Project ENRRICH: A Public Health Assessment of Residential Proximity to a Goods Movement Railyard

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The BP/South Coast Air Quality Management District (AQMD) Public Benefits Oversight Committee

RESPONSE TO RFP:
Community Benefit Programs Addressing Conditions Caused or Exacerbated by Air Pollution

TITLE OF ORIGINAL APPLICATION:
Responding to a Community's Call for Action: Studying the Health Effects of an Intermodal Railyard in San Bernardino

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FINAL REPORT

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DISCLAIMER:

Scientists from Loma Linda University developed this report for the *BP/South Coast Air Quality Management District (AQMD) Public Benefits Oversight Committee* as a basis for further scientific evaluation and technical discussion. Regulatory action cannot be construed from this report, nor does it have the force or effect of regulation. This report's contents are solely the responsibility of the grantee and do not necessarily represent the official views of the South Coast Air Quality Management District or BP.

This report presents a public health assessment which focused on gathering baseline information on community conditions and on specific health outcomes in the populations residing near a goods movement railyard facility in the City of San Bernardino, California. Causality in the exposure-outcome associations that were evaluated cannot be established given the cross-sectional study design. The information contained in this report is intended for use in the formulation of mitigation strategies and in guiding additional research efforts. However, whether and how this report should be used in potential mitigation and/or policy processes is outside the purview and responsibility of the authors and of Loma Linda University.

TABLE OF CONTENTS

Thank You to Our Funders and Partners

The Environmental Railyard Research Impacting Community Health (ENRRICH) Project is a collaborative effort involving several entities. In this report, we acknowledge the following agencies, organizations, and individuals for their contributions to the development and implementation of Project ENRRICH:

- The BP/South Coast Air Quality Management District (AQMD) Public Benefits Oversight Committee funded the study under LLC grant # 659005.
- Dr. Susanne Montgomery received partial support from the Loma Linda University Center for Health Disparities under NIH grant 1P20MD006988.
- The Center for Community Advocacy and Environmental Justice (CCAEJ) and the Director, Ms. Penny Newman, provided invaluable support as true partners throughout the study.
- Dr. John Morgan, Regional Epidemiologist for the Desert Sierra Cancer Surveillance Program (Region 5 of the California Cancer Registry) and Professor of Epidemiology at LLU School of Public Health, conducted the population-based cancer assessment and contributed to Chapter 3.
- Our LLU team of epidemiologists and statisticians provided expertise, input, and technical guidance in the design and analytical phases of the study: Rhonda Spencer-Hwang, Synnove Knutsen, David Shavlik, Larry Beeson, and Mark Ghamsary.
- Dr. Xinqiu Zhang, South Coast Air Quality Management District, provided emissions data from the Multiple Air Toxics Exposure Study (MATES).
- The San Bernardino City Unified School District (SBCUSD) and the Fontana Unified School District (FUSD) and their respective Education Boards approved and facilitated the school-based health assessments. We are grateful to Mr. Danny Tillman, member of the Board of Education at SBCUSD, and Dr. Barbara Flores, past Board President at SBCUSD, for their support and leadership.
- Principals Luis Chavez-Andere (SBCUSD) and Joel Avina-Sanchez (FUSD) and their respective faculty provided incredible support through the planning and implementation of the schoolchildren's respiratory health screenings.
- The Arrowhead Regional Center Breathmobile® collaborated with Project ENRRICH in the respiratory health screening activities.
- The Aerocrine Corporation contributed technical assistance during the respiratory health screenings and donated additional $F_{E_{NO}}$ (airway inflammation) tests to offer screenings to all children at both schools.
- Past San Bernardino Mayor Patrick Morris, County Supervisor Josie Gonzalez, San Bernardino Councilmember Virginia Marquez, and Dr. Maxwell Ohikhuare, San Bernardino County Health Officer, for their vision and leadership.
- Dr. David Dyjack, past Dean, LLU SPH, and Dr. Patricia Penniecook, current Dean, LLU SPH, were instrumental in the establishment of Project ENRRICH and made resources available throughout this project, including partial support for Drs. Soret and Spencer.
- Dr. Richard Hart, Loma Linda University President, was instrumental in enabling the partnership between the City of San Bernardino and Loma Linda University, which led to the establishment of Project ENRRICH.

TABLES

FIGURES

EXECUTIVE SUMMARY

Freight logistics systems are considered a crucial component of modern societies. The rail sector has been and continues to be a fundamental backbone of the goods movement system in the United States (US). The overall impacts of the growth of international trade and the movement of goods are generally seen as positive. However, society has paid relatively little attention to possible health and other community impacts on local residents who live near goods movement hubs and corridors and who tend to be low-income and minority families. As part of a statewide plan for reducing railroad pollution, the California Air Resources Board (CARB) has conducted a series of health risk assessments of the major railyards in California. According to the Health Risk Assessment (HRA) reports, out of the 18 railyards assessed, the Burlington Northern and Santa Fe (BNSF) San Bernardino Railyard (SBR) ranked 5th in terms of diesel emissions and 1st in projected community health risk. However direct collection of health data on local residents was not part of the health risk assessment process. In response to the need for primary health data, scientists from the Loma Linda University (LLU) School of Public Health developed a research and community engagement initiative, the *Environmental Railyard Research Impacting Community Health (ENRRICH) Project.* To more effectively reach and engage community members, a community based participatory research (CBPR) strategy was employed in collaboration with the Center for Community Action and Environmental Justice (CCAEJ).

Study Purpose

The overall goal of Project ENRRICH was to characterize the community health burden in the residential areas near the SBR, a major goods movement facility located in the City of San Bernardino in inland southern California. Specifically, the fundamental question examined was whether there is a relationship between adverse health effects for residents and proximity to the SBR. This report presents findings of this 2-year public health assessment initiative, conducted with funding from *BP/South Coast Air Quality Management District (AQMD) Public Benefits Oversight Committee*. The overall ENRRICH Project included four major components: 1) a population-based cancer assessment of residents near the SBR (aka Cancer Assessment); 2) a household-level health assessment of adult residents; 3) a children's respiratory health study; and throughout, 4) community engagement toward positive community impacts and mitigation.

1. Cancer Assessment

We conducted a non-concurrent cohort study by extracting annual counts of observed new cancers for 1996-2008 in 16 contiguous Census Tracts overlapping and immediately surrounding the SBR. Data were extracted from the California Cancer Registry (CCR) confidential database for all invasive cancers combined, classifying them by age, sex, and race/ethnicity. Observed new cases were compared with expected numbers of new cancers based on the average annual cancer incidence proportions (rates) for 1998-2002 in the standard Desert Sierra Cancer Surveillance Program (DSCSP; i.e., Mono, Inyo, San Bernardino and Riverside) population and the Tract-specific demographic characteristics reported in the 2000 US Census. Tracts were classified into three exposure categories, railyard-high, moderate, and low, with each representing higher exposure to diesel emissions than the DSCSP standard population.

<u>All Cancers</u>

We found 1) a statistically significant but modest elevation for both sexes combined, all race/ethnic groups combined (SIR = 1.10; 95% CI: 1.06-1.13); 2) statistical elevations among Hispanic (SIR = 1.18; 95% CI: 1.10-1.27) and non-Hispanic White (SIR = 1.23; 95% CI: 1.13-1.34) male residents; 3) lower than expected cancer counts among Asian/other residents (SIR = 0.75; 95% CI: 0.60-0.93); and 4) no clear evidence of a "dose-response" trend across a hypothesized low-moderate-high exposure gradient within the area defined by the 16 contiguous tracts surrounding the SBR. We did not find evidence of risk elevations for non-Hispanic Black residents.

<u>Site-specific cancers</u>

We found elevations for residents in the high-exposure Census Tracts: (1) a statistical excess of lung/bronchus cancer (SIR = 1.78; 95% CI: 1.09-2.76) among females; (2) non-significant elevations for colon/rectum cancer among females (SIR = 1.13; 95% CI: 0.63-1.87) and males (SIR = 1.44; 95% CI: 0.89-2.20). In the railyard-moderate and low exposure Tracts the results for site-specific cancers did not follow a clear pattern, with mostly null findings mixed with some statistical deficits and elevations. However, results for both sexes combined revealed a pattern of non-significant but increasing SIRs across the low-moderate-high exposure railyard gradient for lung, colon/rectum, and pancreas, suggestive of a possible dose-response trend. When data for all 16 contiguous Census Tracts surrounding the SBR were combined, we found: 1) statistical elevations for breast cancer (SIR = 1.30; 95% CI: 1.06-1.59) among Hispanic residents and for all cancer sites combined among females (SIR = 1.09; 95% CI: 1.01-1.17) and males (SIR = 1.18; 95% CI: 1.10-1.27); 2) statistical elevations for lung/bronchus cancer among non-Hispanic White females (SIR = 1.34; 95% CI: 1.08-1.66) and males (SIR = 1.37; 95% CI: 1.10-1.69); and 3) fewer than expected counts for all cancer sites combined among females and markedly lower than expected counts of colorectal cancer among Asian/other residents.

2. Adult Household-level Study

We used a serial cross-sectional design (summer 2011 and winter/spring 2012 to account for seasonal variations) to conduct household interviews with adult residents who lived at various distances from the SBR. In all, 1,075 household interviews were conducted to collect data fundamentally on the prevalence of respiratory symptoms and conditions as well as two biologic outcomes: Peak Expiratory Flow (PEF) and airway inflammation. In line with the CARB HRA report, data were collected from within three sampling zones, A, B, and C, in the communities surrounding the SBR, representing decreasing levels of air pollution exposure, from highest (A) to lowest or background (C), away from the SBR. We defined exposure based on our sampling regions A, B, and C, which denoted residential distance to the railyard as a proxy of exposure to diesel emissions. Three exposure categories were defined: *Exposed (zones A and B)*, *High Exposure (zone A)*, and *Moderate Exposure (zone B)*. Region C served as our comparison (*background*) group.

Log-binomial regression models were used to estimate the effect of residential proximity as a proxy for exposure to SBR excess emissions on prevalence of self-reported, doctor-told respiratory symptoms and illness, cardiovascular disease (CVD), and two biological measurements: PEF (a lung function indicator) and fractional exhaled nitric oxide, $F_{E_{NO}}$ (a marker of airway inflammation). All models were adjusted for potential confounders including age; sex; race/ethnicity; household income; tobacco use; exposure to environmental tobacco smoke (ETS); time spent outdoors; proximity to nearest major road; and total diesel PM from local sources.

Respiratory tests identified 38% (n=352) of all subjects with low PEF (< 80% of the predicted value, adjusted for gender, age and height). Intermediate to high $F_{E_{NO}}$ values (≥ 25 ppb) were detected for 19% of study participants (n = 178). Nearly one fifth of all subjects reported a doctor-diagnosed respiratory illness (asthma, bronchial conditions, emphysema) and 10% use a physician-prescribed inhaler. With respect to self-reported respiratory symptoms, close to one-third of all subjects (n = 346) experienced frequent morning or nighttime coughing, 40% (n = 429) said they experienced shortness of breath, 27% (n = 288) reported frequent sputum or mucus from lungs, 28% (n = 303) exhibited wheezy breathing, and almost 20% (n = 210) had a doctor-diagnosed respiratory condition. While not statistically significant, a consistent trend of increased prevalence of adverse outcomes was observed from the *Moderate* to the *High* exposure regions. Across endpoints and exposure levels, elevations ranged from small to moderate. The strongest associations were observed for self-reported respiratory symptoms, PR = 1.20, followed by self-reported, doctor-diagnosed respiratory conditions, PR = 1.17, and CVD, PR = 1.15. The weakest associations overall were found for low PEF (PR = 1.06) and intermediate-to-high $F_{E_{NO}}$ (PR = 1.08). The observed associations for respiratory symptoms and CVD were borderline significant.

3. Children's Respiratory Health Study

We used a cross-sectional design to compare two socio-demographically matched elementary schools: the exposure school (ES), located 500 meters directly downwind from the SBR, and the comparison school (CS), located seven miles west, outside the CARB-identified railyard impact zone (RIZ). Parents completed a brief questionnaire containing questions on potential confounding variables, the child's respiratory symptoms and past health history. Using trained and standardized technicians, children's PEF, $F_{E_{NO}}$, and anthropometric measurements were collected for 1,066 children (74% participation). Linear as well as log-binomial regression models for dichotomous outcomes for PEF (< 80% of their predicted values *vs*. 80+) and $F_{E_{NO}}$ (≥ 20 ppb *vs*. < 20 ppb), with adjustment for potential confounders, were used to calculate prevalence ratios (PR) and 95% confidence intervals (95% CI). Sensitivity analyses were conducted limiting the study population to students who had lived 6+ months at their current address (N=765).

Of the 877 children with complete data, 21% of students had low PEF results and 16.3% had high $F_{E_{NO}}$ values, indicative of airway obstruction and/or lung inflammation. Both the linear regression and log-binomial regression analysis revealed consistent findings across the crude, adjusted, and sensitivity analysis models, indicating that children from the ES exhibited an increased prevalence of poorer PEF results compared to the comparison school. After adjusting for age, sex, race/ethnicity, ETS, time spent outdoors, median household income, proximity to nearest major road, and local DPM emissions, the ES children experienced a significant 59% increase in the prevalence of reduced PEF compared to the CS children (PR= 1.59, 95% CI: 1.19-2.12). Sensitivity analyses with students who resided 6 months or longer at their current address confirmed the earlier PEF results (PR= 1.41, 95% CI: 1.03-1.92). The findings for FE_{NO} were less clear: no association was found using the linear regression model. However, when using the recommended cutoff of 20 ppb, the children in the ES were 33% more likely to have an abnormal value (PR=1.33, 95% CI: 0.95-1.85) compared to the CS. Sensitivity analyses resulted in estimates becoming stronger and statistically significant (PR=1.44, 95% CI: 1.02- 2.02). Additional analyses of parent-reported outcomes and symptoms identified statistical elevations for cough (PR = 1.74; 95% CI: 1.20-2.51), wheeze (PR = 1.72; 95% CI: 1.23-2.39). Non-significant elevations were observed for parent-reported asthma/inhaler use (PR = 1.30; 95% CI: 0.93-1.82) and ED utilization for respiratory related problems (PR = 1.53; 95% CI: 0.84-2.79).

