). Moreover, school absenteeism is linked to poor academic performance (Coelho et al., 2015) which likely leads to affected students who miss more days of school also scoring lower on standardized tests, pitting them at risk for disengaging in school and for drop out (Hammond et al., 2007). Poor school performance and

subsequent drop out, results in limited employment opportunities as an adult and inevitably reduces children's economic earning potential (Needham et al., 2004). Environmental exposures that not only hinder children's health, but adversely impact academic achievement as well, in essence creates a "double jeopardy" situation for children, with the potential for lifelong adverse consequences.

5. Strengths and limitations

Our study has a number of strengths. The research database involves thousands of asthma related events across the state of California, allowing for broad regional representation as well as sufficient power to detect potential associations. The database has high level of validity as California's OSHPD regularly conducts a series of audits to ensure accuracy of the reported data (Laditka et al., 2003). The large database also included wide variety of variables to adjust for potential confounders in our models, supporting the likelihood that the found association truly exists. Additionally, as our research focused on all 18 intermodal railyards in California rather than assessing the impact of a single railyard, our findings are applicable to a wider audience.

Our study also has some limitations that merit discussion. Due to confidentiality and privacy rules inherent in the de-identified data set precluded us to get actual patient addresses, limiting us to ZIP code data as an approximation of patient's residential address. In lieu of having an address, a widely used alternative, though not as precise is the use of ZIP codes for exposure assignment (Pope et al., 2015; Xiao et al., 2016; O' Lenick et al., 2017). Another limitation of the study is that we were unable to account for the time an individual spent at their current address, limiting our ability to know how long the children were exposed to the air pollution under study. However, air pollutants have both short-term and long-term health impacts and it is likely that ER visit may represent the more short-term, immediate health effects. Finally, we did not have patient-level information on exposure to tobacco smoke, a potential important confounder. To address the missing smoking variable, we used available smoking product sales index available at the ZIP code level.

6. Conclusion

The goods movement industry and associated air pollution is becoming an increasingly important concern as transportation hubs are expanding with rising trading volumes. Our data suggest that freight railyards indeed are associated with much higher asthma related ER visits, especially for low income minority children. Increasing our understanding of the health effects of residential proximity to railyards and whether disadvantaged populations are particularly vulnerable to these environmental hazards is critical. Future studies should further investigate our findings, and if these are supported, policies should consider how to protect vulnerable children from a lifetime of chronic asthmatic disease related to railyard proximity. This is especially important as the majority of children suffering from the detrimental effects we observed were young (ages 1-4 yrs.), presenting with asthma at a critical developmental time. Mitigation efforts should create policies that will reduce children's exposure risk to diesel particulate matter, including retrofitting homes near these railyards with filters and limiting children's outdoor playtime activities as well as promoting cleaner railyard locomotives in railyards close to high density residential communities. Through coordinated and sustained efforts we can work to promote healthier communities where children and their families can live and thrive.

Grant information

Competing interests

The authors have not published or submitted any related papers from this same study. The authors have no financial conflict of interest. All authors have read the manuscript, agree the work is ready for submission to a journal, and accept responsibility for the manuscript's contents.

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