4. Community Engagement

In working with the community to better understand their challenges and perceptions we conducted focus groups (N=5; 53 community members) and key informant interviews (N=12). In addition, we also added questions to the household survey to assess community needs and perceptions. Responses to questions were coded for recurrent themes and organized into categories.

The findings indicate that community members expressed concern for poor air quality in their community, but that other challenges take higher priority (i.e., jobs, providing for families, access to healthcare). Residents closest to SBR expressed concerned about immediate and tangible issues: police, security, law enforcement; street lighting and repair; and trees and greenery. Participants felt that the railyard has a positive reputation and is highly valued for the jobs and economic growth it provides. However, it was also perceived as a major contributor to the already poor local air quality and seen as a major source of noise pollution. Some participants feel that they have sacrificed for the benefit of the railyard and are concerned about the health impact of life near such a busy freight facility, especially for their children. Residents were vocal on a number of ideas for promoting and sustaining a healthier community and made specific suggestions for the goods movement sector, local government, research institutions and healthcare providers.

Discussion

Findings from the public health assessments conducted under ENRRICH suggest elevations in the prevalence of adverse health outcomes among participants living and/or attending school near the SBR, compared to residents in the background regions outside the CARB-identified RIZ. Not unexpectedly, the prevalence of health effects was stronger for children than for adults, but, overall, there was a consistent trend across endpoints. These results emerged against a complex exposure and population setting. Pervasively high levels of background, transported air pollution and emissions from local sources, together with underlying respiratory health challenges and sociodemographic homogeneity, define an overall exposure setting within which, *a priori*, it may be difficult to find a distinct pattern of adverse outcomes with respect residential proximity to the railyard facility. Nevertheless, elevations were observed consistently with respect to increasing proximity to the SBR. Although according to data from our own community assessment, indicators of socioeconomic disadvantage seem to improve away from the SBR, residential stability was comparable across the study area and other relevant factors such as exposure to ETS, or past and current tobacco use, actually decrease towards the SBR. This pattern of tobacco use is relevant as it is well known that smoking, a critical risk factor for many chronic diseases, confounds the associations with air pollution.

In gauging the increased adverse health outcomes identified through ENRRICH Study, it is important to determine whether reasonable correlational evidence suggests that the SBR may conceivably contribute to excess health risks in adjacent areas. The overall study results need to be considered in light of the status of the SBR as the largest local emitter, together with the biological plausibility for adverse health effects of diesel pollution, and the potential for enhanced air pollution exposures and toxicity in the areas near the SBR. The absolute amount of diesel emissions, 22 tons annually, attributed to the SBR ranked 5th among the 18 California railyards assessed by CARB. The emissions attributable to the SBR represent 67% of the total diesel PM emissions arising from all stationary and mobile sources within one mile of the facility. In contrast, at the other 17 major California railyards, onsite diesel emissions represent on average 22% of all local diesel emissions. Given that status of the railyard facility as a major local source, the next fundamental issue is the evidence for detrimental human health impacts of diesel PM through plausible physiological mechanisms. Emerging immunologic evidence and the proposed cellular mechanisms fit well with the epidemiologic evidence indicating that exposure to diesel pollution indeed enhances the risk for a wide array of adverse health effects including cancer, respiratory and cardiovascular endpoints. In addition, recently published evidence demonstrates a distinct spatial gradient within the South Coast Air Basin of increased concentrations eastward and greater toxicity of certain organic species found in diesel particles as they are transported inland. Thus there is a plausible scenario of enhanced exposures and toxicity in the SBR region. Residents may be receiving the combined exposures from imported diesel-related pollutants and from the local emissions arising from the SBR. Finally, confounding may increase, decrease, or obscure attribution of the health effects from the ambient exposures. Our models adjusted for age; sex; race; economic differences; smoking status and ETS exposure; time spent outdoors; exposure to local (stationary and mobile) sources of diesel PM and residential proximity to major roads.

Conclusions

The ENRRICH study has identified a significant association with increasing proximity to the local railyard and adverse respiratory health outcomes among children, in an area already plagued with poor background air quality. Although not significant, results for adults follow the same trends toward negative associated adverse health endpoints in the *Moderate* and *High* exposure regions closest to the railyard. While not statistically significant, these findings should be considered relative to their public health implications. The results from the population-based cancer assessment defied in some cases straightforward interpretations. However some of the findings, such as the risk elevations for Hispanic females and males and for non-Hispanic white males are relevant from a public health perspective and warrant further investigation.

Our models adjusted for relevant confounders, and the fact that even after analytical adjustments we still found modest to moderate elevations across health endpoints does not appear to support a basic hypothesis of no association between residential proximity to the railyard and adverse health outcomes among local residents. It is likely that community perceptions and concerns will not be dissipated. This said, most community members are supportive of the railyard as an employer, both directly and indirectly, but want this to occur minimizing risk as much as can be controlled and wished for the railyard to do more. This includes reducing the noise pollution and being more responsive to the community by implementing more mitigation efforts such as moving the gate from opposite the more densely populated area and schools, using more “clean” engines on site and creating more green barriers to help shield community from the pollution.

While the direct measurement of respiratory health is an important addition to previous modeled research, our study is correlational in nature and clear causality cannot be established. We cannot exclude the possibility that the lack of statistical significance for the findings for our adult study population may simply be the reflection of insufficient statistical power. Further research is warranted with follow-up studies assessing individual level exposures and the long-term health risks associated with chronic exposure in order to confirm/disprove the associations suggested by our analyses.

Under complex scenarios at the interface of science and policy, such as the one concerning the ENRRICH Project, the criteria for practical action do not always match the scientific opinion or consensus on causality. In the spirit of prevention, public health authorities are faced with the difficult task of determining, given the available evidence, if the exposure is sufficiently widespread and the health consequences serious. Notwithstanding its methodological limitations, we believe that the public health implication of our investigation is that residents near major goods movement hubs should be protected from potentially damaging exposures.

INTRODUCTION

Freight logistics systems are considered a vital, and generally beneficial, component of modern societies [1]. The goods movement system in the United States includes a complex network of transportation and logistics segments, of which the rail sector is a fundamental backbone. The overall impacts of the steady growth of international trade and the accompanying nationwide movement of goods are generally seen as positive on the national level because they are thought to promote better access to employment opportunities and cheaper goods and services. Positive impacts are anticipated at many U.S. Atlantic and Pacific port regions as the economy recovers and the pace of global trade picks up speed. However, such benefits should not obscure the potential for undesired consequences. For example, the experience of the communities bordering a goods-movement corridor can be quite different from the general population, but society has paid relatively little attention to possible health threats and other impacts to the communities crisscrossed by the goods movement network. Traditionally, the transportation sector has referred to impacts such as decreasing property values, physical fragmentation of neighborhoods, and even negative health effects as “externalities.” For example, while on a per-ton-mile basis the efficiency and environmental benefits of railways in the long-range transportation of goods are undeniable, current technical analyses produced by transportation experts exclude societal impacts and do not account for either onsite movements or intermodal operations [2-4].

Public health scientists are beginning to point to the way in which goods and services are accessed and distributed and various societal, environmental, and health impacts. Conceivably, the transportation of goods can both promote and damage health. A community’s health can be enhanced, for example, if transportation activities enable access to jobs and better services. However, goods movement can be health damaging because of impacts such as air pollution, climate change, injuries, noise, stress and anxiety, segregation, loss of land, and blight that can burden local communities. According to Liam Donaldson, Chief Medical Officer for the United Kingdom from 1998 to 2010, "the causes of ill health, the solutions to some of our major health problems and the sustainability of our environment are intricately interwoven with the way that we move from place to place both locally and across the globe. The scope of any analysis in this area of public health also needs to encompass the way that goods and services are accessed and the ways that groups of people gather" [5].

The prospect that local residents who live near ports, railyards, distribution centers, and along high-traffic corridors could be disproportionally impacted by ambient air pollution prompted the State of California to implement emission reduction strategies specifically focused on goods movement [6]. An added concern is that in California, a higher percentage of residents who are from minority or low-income households live near transportation corridors and hubs [7]. Greater exposures resulting from higher levels of ambient air pollutants associated with the goods movement network may contribute to enhanced vulnerability [8-10]. Moreover, low-income, minority families are likely to experience psychosocial stress as they often focus on day-to-day survival, with incipient evidence suggesting that children from stressed households are even more susceptible to the respiratory health effects of transportation-related pollution [11, 12]. Thus, public health concerns may be compounded by worrisome environmental justice challenges.

Current California Air Resources Board (CARB) guidelines recommend avoiding construction of new schools and residential housing within a mile of a railyard facility. In 2003, the California Legislature passed SB 352, which requires that a school district verify that any railyard within a quarter mile of a new school will not present a public health threat. However, decades ago when residential areas and schools were first built, little was known about the health effects of air pollution, and the nearby roadways, rail lines and facilities were not nearly as busy as they are today. Out of concern that residents who live near major freight hubs may experience disproportionate, cumulative health impacts, a Statewide Railroad Pollution Reduction Agreement (SRPRA) was established between CARB and the rail companies operating in California.[i]

Under the SRPRA, CARB conducted a series of risk assessments of the major railyards in the State following the framework established by the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA). Out of the 18 railyards assessed, the Burlington Northern and Santa Fe Railway Company (BNSF) San Bernardino Railyard (SBR) ranked 5th in California in terms of diesel emissions and 1st in projected community health risk [13]. Concerns about significant health impacts are not unreasonable since this busy facility is in very close proximity to residential neighborhoods and other sensitive receptors such as day care facilities and schools.

The CARB's Health Risk Assessment (HRA) Report on the SBR prompted significant community response and based on several community meetings, many residents were concerned about possible negative health effects , but no actual health *outcome* studies (as opposed to studies that model *impact*) at that time had been conducted to quantify and isolate those impacts and correlate them with emissions. Individual residents and community groups requested action from the City of San Bernardino Mayor's office, community leaders, and researchers from the Loma Linda University School of Public Health to investigate these issues further, with the idea that study results could point the way to mitigation strategies. In response, the City of San Bernardino has worked with community groups and BNSF to identify mitigation measures that could lessen the impact of air pollution caused, directly or indirectly, from the operations of the SBR. However, the City does not possess any direct regulatory influence on the railroads; only the Federal government has jurisdiction over the railroads via the Interstate Commerce clause of the U.S. Constitution.

The health impacts advanced in the HRA Report were not based on health data on specific individuals of the local community. This lack of available information on the actual exposures and disease burden experienced by the local residents limits the opportunities for policy changes since the possibility of adverse health effects is often dismissed due to the indirect nature of the evidence. While a neighborhood-level

[i] For the full text of the agreement: http://www.arb.ca.gov/railyard/ryagreement/ryagreement.htm.

ambient air monitoring study was recently conducted by UCLA scientists to more closely characterize chemically and toxicologically ambient air pollution near the SBR, no formal investigations existed before 2011 on the potential for adverse health outcomes among nearby residents.

Purpose

In response to the need for primary health data for the communities near the SBR, scientists from the Loma Linda University (LLU) School of Public Health (SPH) developed a research and community engagement initiative, the *Environmental Railyard Research Impacting Community Health (ENRRICH) Project.* The overall goal of Project ENRRICH was to characterize the community health burden in the residential areas near the BNSF SBR. Specifically, the fundamental question examined was whether there is a relationship between adverse health effects for residents and proximity to the BNSF SBR. Adopting a community-based participatory research (CBPR) approach, Project ENRRICH represents one of the first public health investigations into the concerns that communities near a goods movement intermodal railyard may face greater cumulative impacts from pollutants.

Health Issues of Concern−Current Research Evidence

The dominant toxic air contaminant associated with the SBR facility is diesel exhaust, a primary contributor to fine particulate matter (PM) concentrations in transport-affected communities. The diesel PM particles are very small, and by mass, are largely dominated by sizes less than 2.5 microns in diameter ($PM_{2.5}$). Because of their small size, diesel PM particles are readily respirable and can penetrate deep into the lungs and enter systemic circulation, carrying with them an array of toxins. Exposure to diesel PM is a health hazard, particularly to sensitive individuals, children (whose lungs are still developing), and the elderly, who may have other serious health problems.

It has been shown that fine particles present in high concentrations near busy roads can elicit oxidative and nitrosative stress in the airways, leading to inflammation, and they have also been correlated with the amount of carbon in the airway macrophages of children, which is in turn associated with impaired lung function [14]. Recent experimental evidence indicates that diesel exhaust particles in the lung aggravate acute renal failure in rats and exacerbate oxidative stress in human embryonic kidney cells[15, 16].

Numerous studies have associated fine PM with a variety of respiratory and cardiovascular problems, such as increased hospitalizations for cardio-respiratory causes, aggravated asthma, other lower respiratory symptoms, acute bronchitis, irregular heartbeat, heart attacks, and premature death in people with heart or lung disease [17-22]. Li et al. have demonstrated that ultrafine particles from incomplete combustion of engine fuels and lubricating oils can bypass the body's defense mechanisms, gain entry to cells and tissues, and alter or disrupt normal cellular function [23]. There are also concerns about the cancer-causing potential of diesel exhaust based on findings from occupational studies. Silverman and Samanic found an increased risk of death from lung cancer in exposed underground miners [24]. In 2012, the International Agency for Research on Cancer (IARC) classified diesel engine exhaust as Group 1, or carcinogenic to humans, based on sufficient evidence that exposure is associated with an increased risk for lung cancer.

Epidemiologic evidence is gradually mounting on the adverse health effects associated with proximity to transportation facilities and roadways [17-22, 25]. Gauderman et al. have shown that children living near freeway traffic had substantial deficits in lung function development between the ages of 10 and 18 years, compared with children living farther away [26]. Other recent studies have linked traffic exposure to increased risk of low birth weight and premature birth [27]. There seems to be consistent evidence that living near traffic sources is associated with asthma occurrence and exacerbations have reported that adults with asthma who spent 2 hours walking on a street with heavy diesel traffic suffered acute transient effects on their lung function along with an increase in biomarkers that indicate lung and airway inflammation [28, 29]. A German study reports that adults who live for years in close proximity to high volumes of traffic are more likely to develop hardening of the arteries [30]. Recent evidence indicates that in addition to regional air pollution, local exposure to roadways is associated with serious respiratory health effects [26]. For instance, in a study of respiratory diseases among children and the association between exposure to $PM_{2.5}$ and several of its chemical species and hospital admissions researchers found that elemental carbon (a chemical tracer of diesel exhaust) exhibited one of the strongest associations with acute bronchitis, pneumonia, and asthma [31]. This suggests that even in relatively clean areas, children living near major traffic sources are at increased risk, and it also implies that children who live near traffic in a high pollution region experience a combination of both local and regional pollution. This is precisely the case for children living near the SBR, who in addition to high regional levels of air pollution are likely exposed to railyard as well as nearby freeway diesel emissions.

It has been suggested that disadvantaged populations under chronic psychosocial stress may experience greater susceptibility to environmental hazards [32]. In our target community, San Bernardino, 27.6% of residents live below the poverty line and FBI crime statistics report a per capita violent crime rate that is nearly 2.5 times the national average. This regional “double jeopardy” makes it possible to evaluate the interaction of nonchemical and pollution-related stressors in the pathophysiology of disease in this population. Recent data support this strongly. For instance, it has become clear that asthma is a socially patterned disease based on demographic and socioeconomic indicators clustered by areas of residence [33]. In the US, this disease disproportionately affects minority children living in urban areas and children living in poverty [34]. However, the variation in asthma morbidity across urban neighborhoods cannot be explained by socioeconomic factors alone. Specific community characteristics, such as rates of violent crime, are strongly associated with asthma symptoms [33, 35, 36]. In addition, individual-level psychosocial stress is also implicated in the pathophysiology of asthma [37]. Although both nonchemical and chemical exposures have been independently associated with inflammatory lung disease, their combined interactions have only begun to be evaluated [38-42].

Overview of Report

This report presents the findings from research and community engagement activities conducted under Project ENRRICH funded in 2011 by the BP/South Coast Air Quality Management District (AQMD), Public Benefits Oversight Committee. ENRRICH was aimed at 1) the promotion of partnerships between community members and researchers, and 2) the establishment of objective, baseline information about the prevalence of adverse health effects among residents in areas surrounding the SBR in west San Bernardino. The resulting data can be used to inform a community response to current railyard-related emissions and the resulting environmental impact challenges, including intervention development and organizing toward health ameliorating policy changes.

CHAPTER 1. STUDY AREA AND SETTING

Globalization and international trade have dramatically changed southern California, which has increasingly become a distribution economy. Over 40% of the containerized cargo entering the U.S. flows through the San Pedro Bay ports. Most of it is shipped through some of southern California's poorest neighborhoods on trucks and trains to "inland ports"[ii] for distribution throughout the U.S. heartland.

Since the 1990s, San Bernardino and its immediately surrounding areas in inland Southern California have emerged as a wholesale and trade center for the massive Los Angeles-Long Beach port complex. Its strategic location and the presence of major rail and freeway lines have provided the area with unique surface transportation assets. The Inland Empire is now on the short list of current areas widely recognized as full-fledged "inland ports" in the U.S.[iii] Millions of cargo containers on diesel-powered locomotives and trucks take several rail and freeway routes through southern California to the inland ports, most notably the SBR, from which they are distributed to the rest of the country (**Figure 1-1**). With operations running 24/7, there are between 12-14 intermodal long chain trains that enter or exit the railyard daily, with nearly 500,000 lift operations occurring annually at the facility.

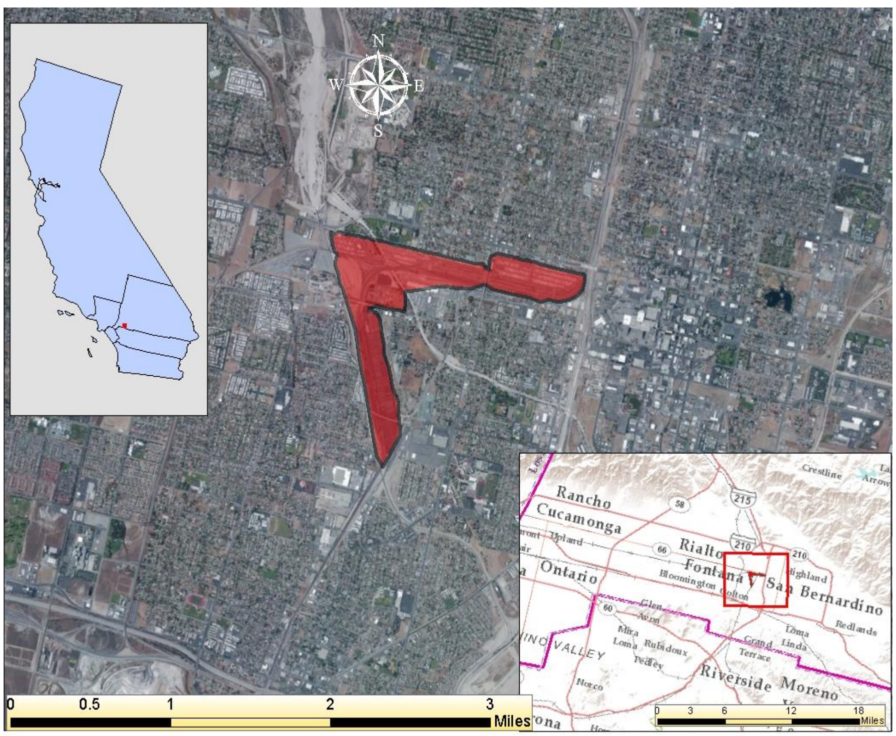

FIGURE 1-1. LOCATOR STATE AND REGIONAL MAPS OF THE BNSF SAN BERNARDINO RAILYARD IN SOUTHWESTERN SAN BERNARDINO COUNTY IN INLAND SOUTHERN CALIFORNIA

The expansion of the logistics sector, coupled with rapid industrialization, have propitiated overall economic growth but have also affected the immediate surrounding areas, which are increasingly plagued with high indices of urban poverty, deprivation, and health

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[ii] Inland ports are intermodal logistics hubs connected directly to major maritime ports and are designed to efficiently move international shipments from seaports into inland locations. Inland ports are becoming a critical link in the global supply chain as international trade volume rises.

[iii] The other inland ports in the U.S. are Dallas/Fort Worth, Houston, Chicago, Kansas City, St Louis, Atlanta, Memphis, Columbus, and Charlotte.

disparities, a prime example of which is the west side of the City of San Bernardino, where the SBR is located.

San Bernardino County is located in what is often referred to as the *Third California*, a term used by the Brookings Institution to describe the disparities in health outcomes and economic growth between sub-regions in California [43]. Metro San Bernardino epitomizes the Third California, characterized by dynamic demographic growth—the Inland Empire is the largest and fastest growing metro area in the state—while facing severe problems with pollution, growing congestion, out-migration, racial stratification, and industrial decline. It is one of the most underfunded regions in the state, overshadowed by nearby metropolitan Los Angeles to the west. San Bernardino County has a density of only 102 people per square mile, yet a metropolitan population of more than 2 million. The median age is 32 years, with nearly one third of residents below 18 years of age. It "boasts" the third largest number of gang members in the United States, after Los Angeles and Chicago. The unemployment rate is one of the highest in the country, and he per capita income is less than $30,000 and dropping. High school graduation rates are low and less than one fourth of graduating high school seniors is eligible to enter college. The death rate for children under 5 is one of the highest in California. More than 60 percent of students live in low-income housing and are eligible for subsidized meals. The rate of obesity has increased 26 percent in 4 years, with 36 percent of the population considered overweight (20 percent above ideal) and 32 percent obese (30 percent above ideal weight). This has led to a marked increase in diabetes of 47 percent over the past 5 years, now totaling 10.6 percent of all adults. San Bernardino has one of the worse rates of cardiovascular disease and respiratory cancer in the state and the nation [44]. Southwestern San Bernardino County is also notorious for having some of the highest levels of ambient air pollution in the nation.

San Bernardino and the surrounding areas are considered a “hot zone” for economic development due to its swaths of underdeveloped land, cheaper housing, and relatively inexpensive workforce; thus overall income and other SES levels are lower than those in many other major California counties. Latinos, including undocumented migrant workers, accounted for up to 53% of the county’s population in 2007. Due to the recent immigrant status of many Latinos, one-third of all children of immigrants younger than 6 years old live in “linguistically isolated” homes, in which all persons over 14 years of age have limited English skills. Limited English ability is strongly associated with poverty, food insecurity, and environmental inequity. It also leads to difficulty navigating schools, the health care system, and other services, making Latinos an extremely vulnerable and often overlooked population with respect to environmental justice issues. Available health outcomes data suggest tremendous health disparities between the region’s African Americans and Latinos and the Caucasian population. While the county’s poverty rate is 15.8%, the rate for Latinos stands at 34.9%. This far exceeds the overall poverty rate for the nation, 12.4%, and for the state, which stands at 14.2%. It even exceeds California’s Latino poverty rate of 28% [45]. San Bernardino is one of the area’s poorest municipalities, with a disproportionate number of neighborhoods facing a host of economic, educational, health, and environmental challenges and more recently, the bankruptcy of the city government itself.

The exposure setting specific to the SBR railyard is complex, with many densely populated areas surrounding the facility and with sensitive receptors in close proximity, including schools, daycare centers, nursing homes, and hospitals. According to the CARB's HRA report, the diesel PM emissions from the SBR within 1 mile of the facility are estimated at about 22 tons per year, which represent 66% of the total (i.e., on-site and off-site emissions combined). The concentration of diesel PM and associated carcinogenic risk shows a distinct gradient away from the facility shaped by site-specific topographic and meteorological conditions. **Figure 1-2** shows the SBR and the isopleths that define the risk zones associated with on-site diesel emissions. Near the property boundaries, the estimated excess cancer risk is generally above 500 in a million (assuming a 70-year lifetime exposure duration), with a corresponding exposed population of 4,000 people. The point of maximum impact (PMI, i.e., the location with the highest excess cancer risk level based on the highest diesel PM concentration estimated from the modeling results outside the SBR) is about 3,300 in a million (based on a 70-year lifetime exposure duration), predicted to be along the "A" yard fence line on the north side of the railyard's west intermodal area. The estimated high level of the PMI is primarily due to the density of emission sources near the west intermodal area, where land use is a mix of industrial and dense residential. In the residential area, the maximum individual cancer risk (MICR, or the "potential cancer risk for the maximally exposed individual resident"), which is predicted to occur in close proximity to the PMI, is estimated at about 2,500 chances per million. However, the PMI and MICR indicators are for comparative purposes and should not be interpreted as a literal prediction of cancer incidence.

FIGURE 1-2. ESTIMATED REGIONAL CANCER RISK (CHANCES PER MILLION) FROM THE BNSF SAN BERNARDINO RAILYARD DISPLAYED AS WHITE ISOPLETHS (FROM REFERENCE 13)

It is important to understand that these risk levels represent the potential cancer risks in addition to the regional background risk from diesel PM emissions. To put it in perspective, the estimated regional background risk level in the entire L.A. basin is 1,000 excess cancer cases per million caused by all toxic air pollutants [13]. Therefore, residents living near the MICR location would have a potential cancer risk of about 3,500 in a million (based on an exposure of 70 years). At about 2.5 miles from the SBR, as the diesel PM concentration is projected to decrease, the risk is predicted to drop to about 25 excess cancer cases per million. Finally, further away from this cancer risk zone, risk assessors identified an area where risk is estimated to be 10 chances in a million (corresponding to the 10 isopleth line on **Figure 1-2**). The overall *railyard impact zone* (RIZ) with an estimated risk above 10 chances in a million (i.e., as delineated by the 10 isopleth risk line in **Figure 1-2**), encompasses approximately 62,000 acres where about 340,000 residents live, based on data from the 2000 U.S. Census Bureau. For this same impact area, we have estimated that nearly 16,000 babies are born annually, based on California Vital Statistics data for the years 2004-2008.

CHAPTER 2. POPULATION-BASED CANCER ASSESSMENT

The Health Risk Assessment (HRA) conducted by CARB for the SBR followed *The Air Toxics Hot Spots Program Risk Assessment Guidelines* published by the California EPA's Office of Environmental Health Hazard Assessment.[iv] The characterization of potential cancer risk in the HRA is based on the railyard-specific emission inventory and air dispersion modeling predictions. In the HRA, mathematical models, together with available toxicity information, were used to estimate potential long-term cancer risk. The HRA did not gather information on specific individuals, but represents an estimate for the potential cancer risk on the population at large near the SBR. The potential cancer risk from a given carcinogen is expressed as the incremental number of cancer cases that could develop per million people, assuming the population is exposed to the carcinogen at a constant annual average concentration over a presumed 70-year lifetime. This risk corresponds with the epidemiologic measure known as excess risk, rather than relative risk, and is not expressed in direct correspondence to any specific cancer type but to overall cancer risk.

We assessed through analyses of California Cancer Registry (CCR) data whether there is an excess in the observed number of new and fatal cancer cases during the 1999 through 2008 time period that could be attributable to diesel smoke and other airborne emissions. For this, we limited analyses to within a theoretical impact area demarcated by a set of census tracts (CTs) surrounding the SBR. On an east/west direction, the investigated CTs are all contained within the area where risk is estimated to be 25 chances in a million (corresponding to the 25 isopleth on **Figure 1-2**). On a north/south direction, the set of CTs is contained within area where cancer risk is estimated to be 50 chances in a million (the 50 isopleth line on **Figure 1-2**). To follow the reporting approach in the HRA, we present results on outcomes for all cancers combined (overall cancer risk) as well as for specific cancer types.

2.1 Background and Justification for Cancer Data Analyses

The San Bernardino Mountains form a natural barrier that channels and traps air pollutants in the San Bernardino Valley [46] surrounding the City of San Bernardino. The hot, dry Santa Ana winds that are common in the autumn and winter months combine with intensive sunshine consistent with the southern latitude to produce a Mediterranean Dry climate zone [46]. The seasonal Santa Ana winds clear the air in the greater San Bernardino area, blowing local smog toward the Pacific coastline [47]. However, during the typical warm and sunny summers, an absence of natural scavenging processes, like rain, and prevailing on-shore breezes coming from the ocean through the Los Angeles metro area contribute to the formation and accumulation of smog and ozone in the region. A higher elevation inversion layer tends to keep lower elevation air pollution layers near the surface, contributing to the accumulation of pollutants in the San Bernardino Valley [48].

[iv] See: OEHHA, 2003. Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments. Office of Environmental Health Hazard Assessment. August, 2003.

In addition to the inversion layer and polluted air that migrates from the Los Angeles basin, there are numerous local air pollution sources in the Inland Empire, including pollution from the dense population and numerous freeway and highway systems. The unique topographic and meteorological characteristics and abundance of air pollution sources combine to create the unique conditions which result in San Bernardino being among the worst air pollution areas in the United States (US). Adding to air pollution in the San Bernardino Valley is the BNSF railyard, located in the heart of the City of San Bernardino. The BNSF encompasses an area of approximately 168 acres and is located mainly in a commercial manufacturing area of San Bernardino that is surrounded by private residences. Some homes are as close as 200 feet to the BNSF facility.

About 40 percent of all goods that the U.S receives in overseas shipments enters through seaports in Los Angeles and Long Beach, with much of this freight moved overland to retailers across the country by the BNSF [49]. In addition to the obvious national, statewide, and regional economic benefits provided by the low cost transport of goods throughout the U.S., the San Bernardino BNSF facility is one of 18 California railyards deemed a “risk to public health” by the California Air Resources Board (CARB). CARB ranks the San Bernardino BNSF railyard as the leading contributor to excess carcinogenic risk resulting from air pollution [13].

Concerns about the potential carcinogenic risk posed by the San Bernardino BNSF facility have been raised by air quality regulatory agencies, county and local authorities in San Bernardino and residents living near the facility. While initially the jobs created by the BNSF facility have supported economic growth in the area and were instrumental to the formation and continued viability of San Bernardino, currently few jobs at the railyard are actually held by residents living near the San Bernardino BNSF facility and for some of them any direct economic benefits are countered by higher air and noise pollution levels endured by those.

Some studies have identified increased risk of lung cancer in city dwellers [50, 51], exposed to diesel exhaust, attributing this association to urban air pollution, while other scientists note that urban residence frequently predicts higher tobacco use [52, 53], the principle risk factor for lung and numerous other cancer types. Though it is unethical to conduct high-dose exposure studies in humans, animal studies have provided direct evidence of a carcinogenic effect of high-dose diesel exhaust exposure [54, 55].

Epidemiologic investigations of the relationship between diesel exhaust and cancer are challenged by indirect exposure assessments and have encountered difficulty when attempting to distinguish the consequence of diesel exposure from other, confounding factors, including tobacco use [54]. Ensuring an abundance of caution, the U.S. National Toxicology Program classifies diesel exhaust particulate exposure as “reasonably anticipated” [56] to be a human carcinogen and the U.S. Environmental Protection Agency ranks diesel exhaust as “likely” to be carcinogenic in humans [57].

The main route of human exposure to diesel exhaust is through inhalation; about 10 percent of the diesel particles trapped in airways are deposited in the alveolar region of the lung [57], in the tissue where the majority of glandular lung cancer arises. Predictive models of the deposition of inhaled diesel exhaust particles in humans are based on research conducted in laboratory animals, considering particle and airway size, concentration, and exposure duration [57]. Although the mechanism through which diesel exhaust may cause malignancies in humans is not established, it is reasonable to presume that carcinogenic effects could be related to the small size of diesel exhaust particles, combined with the genotoxicity of highly reactive polycyclic-aromatic hydrocarbons in diesel exhaust that condenses in respiratory airways. Another proposed mechanism of carcinogenesis involves inflammatory processes that lead to increased hyper-, meta-, and dysplastic changes in respiratory tissue [57, 58].

The HRA conducted in the area surrounding the SBR used average annual air pollution emissions, air dispersion modeling, and assumptions about health risks associated with diesel PM pollution [13]. Following OEHHA guidelines, this assessment estimated the potential cancer risk by using a diesel PM cancer potency factor of 1.1 per mg/kg-day. This cancer potency factor was derived by the OEHHA for PM from diesel-fuel engines and was based on a review and meta-analysis of over 30 epidemiological studies of occupational exposure to diesel exhaust and lung cancer.[v] The exposure assumption is of continuous exposure to the diesel emissions that a human would receive from living in the vicinity of the SBR facility for a lifetime (70 years). Using this methodology, the investigators concluded that approximately 2,500 to 3,300 excess new cancers would occur per million persons receiving a lifetime exposure to excess air pollutants emitted by the BNFS facility along the north yard fence line [13]. Risk was modeled to drop to 10 excess cancer cases at about 5 miles from the railyard.

The community cancer assessment component of the ENRRICH research project, funded by the South Coast AQMD, used secondary data from the California Cancer Registry (CCR) [59] to determine whether an excess in the number of new cancers occurred among residents of the area surrounding the SBR from 1996-2008. CCR is the mandated, statewide cancer surveillance system that serves approximately 37 million California residents. The Desert Sierra Cancer Surveillance Program (DSCSP), also known as Region 5 of the CCR, is the regional division of the CCR, serves the approximately 4.1 million residents of Inyo, Mono, Riverside, and San Bernardino counties, adding approximately 14,000 new cancers per year [59].

The general objective of the cancer analyses sub-study was to evaluate all and site-specific cancer occurrence against expected counts for invasive cancers combined for the collection of 16 contiguous San Bernardino County Year 2000 Census tracts surrounding the BNSF railyard. Detailed objectives included assessment of three hierarchal air pollution exposure areas modeled on excess diesel exhaust emissions from the BNSF railyard as railyard- high, moderate, and low excess air pollution areas.

[v] For a description of how the diesel PM cancer potency was derived and the diesel exposure studies that were reviewed: OEHHA, 2002. Air Toxics Hot Spot Program Risk Assessment Guidelines: Part II-Technical Support Document for Describing Available Cancer Potency Factors. Office of Environmental Health Hazard Assessment. December, 2002.

2.2 Methods

We conducted a non-concurrent cohort study by extracting annual counts of observed new cancers for 1996-2008 in the study area from the CCR confidential database for all invasive cancers combined [59, 60]. Observed new cases were identified by residence address at diagnosis in 16 contiguous San Bernardino County Year 2000 census tracts surrounding the BNSF railyard in the City of San Bernardino. Tracts were classified into each of three BNSF HRA report exposure zones as railyard- high, moderate and low, with each representing higher exposure to diesel emissions than the standard (DSCSP) population.

Within each exposure area, individuals were classified using age- (<1, 1-4, 5-9, 10-14,….80-84, and 85+ years), sex-, and race/ethnicity- (Asian/other, Hispanic, non-Hispanic Black and non-Hispanic White) specific mutually exclusive categories [59]. The Asian/other classification included persons recorded as Pacific Islander, Native American (American Indian), Native Alaskan, mixed race, unknown race or ethnicity, or members of racial groups not included in any of the other three race/ethnicity categories. Persons listed as Black, White, or race unknown on a death certificate or medical record having a Hispanic surname were categorized as Hispanic, while persons listed as Black, African, or African American not having Hispanic surnames were classified as non-Hispanic Black. Similarly, persons listed as White or Caucasian in medical records, not having a Hispanic surname, were classified as non-Hispanic White.

Cases reported in the DSCSP database for 1996-2008 included approximately 100 percent of counts projected for the area population [59]. Expected numbers of new cases were computed for each of the census tracts in the study using average annual cancer incidence proportions (rates) for 1998-2002 in the DSCSP and the demographic characteristics for each census tract reported in Census 2000. Year 2000 Census and post-2000 Census population estimates [61, 62] were used to adjust expected counts for population change during non-census years using a fitted linear regression equation, interpolating annual population estimates for each year during the study period. These methods allow adjustment for change in population size during the study period. Findings compare observed and expected numbers of new cancers for the entire study population and within each of the three homogeneous exposure areas, adjusting for variations in age, sex, SES, race/ethnicity, and population size distributions, and for changes in population size during the study period [63]. Unique demographic features of population subsets residing in each of the exposure areas also provided the opportunity to evaluate the effects of tobacco use on cancer occurrence [64].

Similar demographic categories were used to define the observed counts and DSCSP incidence rate denominators (1998-2002), with population count detail obtained from the National Center for Health Statistics, bridged population estimates for 1990-1999 and 2000-2010 [61, 62]. Average annual Year 2000 incidence rates were computed by dividing new cancer counts in the DSCSP for 1998-2002 in each of the 152 unique demographic categories by corresponding DSCSP denominators. Demographic factor-specific, average annual rates were multiplied by the proportional distribution of the population residing within each the 16 census tracts for each of the 152 demographic factor-specific (19 age, 2 sex, and 4 race/ethnicity) categories [65]. These expected annual cancer rates were multiplied by the size of the Year 2000 population residing in each of the census tracts, yielding expected counts for each tract during Year 2000. Census tract-specific expected counts for Year 2000 were weighted by the proportion of the Year 2000 population for each year from1996-2008, with these counts summed for the 13 year study period to form age, sex, race/ethnicity, and population size adjusted expected counts for each of the 16 census tracts during the 13 year study period [63].

Collectively, these standard analytical methods and the CCR data were used to compute standardized incidence ratios (SIR) for all cancer types combined by dividing the observed number of new cancer cases for each tract or collection of tracts by the age-adjusted, race/ethnicity-specific or adjusted, population size-adjusted, and sex-specific or combined expected counts for the same census tract or collections of tracts. Ninety-five percent confidence interval limits (95% CI) for observed counts were computed using an equation based on the Poisson distribution [65]. Data analyses were conducted using SEER* Stat [66] , Microsoft Excel, and SAS version 9.2 software [67].

Railyard- high, moderate, and low exposure categories were defined by incorporating into our analysis the spatial output (**Figure. 1-2**) presented in the HRA, which was derived in turn from the U.S. Environmental Protection Agency's **A**merican Meteorological Society/**E**PA **R**egulatory **MOD**el (AERMOD) [68]. This air dispersion model assumes a steady-state plume and is based on mathematical relationships that incorporate air dispersion characteristics established for planetary boundary layer turbulence, structure and scaling concepts, surface and elevation characteristics, and both simple and complex terrain features [13]. The emission sources from locomotives and other diesel particulate matter (PM) sources at the BNSF San Bernardino Railyard were considered as the '*source types*' in the dispersion modeling.

Using GIS techniques, isopleths were converted into a polygon layer. Each polygon in this layer was used to model a "homogeneous" exposure zone and was assigned a proxy "exposure" score calculated as the average of the cancer risk levels of the bounding isopleths (**Figure 1-2**). For example, the risk polygon delineated by isopleths 10 and 25 received an exposure score of 17.5, etc. The 500-risk zone is defined by a single isopleth (**Figure 1-2**) and therefore the corresponding polygon received an exposure score of 500.

The risk polygons were next overlaid with Year 2000 CT boundary maps used to distinguish the excess air pollution exposure areas associated with the BNFS facility. The overlay procedure results in the splitting of the CTs, with each new polygon representing a unique CT-exposure combination. Next, using this new polygon layer, a set of area weights was developed based on the proportion of a tract covered by the various exposure zones. Each weight was calculated as the ratio of the areal extent of a given polygon to the area of the parent CT. Each CT then received a final value corresponding to an area-weighted CT-wide average exposure score. Finally, we applied a clustering method to classify the CTs into exposure groups from the area-weighted exposure scores.

We employed a *Natural Breaks* method, based on the Jenk's mathematical algorithm, available from the ArcGIS software (Esri, Redlands, California), which implements repeated sampling and resampling to identify natural groupings in an empirical dataset [68]. Through this approach we identified three exposure areas: the highest impact region (high excess exposure area), and two outlying "rings" (moderate and low excess exposure areas) surrounding the highest exposure zone. The map in **Figure 2-1** depicts the railyard and surrounding Census tracts color-coded according to this exposure level. The "high" exposure area included tracts 4800 and 4900. The "moderate" exposure area included tracts 4300, 4700, 5600, 5700, and 6700. The "low" exposure area consisted of tracts 4201, 4202, 4401, 4402, 5000, 5900, 6600, 6800, and 7000.

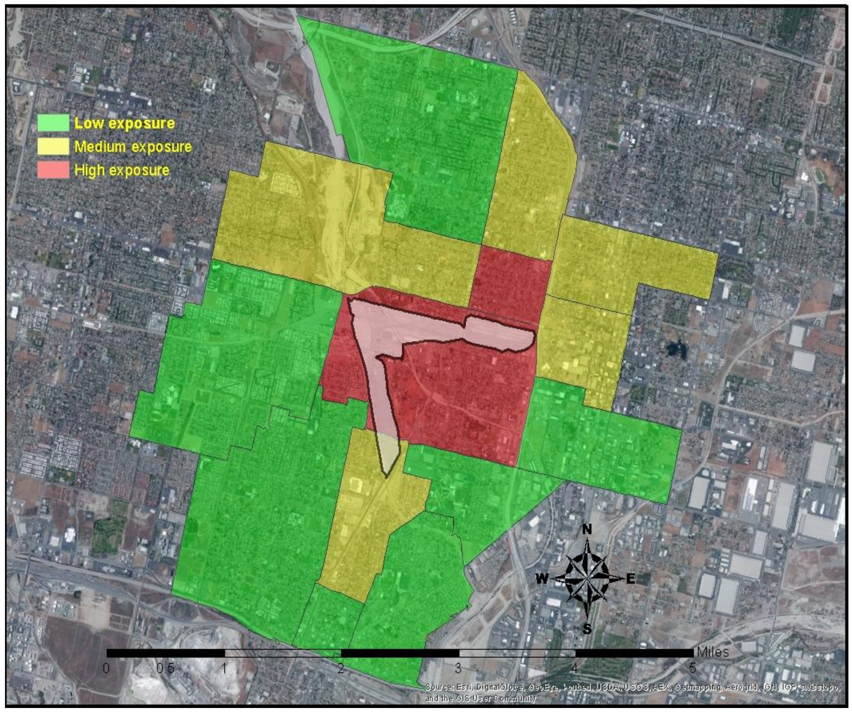

FIGURE 2-1. MAP OF THE SAN BERNARDINO RAILYARD (WEDGE-LIKE SHAPE IN THE CENTER) AND ADJACENT CENSUS TRACTS USED IN THE CANCER ASSESSMENT. CENSUS TRACTS ARE COLOR CODED ACCORDING TO THE MODELED DOSE-RELATED RELATED RAILYARD EMISSION EXPOSURE LEVELS: LOW (GREEN), MEDIUM (YELLOW), AND HIGH (RED).

2.3 Results

2.3.1 All Cancer Sites Combined

Population counts, percentages, and global statistical significance tests with descriptive findings for each of the demographic characteristics in the railyard-high, railyard-moderate, and railyard-low excess exposure areas; all 16 census tracts combined; and the DSCSP are provided in **Table 2-1**. Almost 12% of the railyard study population lived in the railyard-high exposure area, with 25,247 (30.6%) and 47,552 (57.6%) living in railyard- moderate and railyard-low exposure areas, respectively. The standard population of the DSCSP included 3,284,175 residents. Marked differences are seen for the age- and race/ethnicity-distributions for each of the railyard exposure area populations compared with each other and the DSCSP standard population. Each of the railyard exposure populations exhibited a younger age-distribution than the DSCSP.

TABLE 2-1. AGE, SEX, RACE/ETHNICITY†, AND SOCIOECONOMIC STATUS (SES) DISTRIBUTION IN RAILYARD HIGH, MODERATE, AND LOW EXPOSURE AREAS, AND ALL RAILYARD EXPOSURE AREAS COMBINED, COMPARED TO THE DSCSP IN 2000. DATA ARE FROM THE CALIFORNIA CANCER REGISTRY.

Demographic Variables	Railyard High		Railyard Moderate		Railyard Low		All 16 Census Tracts Combined		DSCSP	
Age	Count	%	Count	%	Count	%	Count	%	Count	%
0-19	4,309	44.19%	10,233	**40.53%**	19,309	**40.61%**	33,851	**41.01%**	1,128,960	**34.38%**
20-39	3,043	**31.20%**	7,222	**28.61%**	13,579	**28.56%**	23,844	**28.88%**	935,222	**28.48%**
40-49	1,082	**11.10%**	2,957	**11.71%**	5,760	**12.11%**	9,799	**11.87%**	465,724	**14.18%**
50-74	1,059	**10.86%**	3,781	**14.98%**	7,148	**15.03%**	11,988	**14.52%**	594,309	**18.10%**
75+	259	**2.66%**	1,054	**4.17%**	1,757	**3.69%**	3,070	**3.72%**	159,960	**4.87%**
	p<0.001		p<0.001		p<0.001		p<0.001		Reference	
Sex										
Males	4,939	**50.65%**	12,529	**49.63%**	23,264	**48.92%**	40,732	**49.34%**	1,637,056	**49.85%**
Females	4,813	**49.35%**	12,718	**50.37%**	24,289	**51.08%**	41,820	**50.66%**	1,647,119	**50.15%**
	p=0.11		p=0.48		p<0.001		p=0.004		Reference	
Race/Ethnicity										
A/O	226	**2.32%**	968	**3.83%**	2,520	**5.30%**	3,714	**4.50%**	245,126	**7.46%**
NHB	607	**6.22%**	3,610	**14.30%**	7,004	**14.73%**	11,221	**13.59%**	242,236	**7.38%**
Hisp	8,182	**83.90%**	17,990	**71.26%**	30,851	**64.88%**	57,023	**69.08%**	1,233,214	**37.55%**
NHW	737	**7.56%**	2,679	**10.61%**	7,178	**15.09%**	10,594	**12.83%**	1,563,599	**47.61%**
	p<0.001		p<0.001		p<0.001		p<0.001		Reference	
SES										
1 Lowest	9,752	**100%**	25,247	**100%**	43,853	**92.22%**	78,852	**95.52%**	872,292	**26.56%**
2	0	-	0	-	3,700	**7.78%**	3,700	**4.48%**	981,579	**29.89%**
3	0	-	0	-	0	-	0	-	764,684	**23.28%**
4	0	-	0	-	0	-	0	-	506,135	**15.41%**
5 Highest	0	-	0	-	0	-	0	-	159,485	**4.86%**
	-		-		p‡<0.001		p‡<0.001		Reference	
Total	**9,752**	**100%**	**25,247**	**100%**	**47,553**	**100%**	**82,552**	**100%**	**3,284,175**	**100%**

† A/O signifies Asian/other, NHB is non-Hispanic Black, Hisp is Hispanic, and NHW is non-Hispanic White race/ethnicity
‡ P signifies the probability from the X^2 for independence test for rows minus 1 degrees of freedom contrasting findings for railyard exposure categories with the DSCSP.

Slight differences in the sex distributions were evident for the railyard high excess exposure area (50.7% male) compared to the moderate (49.6% male), low (48.9% Male), and DSCSP (49.9% male) distributions. The race/ethnicity distributions for each of the exposure areas included substantially more persons of Hispanic ethnicity than the DSCSP, with the percent of railyard excess exposure areas that were classified as Hispanic showing a stepwise increase for excess exposure area low (64.9%), moderate (71.3%), and high (83.9%), compared to the DSCSP (37.6% Hispanic). Reverse patterns were evident for each of the other race/ethnic categories in the low, moderate, and high excess air pollution exposure areas.

All census block groups in the railyard-high and moderate excess exposure areas were classified in the lowest SES quintile, while 43,853 (92.2%) residents of the railyard-low exposure population was classified in the lowest California SES quintiles. Among the 47,553 residents of the railyard-low exposure tracts, 3,700 (7.8%) lived in census block groups ranked second to the lowest SES quintile for the state (**Table 2-1**). Collectively, these findings reveal that 95.6 percent of the entire 16 census tract study population was classified in the lowest SES quintile for California, with the remainder residing in census block groups classified in the second from the lowest SES quintile.

All three railyard exposure areas exhibited higher air pollution levels than the average for the surrounding Inland Empire area and DSCSP region. In addition to the higher than average air pollution levels that combine ambient Inland Empire SMOG with high, moderate, and low excess air pollution emissions from the BNSF facility, the population surrounding the San Bernardino BNSF facility is demographically unique in terms of age, race/ethnicity, and SES characteristics. **Table 2-1** reveals that 41 percent of the 82,552 residents of the combined railyard high, moderate, and low excess exposure areas were less than age 20 years in 2000, compared to 34.3 percent in the DSCSP population. The younger age of the study population in light of the increased vulnerability inherent in growing children underscores the importance of protecting youth from the potential adverse effects of air pollution that may cumulate over a lifetime and could have detrimental consequences during early life.

Among the remarkable demographic features of the railyard exposure area population is the substantial proportion characterized by Hispanic ethnicity. As presented in **Table 2-1**, 69 percent of the combined railyard excess exposure population is Hispanic. The proportion of Hispanic residents increases from lowest to highest in the railyard low (64.9%), moderate (71.3%), and high (83.9%) railyard exposure areas.

In addition to the unique age and ethnic characteristics of the population surrounding the BNSF facility is the remarkably low SES of this population. One hundred percent of the population residing in the railyard high and moderate BNSF excess exposure areas resides in Year 2000 census block groups ranked in the lowest SES quintile for California. This compares to 26.6 percent of the DSCSP population in the lowest SES quintile. Approximately 92 percent of the railyard low excess exposure population also resides in block groups classified in the lowest SES quintile for California, with the remaining 8 percent living in the second to the lowest SES quintile block groups (**Table 2-1**). The distinctive demographic features of youth, poverty, and Hispanic ethnicity, combined with the potential for language and cultural barriers to health information, underscores the importance of safeguards that ensure the protection of this demographically unique and likely underserved segment of the San Bernardino city population.

Table 2-2 presents standardized incidence ratios (SIRs) with 95 percent confidence interval limits for SIRs depicting ratios of observed to expected new cancer cases in each of the four major race/ethnic groups. SIR findings in **Table 2-2** are presented for females, males, and sexes combined and are adjusted for the age. We found statistically elevated numbers of observed new cancers, relative to expected counts, among Hispanic and non-Hispanic White residents that represent nearly 82 percent (**Table 2-1**) of the combined railyard excess exposure area population. Disparate SIR findings for various race/ethnic groups, presented in **Table 2-2**, challenge a simple assertion that exposure to excess air pollutants from the SBR is responsible for a cancer excess in the surrounding community. It is reasonable to surmise that differences in residency and exposure duration exist for various race/ethnic groups, with recent residents having exposure durations short of the latency period between exposure and increased cancer occurrence. Assuming that the non-Hispanic Black population is largely composed of recent residents of the railyard exposure area, this conjecture could explain the null findings identified in this race/ethnic group. This argument could only explain the markedly lower observed count of new cancers measured among Asian/other residents of the railyard exposure area, compared to the adjusted expected number (**Table 2-2**), if a substantial fraction of this race/ethnic group migrated from areas having markedly lower cancer occurrence than the DSCSP.

Differences in tobacco use between race/ethnic groups could at least partly explain the markedly higher cancer occurrence among non-Hispanic White males (**Table 2-2**). Tobacco use has traditionally been highest among lower socioeconomic status White males [69]. Nevertheless, this interpretation is challenged by the absence of any excess in observed to expected cancer counts among non-Hispanic Black males, who also reside in low SES census tracts and represent the second highest [69] or highest [70] tobacco use among major race/ethnic groups in the US [69] and California [70], respectively. Findings for higher than expected observed counts for new cancers among Hispanic females and males (**Table 2-2**) may provide the strongest evidence that excess air pollution emissions from the BNSF railyard could contribute to an excess in observed cancer counts. Nevertheless, this interpretation would not explain the differences in SIR findings for race/ethnic groups residing in the excess air pollution area studied.

Table 2-3 presents standardized incidence ratios (SIRs) with 95 percent confidence interval limits for SIRs depicting ratios of observed to expected new cancer cases in each of the three modeled railyard air pollution categories. SIRs are presented separately for females, males, and combined for the sexes, and are adjusted for the age and race/ethnicity characteristics of the study populations measured during the Year 2000 Census.

The ratio of observed to expected counts of new cancers among female residents of the railyard high excess exposure area showed a slightly elevated observed count compared to the age- and race/ethnicity-adjusted expected number (SIR=1.10; 95% CI=0.93-1.29), while the finding for male residents of the railyard high exposure zone was not elevated (SIR=0.95; 95% CI=0.80-1.13) (**Table 2-3**). Findings for female (SIR=0.66; 95% CI=0.61-0.72) and male (SIR=0.73; 95% CI=0.67-0.79 residents of the moderate excess exposure zone showed markedly fewer observed counts of new cancers than age- and race/ethnicity-adjusted expected counts. The finding for the railyard low exposure zone was null for females (SIR=0.99; 95% CI=0.93-1.06) and slightly elevated among males (SIR=1.09; 95% CI=1.02-1.16) (**Table 2-3**).

TABLE 2-2. OBSERVED (O) AND EXPECTED (E) COUNTS, AGE-STANDARDIZED INCIDENT RATIOS (SIR_S) AND 95 PERCENT CONFIDENCE INTERVAL LIMITS (95% CI) FOR SIR_S AMONG ALL CANCERS COMBINED BY SEX AND RACE/ETHNICITY† AND COMBINED FOR 16‡ CENSUS TRACTS (3 RAILYARD EXPOSURE AREAS) COMBINED, 1996-2008.

All Race/Ethnic Groups Combined					Asian/Other† 2.3.1.1					Non-Hispanic Black					Hispanic					Non-Hispanic White				
Count		SIR	95% CI		Count		SIR	95% CI		Count		SIR	95% CI		Count		SIR	95% CI		Count		SIR	95% CI	
O	E	(O/E)	LL	UL	O	E	(O/E)	LL	UL	O	E	(O/E)	LL	UL	O	E	(O/E)	LL	UL	O	E	(O/E)	LL	UL
										FEMALES														
1,572	1,483.7	**1.06**	1.01	1.11	41	57.6	**0.71**	0.51	0.97	296	283.4	1.04	0.93	1.17	750	689.8	**1.09**	1.01	1.17	485	452.8	1.07	0.98	1.17
										MALES														
1,714	1,515.5	**1.13**	1.08	1.19	45	56.8	0.79	0.58	1.06	333	348.6	0.96	0.86	1.06	797	673.3	**1.18**	1.10	1.27	539	436.7	**1.23**	1.13	1.34
										BOTH SEXES														
3,286	2,999.2	**1.10**	1.06	1.13	86	114.4	**0.75**	0.60	0.93	629	632.1	1.00	0.92	1.08	1,547	1363.2	**1.13**	1.08	1.19	1,024	889.5	**1.15**	1.08	1.22

†Asian/other includes Asia n, Pacific Islander, and mixed race/ethnic groups and persons not classified in the other race /ethnicity categories. NH signifies non-Hispanic ethnicity, regardless of Black and White designation.
‡16 Census tracts combined include the 16 San Bernardino County year 2000 Census tracts in the vicinity of the SBR including tracts 4201-4202, 4401-4402, 4300, 4700-4900, 5500-5700, 5900, 6600-6800, and 7000.

TABLE 2-3. OBSERVED (O) AND EXPECTED (E) COUNTS, AGE-, RACE/ETHNICITY-ADJUSTED†, SEX-SPECIFIC AND COMBINED STANDARDIZED INCIDENT RATIOS (SIRS) WITH 95 PERCENT CONFIDENCE INTERVAL LIMITS (95% CI) FOR SIR_S IN HIGH, MODERATE, AND LOW RAILYARD AIR POLLUTION EXPOSURE AREAS‡, 1996-2008.

Railyard High					*Railyard Moderate*					*Railyard Low*				
O	E	O/E	LL	UL	O	E	O/E	LL	UL	O	E	O/E	LL	UL
							FEMALES							
149	135.43	1.10	0.93	1.29	489	738.01	0.66	0.61	0.72	934	943.30	0.99	0.93	1.06
							MALES							
132	138.91	0.95	0.80	1.13	545	751.71	0.73	0.67	0.79	1,037	953.25	1.09	1.02	1.16
							SEXES COMBINED							
281	274.35	1.02	0.91	1.15	1,034	1489.71	0.69	0.65	0.74	1,971	1896.56	1.04	0.99	1.09

†Expected counts for each railyard exposure area are adjusted using indirect age-standardization 22 for age and race/ethnicity using 19 unique age categories ranging from age <1, 1-4, 5-9, 10-14, …, 80-84, and 85+ years; race/ethnic categories are defined in the methods section and in the footnotes for Table 3-2.
‡Railyard high excess exposure includes Census 2000 tracts 4800 and 4900, moderate excess exposure includes tracts 4300, 4700, 5600, 5700, and 6700, low excess exposure includes tracts 4201, 4202, 4401, 4402, 5000, 5900, 6600, 6800, and 7000, and the railyard combined category includes all 16 census tracts.

2.3.2 Specific Cancer Types

We conducted additional analyses for specific cancer types having different etiologic mechanisms. The results from these analyses are summarized in **Tables 2-4** and **2-5** below. **Table 2-5** includes results according to predicted level of exposure: high, moderate, and low. These three categories of surrogate exposure were derived according to the methods described in the Methods section above. Statistically higher than expected occurrence (SIR = 1.78; 95% CI = 1.09-2.76) of lung and bronchus cancer observed among female residents of the railyard high exposure area is perplexing given the lower than expected count for the same cancer among male residents, and null findings for lung and bronchus cancer among residents of the railyard moderate and low excess exposure areas.

Since rates of tobacco use among our Hispanic female respondents in our most impacted area are low, it is reasonable to argue that female residents in this high excess exposure area could have greater exposure to emissions from the SBR facility than males, as males mostly work outside of the area while females are more likely than males to work at home. While the **Table 2-4** findings are derived from all 16 CT areas, they reveal that female and male excess occurrence of lung and bronchus cancer in the railyard high, moderate and low excess exposure areas is substantially limited to non-Hispanic White residents, with this race/ethnic group characterized by greater than average past tobacco use. Slightly lower than expected counts for all cancers combined and for non-Hodgkin's lymphoma among residents of the railyard moderate exposure CTs represents a serendipitous finding.

Male excess occurrence of colorectal cancer was also observed in the high and moderate exposure areas but not in the low exposure region. These non-significant elevations followed an attenuation pattern across the exposure regions: high exposure—SIR = 1.44 (95% CI = 0.89-2.20); moderate exposure—SIR = 1.20 (95% CI = 0.93-1.51); and low exposure—SIR = 0.96 (95% CI = 0.78-1.17). A somewhat similar pattern of non-significant decreasing elevations across exposure areas was also observed for lung and bronchus, colon and rectum, and pancreatic cancers when the data for both sexes were combined (**Table 2-5**). In the high exposure areas, excess occurrences were SIR = 1.12 (95% CI: 0.75-1.61), SIR = 1.29 (95% CI: 0.90-1.79), and SIR = 1.43 (95% CI: 0.68-2.65) for lung, colon and rectum, and pancreas cancer, respectively. In the moderate exposure region, only lung and bronchus and colon and rectum cancers remain slightly elevated, SIR = 1.02 (95% CI: 0.85-1.22) and SIR = 1.03 (95% CI: 0.85-1.23). No elevations were found for those same three cancers in the low exposure area.

Findings included in **Table 2-4** depict slightly fewer than expected counts for all cancer sites combined among Asian/other females and for both sexes combined and markedly lower than expected counts of colorectal cancer among Asian/other residents of the 16 CTs surrounding the BNFS San Bernardino railyard. Hispanic female (SIR = 1.09; 95% CI: 1.01-1.17), male (SIR = 1.18; 95% CI: 1.10-1.27) and sexes combined (SIR = 1.13; 95% CI: 1.08-1.19) experienced slightly higher observed counts of all cancers combined. In all three cases the elevations were statistically significant.

TABLE 2-4. OBSERVED (O) AND EXPECTED (E) COUNTS, RACE/ETHNICITY-SPECIFIC AND SEX-SPECIFIC AND COMBINED AGE-STANDARDIZED INCIDENCE RATIOS (SIRS) WITH 95 PERCENT CONFIDENCE INTERVAL LIMITS (95% CI) FOR SIRS IN 16 CENSUS TRACTS COMBINED[†] IN THE VICINITY OF THE BNSF RAILYARD, 1996-2008.

Cancer Site[¥]	Asian/Other‡					NH Black					Hispanic					NH White				
	Count O	Count E	SIR (O/E)	95% CI LL	95% CI UL	Count O	Count E	SIR (O/E)	95% CI LL	95% CI UL	Count O	Count E	SIR (O/E)	95% CI LL	95% CI UL	Count O	Count E	SIR (O/E)	95% CI LL	95% CI UL
FEMALES																				
All Sites	41	57.59	**0.71**	0.51	0.97	296	283.44	1.04	0.93	1.17	750	689.85	**1.09**	1.01	1.17	485	452.82	1.07	0.98	1.17
Lung	<5	<5	0.21	-	-	41	39.85	1.03	0.74	1.40	63	65.52	0.96	0.74	1.23	87	64.80	**1.34**	1.08	1.66
Breast	15	18.53	0.81	0.45	1.34	74	85.93	0.86	0.68	1.08	96	73.57	**1.30**	1.06	1.59	136	145.24	0.94	0.79	1.11
CRC	<5	<5	0.62	-	-	40	38.70	1.03	0.74	1.41	215	212.10	1.01	0.88	1.16	54	50.63	1.07	0.80	1.39
Pancreas	0	1.20	N/A	-	-	11	9.93	1.11	0.55	1.99	14	16.53	0.85	0.46	1.42	9	11.35	0.79	0.36	1.51
NHL	<5	<5	0.45	-	-	6	8.64	0.69	0.25	1.52	33	35.35	0.93	0.64	1.31	16	17.40	0.92	0.52	1.50
MALES																				
All Sites	45	56.85	0.79	0.58	1.06	333	348.64	0.96	0.86	1.06	797	673.32	**1.18**	1.10	1.27	539	436.72	**1.23**	1.13	1.34
Lung	<5	<5	0.58	-	-	49	56.37	0.87	0.64	1.15	41	48.66	0.84	0.60	1.14	86	62.71	**1.37**	1.10	1.69
CRC	<5	<5	0.15	-	-	34	35.50	0.96	0.66	1.34	208	191.75	1.08	0.94	1.24	57	47.08	1.21	0.92	1.57
Prostate	12	17.36	0.69	0.36	1.21	120	137.24	0.87	0.72	1.05	57	62.76	0.91	0.69	1.18	122	123.59	0.99	0.82	1.18
Pancreas	<5	<5	1.82	-	-	12	8.14	1.47	0.76	2.58	17	19.16	0.89	0.52	1.42	11	9.86	1.12	0.55	2.00
NHL	<5	<5	0.39	-	-	6	10.03	0.60	0.22	1.31	28	30.77	0.91	0.60	1.32	16	18.63	0.86	0.49	1.40
SEXES COMBINED																				
All Sites	86	114.43	**0.75**	0.60	0.93	629	632.09	1.00	0.92	1.08	1,547	1,363.2	**1.13**	1.08	1.19	1,024	889.54	**1.15**	1.08	1.22
Lung	5	11.57	0.43	0.14	1.02	90	99.41	0.91	0.73	1.11	104	112.48	0.92	0.76	1.12	173	127.51	**1.36**	1.16	1.57
CRC	5	13.13	**0.38**	0.12	0.90	74	74.20	1.00	0.78	1.25	153	136.33	1.12	0.95	1.32	111	97.70	1.14	0.93	1.37
Pancreas	<5	<5	0.87	-	-	23	18.08	1.27	0.81	1.91	31	35.70	0.87	0.59	1.23	19	21.21	0.90	0.54	1.40
NHL	<5	<5	0.41	-	-	12	18.67	0.64	0.33	1.13	52	66.13	0.79	0.59	1.03	47	52.40	0.90	0.66	1.19

†16 Census tracts combined include the 16 San Bernardino County year 2000 Census tracts in the vicinity of the BNSF railyard.

‡ Asian/Other includes Asian, Pacific Islander, and mixed race/ethnic groups and persons not classified in the other race/ethnicity categories. NH signifies non-Hispanic ethnicity, regardless of Black and White designation.

[¥]Lung signifies cancer originating in the lung and bronchus, CCR signifies colorectal cancer, NHL is non-Hodgkin"s lymphoma, and Nasophx signifies nasopharyngeal carcinoma.

<5 signifies observed or expected counts fewer than 5. The precise numbers are not revealed to preserve the identities and health status for individuals. N/A SIR is undefined and not available because observed count is zero.

Statistically Significant SIRs indicated in bold.

TABLE 2-5. OBSERVED (O) AND EXPECTED (E) COUNTS, AGE-ADJUSTED, RACE/ETHNICITY-COMBINED AND SEX-SPECIFIC AND COMBINED STANDARDIZED INCIDENCE RATIOS (SIRS) WITH 95 PERCENT CONFIDENCE INTERVAL LIMITS (95% CI) FOR SIRS IN HIGH, MODERATE, AND LOW AIR POLLUTION EXPOSURE AREAS OF 16 CENSUS TRACTS IN THE VICINITY OF THE BNSF RAILYARD.

Exposure →	**Railyard High**					**Railyard Moderate**					**Railyard Low**				
	Count		SIR	95% CI		Count		SIR	95% CI		Count		SIR	95% CI	
Cancer Site[¥]	O	E	(O/E)	LL	UL	O	E	(O/E)	LL	UL	O	E	(O/E)	LL	UL
FEMALES															
All Sites	149	135.43	1.10	0.93	1.29	489	738.01	**0.66**	0.61	0.72	934	943.30	0.99	0.93	1.06
Lung	20	11.22	**1.78**	1.09	2.76	52	54.04	0.96	0.72	1.26	98	103.73	0.94	0.77	1.15
Breast	38	39.56	0.96	0.68	1.32	142	148.53	0.96	0.81	1.13	253	287.78	**0.88**	0.77	0.99
CRC	15	13.26	1.13	0.63	1.87	47	55.30	0.85	0.62	1.13	93	101.28	0.92	0.74	1.13
Pancreas	6	3.76	1.60	0.57	3.50	9	14.75	0.61	0.28	1.16	21	26.13	0.80	0.50	1.23
NHL	6	5.88	1.02	0.37	2.24	16	20.57	0.78	0.44	1.27	30	37.50	0.80	0.54	1.14
MALES															
All Sites	132	138.91	0.95	0.80	1.13	545	751.71	**0.73**	0.67	0.79	1,037	953.25	**1.09**	1.02	1.16
Lung	9	14.70	0.61	0.28	1.17	73	68.52	1.07	0.83	1.34	120	120.11	1.00	0.83	1.19
CRC	21	14.60	1.44	0.89	2.20	70	58.54	1.20	0.93	1.51	97	101.03	0.96	0.78	1.17
Prostate	33	42.15	0.78	0.54	1.10	154	179.87	0.86	0.73	1.00	290	308.44	0.94	0.84	1.05
Pancreas	<5	<5	1.24	-	-	17	12.86	1.32	0.77	2.12	18	22.06	0.82	0.48	1.29
NHL	5	6.95	0.72	0.23	1.69	14	23.57	0.59	0.32	1.00	37	41.43	0.89	0.63	1.23
SEXES COMBINED															
All Sites	281	274.35	1.02	0.91	1.15	1,034	1,489.71	**0.69**	0.65	0.74	1,971	1,896.56	1.04	0.99	1.09
Lung	29	25.92	1.12	0.75	1.61	125	122.56	1.02	0.85	1.22	221	223.84	0.99	0.86	1.13
CRC	36	27.85	1.29	0.90	1.79	117	113.84	1.03	0.85	1.23	190	202.31	0.94	0.81	1.08
Pancreas	10	6.98	1.43	0.68	2.65	26	27.61	0.94	0.61	1.38	39	48.19	0.81	0.58	1.11
NHL	11	12.83	0.86	0.43	1.54	30	44.14	**0.68**	0.46	0.97	67	78.92	0.85	0.66	1.08

[¥] All Sites represents all cancer types combined, lung signifies cancer originating in the lung or bronchus, CRC signifies colorectal cancer, NHL is non-Hodgkin"s lymphoma.

<5 signifies observed or expected counts fewer than 5. The precise numbers are not revealed to preserve the identities and health status for individuals.
N/A indicates SIR values that are undefined because of zero observed or expected cell counts.
Statistically Significant SIRs indicated in bold.

Hispanic females showed a significant, moderately higher occurrence of breast cancer than the expected count (SIR = 1.30; 95% CI: 1.06-1.59). Non-Hispanic White females, males and the sexes combined showed higher occurrence than expected for lung and bronchus cancer and for all cancers combined (males and sexes combined). Those elevations were all statistically significant and ranged from SIR = 1.15 (95% CI: 1.08-1.22) for all cancers, both sexes, to SIR = 1.37 (1.10-1.69) for lung and bronchus cancer among Non-Hispanic White males. Observed counts of new cancers among non-Hispanic Black residents of the 16-CT study area surrounding the San Bernardino BNFS facility are similar to the counts expected and are unremarkable. These findings are consistent with lower risk of colorectal cancer reported among Asian/other California residents. The slightly higher than expected occurrence of cancer for all sites combined and for breast cancer among Hispanic residents of the 16-CT area is largely unexplained, and is consistent with the slightly, but not statistically significantly higher occurrence of colorectal cancer among Hispanics.

2.4 Discussion

As early as 1998, following a ten-year review process by the California Office of Environmental Health Hazard Assessment (OEHHA), CARB identified diesel PM as a toxic air contaminant (TAC) under the State's air quality regulatory framework. This classification was based on the potential of this contaminant to cause adverse health consequences, including cancer. Subsequent to this action, there has been mounting concern about the cancer-causing potential of diesel exhaust, particularly based on findings from epidemiological studies in connection with various occupational settings. Concerns were renewed by the publication in 2012 of the results of a large U.S. National Cancer Institute/National Institute for Occupational Safety and Health study of occupational exposure among underground miners in the U.S. The *Miners Study* showed an increased risk of death from lung cancer in workers exposed to diesel exhaust [24]. In the summer of that same year, the WHO's International Agency for Research on Cancer (IARC) classified diesel engine exhaust as Group 1, carcinogenic to humans, based on sufficient evidence that exposure is associated with an increased risk for lung cancer.

The authors of the *Miners Study* stated that their findings are relevant not only for miners but also for millions of workers exposed to diesel exhaust and for urban populations worldwide. In the study, diesel exhaust exposure was represented by respirable elemental carbon (EC). The authors highlighted the high average EC levels (4-12 $\mu g/m^3$) reported in several big urban areas in the US, Mexico, Europe, or China as a serious public health threat, concluding that:

> Environmental exposure to average elemental carbon levels in the 2-6 $\mu g/m^3$ range over a lifetime as would be experienced in highly polluted cities approximates cumulative exposures experienced by underground miners with low exposures in our study. Because such workers had at least a 50% increased lung cancer risk, our results suggest that the high air concentrations of elemental carbon reported in some urban areas may confer

> increased risk of lung cancer. Thus, if the diesel exhaust/lung cancer relation is causal, the public health burden of the carcinogenicity of inhaled diesel exhaust in workers and in populations of urban areas with high levels of diesel exposure may be substantial.[vi]

EC ambient concentrations exceeding 3 μg/m^3 have been reported for central Los Angeles and for inland locations in the South Coast Air Basin, including Mira Loma and Ontario.[vii] Busy goods movement rail facilities, where diesel-powered trains, trucks, and cargo vehicles operate, are likely to locally increase ambient diesel PM concentrations. In light of the conclusions from the *Miners Study*, the potential for enhanced exposures to diesel exhaust near busy goods movement hubs raises concerns about cancer risk among residents in nearby communities.

The potential for elevated cancer risks near the SBR was the main conclusion of the 2008 HRA conducted following the established risk assessment guidelines developed by the OEHHA under the State's Air Toxics Hot Spots Program (ATHSP).[viii] The results presented in this chapter were generated through a population-based epidemiologic investigation of cancer risk in the same region. The task of interpreting and reconciling the conclusions resulting from both processes can be challenging for non-experts. Further complexities arise in connection to the different perspectives that are frequently held by scientists and outraged citizens as to what constitutes an unacceptable level of risk warranting regulatory action.[ix] Public health regulatory authorities themselves face the difficult task of establishing the rationale for pursuing, or not pursuing, regulatory action based on the available information.

Contextualizing the results and providing clarification about certain technical aspects is needed not only to appropriately interpret the findings from the population-based cancer assessment, but also to build community trust by bringing intelligibility to the process of risk communication. The two modalities of cancer risk assessment, i.e., OEHHA-based[x] *vs*. a population-based epidemiologic investigation, follow different approaches and are intended to answer different questions since epidemiologists and risk assessors differ on how to conceptualize and measure risk. Epidemiologists, for example, focus on estimating risks and investigating causality; thus, an epidemiological approach to investigating railyard exposures would ask the question: what is the risk of

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[vi] Cited from Reference 24.

[vii] The EC concentration for Mira Loma (3.7 μg/m^3) was higher than that observed for Ontario (3.3 μg/m^3) but not as high as the levels measured in central Los Angeles (4.0 μg/m^3), as reported in: O'Kelly JC. South Coast Air Quality Management District Monitoring and Analysis Mira Loma PM10 Monitoring Sampling. Sampling Conducted By Sumner Wilson, Senior Air Quality Instrument Specialist Sample A. January 3, 2001.

[viii] See the 2006 ARB Health Risk Assessment Guidance for Railyard and Intermodal Facilities (available from: http://www.arb.ca.gov/railyard/hra/1107hra_guideline.pdf).

[ix] See the risk communication model (hazard *vs*. outrage) advanced by Peter Sandman (www.psandman.com). For a recent technical evaluation of Sandman's model see: Lachlan K, Spence PR. 2010. Communicating risks: examining hazard and outrage in multiple contexts. Risk Anal. 30(12):1872-86.

[x] Similar to the U.S. EPA risk assessment framework under the Superfund program.

cancer in the presence of exposure to diesel emissions relative to the risk of cancer in the absence of exposure to diesel emissions? The outcome is defined as relative risk (or risk ratio), i.e., the risk in the "exposed" group *divided* by the risk in the referent group (e.g., those outside the railyard impact zone, several miles away from the SBR). In contrast to the epidemiological approach, environmental risk assessors address the question: how many excess cases of cancer will occur in a population of defined size due to exposure to diesel emissions at a concrete dose level? The outcome is exclusively defined as added or excess risk (e.g., 500 excess cancer cases per million persons exposed) and is usually related to a time period (e.g., a lifetime for adults). Added or excess risk is the risk in the "exposed" group *minus* the risk in a referent group. While an epidemiologic investigation produces estimates of disease incidence, the standard OEHHA-based risk assessment does not predict individual exposures or individual health outcomes in the affected communities.

The main concerns prompted by the findings from the HRA for the SBR focused on the high cancer risk that was estimated for the areas surrounding the facility. According to the HRA's projections, at the point of maximum impact (PMI), 3,300 excess new cancers would occur per million persons receiving a (70-year) lifetime exposure—24 hours a day and 7 days a week—to excess air pollutants emitted by the SBRfacility along the north side of the west end of the A yard fence line. For the residential areas, the potential cancer risk for the maximally exposed individual resident (MEIR) was estimated at 2,500 excess cancers per 1,000,000 persons. The MEIR rate corresponds to the estimated risk at the point with the highest air concentration of the cancer-causing chemical. It should be noted that these risk levels represent the potential cancer risks in addition to the regional background risk from diesel PM emissions: 1,000 excess cancers/million.[xi]

The acceptable level for individual cancer risk varies in different Federal and State programs. The U.S. EPA under the Superfund program defines the acceptable risk range for exposure to a carcinogen as 1×10^{-4} (1 in 10,000) to 1×10^{-6} (1 in 1,000,000) excess lifetime cancer risk. Exposures that are projected to cause a number of excess cancers above those benchmarks are considered to be of concern and may require action to reduce the exposure and associated risk. Under California's Hot Spots program, 1×10^{-5} (1 in 100,000) is a common standard for the Air Districts. Thus, the PMI and MEIR estimated for the SBR are 330 and 250 times, respectively, the regulatory acceptable risk level under the State's regulatory framework. Upon the release of the CARB health risk assessment, fears about these high cancer risks spread among residents, and local authorities also voiced concern. Some emphasized that projections of

[xi] For the entire South Coast Air Basin, the estimated background risk level has been estimated at 1,005 excess cancers/1,000,000 caused by all toxic air pollutants in the year 2000, as reported in the Air Resources Boards' 2009 *California Almanac of Emissions and Air Quality*, available from: http://www.arb.ca.gov/aqd/almanac/almanac.htm.

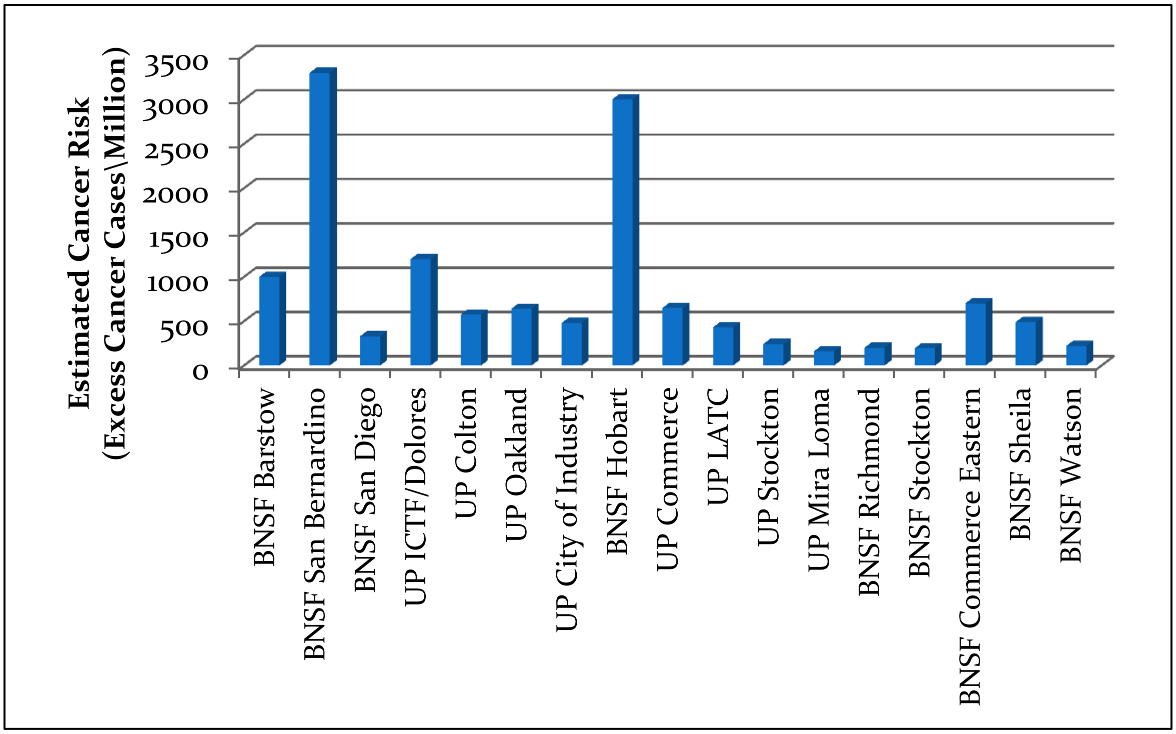

FIGURE 2-2. ESTIMATED EXCESS CANCER RISK AT POINT OF MAXIMUM IMPACT FOR THE DESIGNATED RAILYARDS IN CALIFORNIA UNDER THE STATEWIDE RAILROAD AIR POLLUTION REDUCTION AGREEMENT (SOURCE: CALIFORNIA AIR RESOURCES AIR BOARD'S WEBPAGE, *RAILYARD HEALTH RISK ASSESSMENTS AND MITIGATION MEASURES* HTTP://WWW.ARB.CA.GOV/RAILYARD/HRA/HRA.HTM).

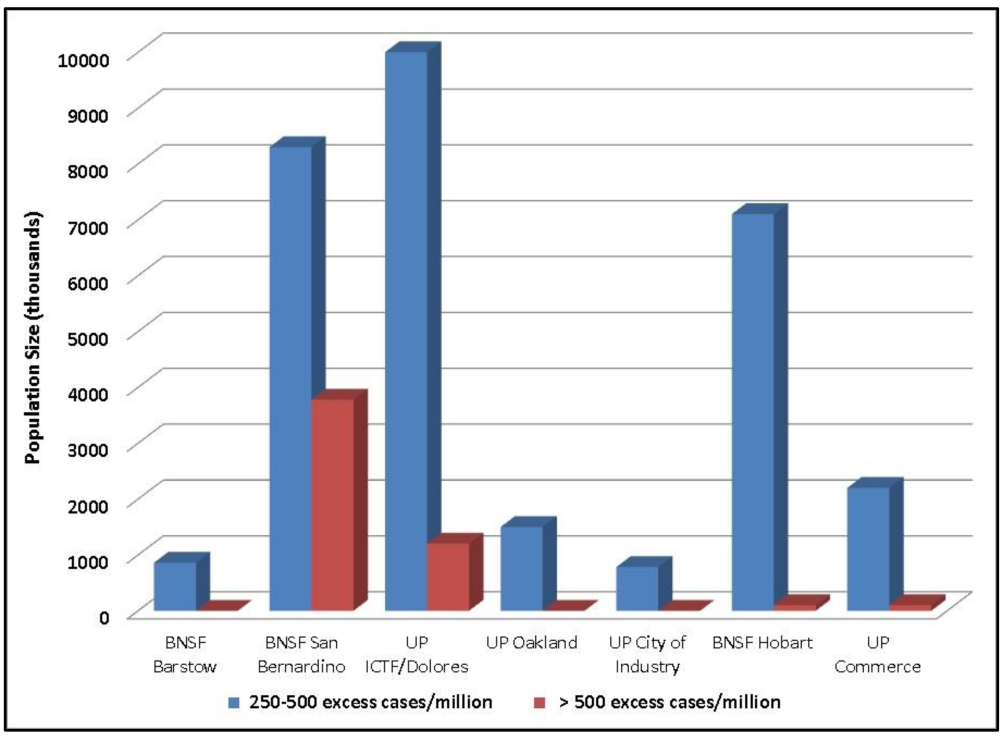

FIGURE 2-3. COMPARISON OF ESTIMATED EXPOSED POPULATIONS ASSOCIATED WITH THE TWO HIGHEST CANCER RISK LEVELS (ASSUMES A 70-YEAR EXPOSURE) PROJECTED FOR SEVEN CALIFORNIA RAILYARDS.

cancer risk within OEHHA's risk assessment framework are conservative by design and subject to statistical uncertainty. Others underscored that the projected risks should not be interpreted as a literal prediction of cancer incidence in the affected communities, and that HRAs are simply a tool for comparing the relative risk between one facility and another.[xii] Yet comparisons with the results from the HRAs for other major California railyards did not diminish but rather intensified concerns among residents, since the SBR ranked first in terms of projected cancer risk among the assessed railyards **(Figure 2-2).**

With the exception of the BNSF Hobart facility, the SBR's PMI risk level amply exceeded (3x to 6x) those estimated for other California railyards***.*** It has been noted that the individual cancer risk approach has limitations in terms of protecting public health.[xiii] For example, a railyard with an unacceptable individual cancer risk level located in a sparsely populated area could impact few individuals; while a facility in a densely populated area with a lower individual cancer risk level is technically lower risk but has the potential to expose many more people. The latter can potentially cause more cancer cases than the former and thus have a greater public health impact. For a large facility such as an intermodal railyard with multiple air pollution sources, i.e., train engines, trucks, and other machinery, the risk to the population as a whole is the primary public health concern. *Individual cancer risk* is a poor method of determining impact on a population; therefore, a *population risk* metric is a better measure of determining public health impact.

The OEHHA has proposed the number of residents at a particular cancer risk level (e.g., 1×10^{-6}, 1×10^{-4}, etc.) as a surrogate measure of population burden. This metric can be derived via the number of individuals within the isopleths delineating the specific cancer risk levels. The HRAs conducted under the 2005 SRPRA contained data on the estimated exposed population associated with the various cancer risk levels (assuming a 70-year exposure). These estimates were derived based on the 2000 U.S. Census Bureau's data. **Figure 2-3** shows a comparison across railyards of the estimated populations associated with the two highest cancer risk levels (250-500 and > 500 excess cancers/million) that were estimated for the assessed railyards. For ten railyards, the models predicted that all impacted residential areas were at risk levels between 10 and < 250. Only seven railyards were predicted to have residents above the 250-risk level. With

[xii] The value of HRAs is to be understood within the 'Precautionary Principle' approach, which in some legal systems, as in the law of the European Union, have been made a statutory requirement. As aptly noted by one of the nation's leading environmental epidemiologists: "[W]ithout risk assessment, the default assumption is frequently that of zero risk. 'No risk has been shown' is easily interpreted as 'there is no risk', and risk assessment as a way of thinking can guard against this pitfall." See: Hertz-Picciotto I: Environmental Risk Assessment. In *Introduction to Environmental Epidemiology;* pp 23-38. E.O. Talbott and G.F. Craun (eds). Boca Raton, Florida, CRC Press: 1995.

[xiii] See the discussion on population *vs.* individual risk in chapter 11 of the OEHHA's Technical Support Documentation for Exposure Assessment and Stochastic Analysis, August 2012 (http://www.oehha.org/air/hot_spots/tsd082712.html).

8,300 residents estimated to live in the 250-500 excess cancer risk level, the SBR ranked second for that risk range, behind the UP ICTF/Dolores in Los Angeles.

Only four railyards out of 17 assessed,[xiv] were predicted to have residents at a risk level > 500 in excess cancers/million: UP Commerce (100 persons); BNSF Hobart (100 persons); UP ICTF/Dolores (1,200 persons); and BNSF San Bernardino (3,780 persons). Thus, the SBR ranks first in California both for individual cancer risk (PMI and MEIR) and for population burden measured by the number of people with the highest excess cancer risk levels modeled across railyards. Such high risks, revealed by the railyard-based risk assessments performed under the current State regulatory framework, raise concerns about the potential cancer burden in the communities near the SBR. Thus, in the ENRRICH Project and using data from the CCR, we conducted a non-concurrent cohort study to determine whether an excess in the number of new cancers occurred in the communities near the railyard.

The number of new cancer cases among residents in 16 contiguous CTs surrounding the SBR was evaluated against a standard population: the 4.1 million residents of the four counties which make up Region 5 of the CCR, San Bernardino, Riverside, Mono, and Inyo. Assessments were conducted for all cancer types combined and for specific cancer sites: lung, breast, colorectal, prostate, pancreas, and non-Hodgkin's lymphoma. The patterns of cancer occurrence in the target region need to be interpreted with respect to the hypothesized exposure gradient and in relation to the known differences in cancer incidence among the various race/ethnic groups. According to data reported by the DSCSP for Region 5 and California (**Figure 2-4**), among major racial groups, cancer incidence is highest for African Americans for all cancer sites combined and for most specific cancer types. Cancer incidence among non-Hispanic Whites in the area is higher than that found among Asian Americans and Hispanics.

[xiv] An HRA conducted for the UP Roseville Railyard (Sacramento County) in 2004 prior to the implementation of the SRPRA had estimated that 685 people resided in the > 500 excess cancers/million impact zone (http://www.arb.ca.gov/railyard/hra/hra.htm).

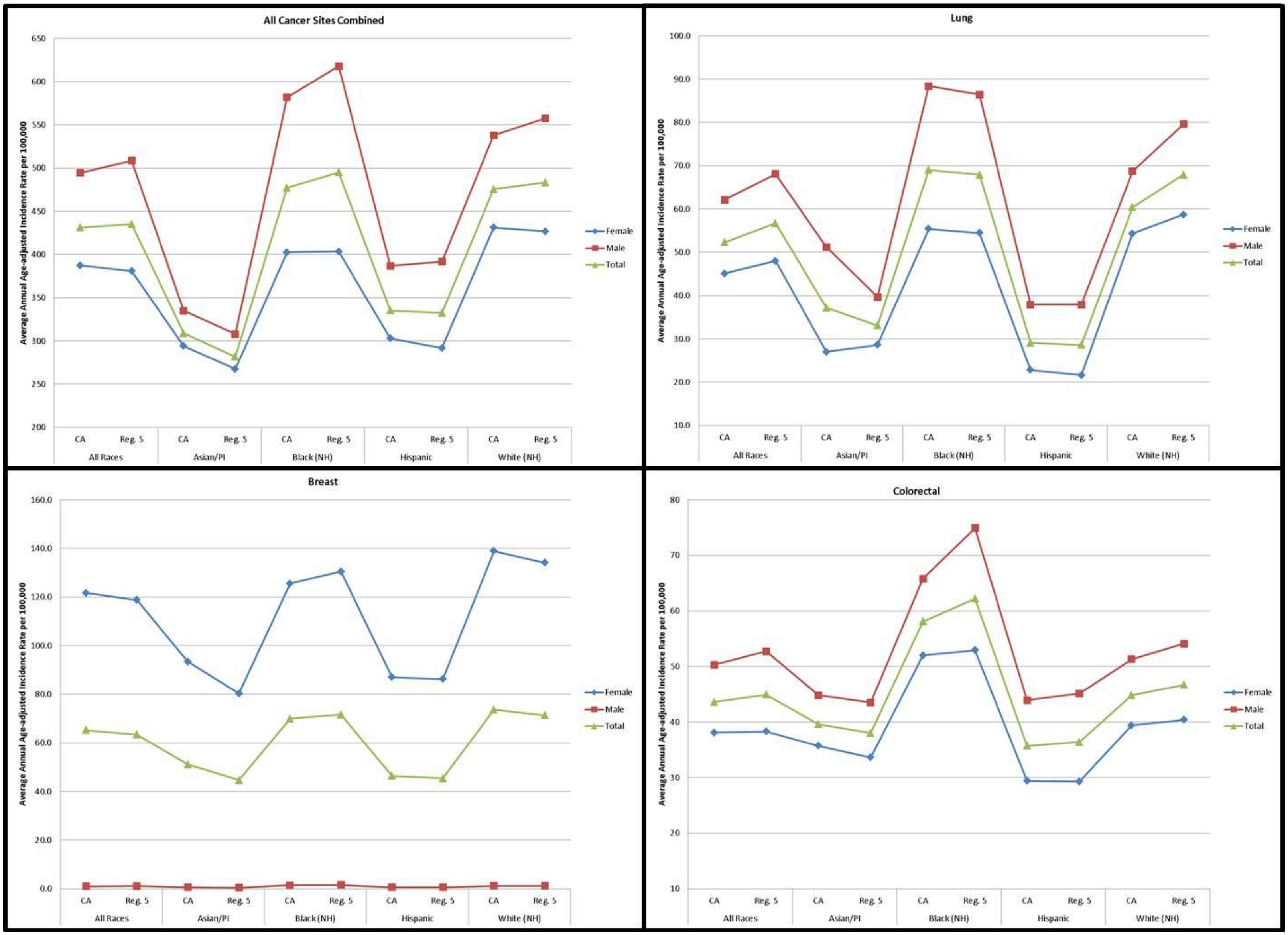

FIGURE 2-4. AVERAGE AGE-ADJUSTED INCIDENCE RATES PER 100,000 BY SEX FOR CALIFORNIA AND REGION 5 OF THE CCR (2004-2008)—INVASIVE CANCER. INCIDENCE RATES ARE PRESENTED FOR ALL CANCER SITES COMBINED AND FOR THREE CANCERS: LUNG, BREAST, AND COLORECTAL.

2.4.1 Key Findings: All Cancers Combined

Our assessments of observed and adjusted expected counts of new cancers among residents in the combined 16-tract region identified: 1) a statistically significant but modest elevation for all cancers, both sexes combined, all race/ethnic groups combined (SIR = 1.10; 95% CI: 1.06-1.13); 2) noticeable statistical elevations among Hispanic (SIR = 1.18; 95% CI: 1.10-1.27) and non-Hispanic White (SIR = 1.23; 95% CI: 1.13-1.34) male residents; 3) lower than expected cancer counts among Asian/other residents (SIR = 0.75; 95% CI: 0.60-0.93); and 4) no clear evidence of a "dose-response" trend across our hypothesized low-moderate-high exposure gradient within the area defined by the 16 contiguous tracts surrounding the SBR. We did not find evidence of risk elevations for non-Hispanic Black residents.

However, it is helpful to put these findings in perspective. For example, by epidemiologic standards, an elevation of 0.10 is regarded as small. Still it is illustrative to consider how such a seemingly small elevation can translate into a high value in terms of excess risk (the metric used in the OEHHA's risk assessment framework). For example, an SIR = 1.10 could translate into 40,760 excess cancers/million if we factor the background lifetime risk of being diagnosed with cancer in the U.S. to be 40.76%.[xv]

Elevated counts of new cancers are seen among females but not among males in the railyard high excess air pollution exposure area, while the reverse effect is seen in the railyard low excess exposure zone. This could be due to the fact that the mainly low-income Hispanic females residing in the area may well spend more time at home than males, who presumably are working away from home in areas with different exposure levels. Failure of these findings to portray an unambiguous pattern with airborne pollutants is underscored by the markedly lower observed cancer counts than the age- and race/ethnicity-adjusted expected numbers for females, males, and sexes combined in the railyard moderate excess exposure zone.

Differences between the SIR findings for all race/ethnic groups combined (race/ethnicity-crude) in **Table 2-2** and those presented in **Table 2-3** for the race/ethnicity-adjusted, railyard exposure combined are a consequence of the mixing of race/ethnic effects in **Table 2-2** and the mixing of the railyard excess exposure level effects in **Table 2-3**. In spite of these limitations, the age-adjusted and race/ethnicity-specific findings presented for females, males, and sexes combined isolate individual race/ethnic effects for the combined railyard excess exposure areas. Similarly, **Table 2-3** findings adjust for age and race/ethnicity, isolating the effects within each of the three railyard excess exposure areas for females, males, and sexes combined. Disparate findings for the race/ethnic groups and between the sexes and contradictory findings for the three excess exposure zones do not provide clear evidence that exposure to airborne emissions from the SBR elevates cancer

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[xv] See SEER Lifetime Risk Tables (http://seer.cancer.gov/csr/1975_2010/results_merged/topic_lifetime_risk.pdf). Using SEER's 40.76% lifetime cancer risk in the U.S., we can predict 407,600 cancers to occur in a population of 1,000,000. Then 448,360 cancer cases would be expected to occur under a scenario of a 10% elevation in the risk (SIR = 1.10). The excess number of cancers is 40,760/million (448,360 *minus* 407,600).

occurrence in the surrounding community. That said, some of the observed elevations might be explained by other factors.
It is reasonable to surmise that differences in residency and exposure duration exist for various race/ethnic groups, with recent residents having exposure durations short of the latency period between exposure and increased cancer occurrence. Assuming that the non-Hispanic Black population is largely composed of recent residents of the railyard exposure area could explain the null findings identified in this race/ethnic group. Based on data from our household survey, we have confirmed that there is indeed a higher proportion of long-term residents among the Hispanic and non-Hispanic White populations in the areas surrounding the SBR, compared to the non-Hispanic Black population. We have estimated that while 61% (n = 104) of the African American participants report residing at their current address < 5 years, this proportion decreases to 40% (n = 101) among White participants and 52% (n = 711) among Hispanics. We have also estimated from our ENRRICH household survey that 40% of White respondents report having lived at their current address ≥ 11 years, while this same proportion is 26% and 22% among Hispanic and Black residents, respectively. Our ENRRICH population sample included few observations for Asian households and therefore it was difficult to calculate reliable proportions. Short residential history could only explain the markedly lower observed count of new cancers measured among Asian/other residents of the railyard exposure area, compared to the adjusted expected number if a substantial fraction of this race/ethnic group migrated from areas having markedly lower cancer occurrence than the DSCSP.

Differences in tobacco use between race/ethnic groups could, at least partly, explain the markedly higher cancer occurrence among non-Hispanic White males. Tobacco use has traditionally been highest among lower socioeconomic status White males. Nevertheless, this interpretation is challenged by the absence of any excess in observed-to-expected cancer counts among non-Hispanic Black males, who also reside in low SES Census tracts and represent the second highest or highest tobacco use among major race/ethnic groups nationally and in the State.

Patterns of smoking prevalence also would not seem to explain either the elevated cancer risk found among Hispanics or their overall cancer incidence rates compared to other groups in California or in Region 5. Only Asian/Pacific Islanders (8.1%) have lower smoking prevalence in California than Hispanics (10.2%).[xvi] A similar trend exists for these two groups with respect to overall cancer incidence (see **Figure 2-4**). Altogether, findings for higher than expected observed counts for new cancers among Hispanic females and males may provide the strongest evidence that excess air pollution emissions from the SBR could contribute to an excess in observed cancer counts.

The lack of clear evidence for higher occurrence of cancer across the exposure range (low-moderate-high) defined in our assessment requires additional commentary. Under a scenario of a sharp gradient in the dispersion of emissions away from the railyard, it would be reasonable to predict an accompanying marked elevation in cancer risk moving from the

[xvi] Smoking prevalence statistics for California by can be found at: Al-Delaimy WK, White MM, Mills AL, Pierce JP, Emory K, Boman M, Smith J, Edland S. Final Summary Report of: Two Decades of the California Tobacco Control Program: California Tobacco Survey, 1990-2008, La Jolla, CA: University of California, San Diego; 2010.

low to the high exposure zones. Not seeing clear evidence of a dose-response trend needs to be understood in light of the spatial configuration of the risk ranges used in defining our low, moderate, and high exposures (**Figures 1-2** and **2-1**). Those risk ranges intersect with the boundaries of the census tracts (CTs). As can be seen in **Figure 2-5,** every tract contains a complex combination of multiple exposure risk ranges. Our approach relied on “averaging” exposure across each tract (see Section 2.2). Even though the averaging was area-adjusted, our approach may have oversimplified the within-tract, short-scale spatial variation. In other words, using CTs as the geographic unit of analysis may not afford the adequate, fine spatial resolution to model the natural, short-scale air pollution gradients, a limitation that can potentially result in exposure misclassification. Non-differential misclassification of exposure is likely to bias towards the null. These results may in fact be misleading, since this exposure classification method is likely to show a lower or even non-existent association. The possibility also exists that diesel emissions disperse according to a more gentle gradient than anticipated within the spatially compact (approximately 9,500 acres) 16-tract region, located in relative close proximity to the SBR—within a 2.5-mile radius (see **Figure 2-5**). Therefore, we cannot exclude the

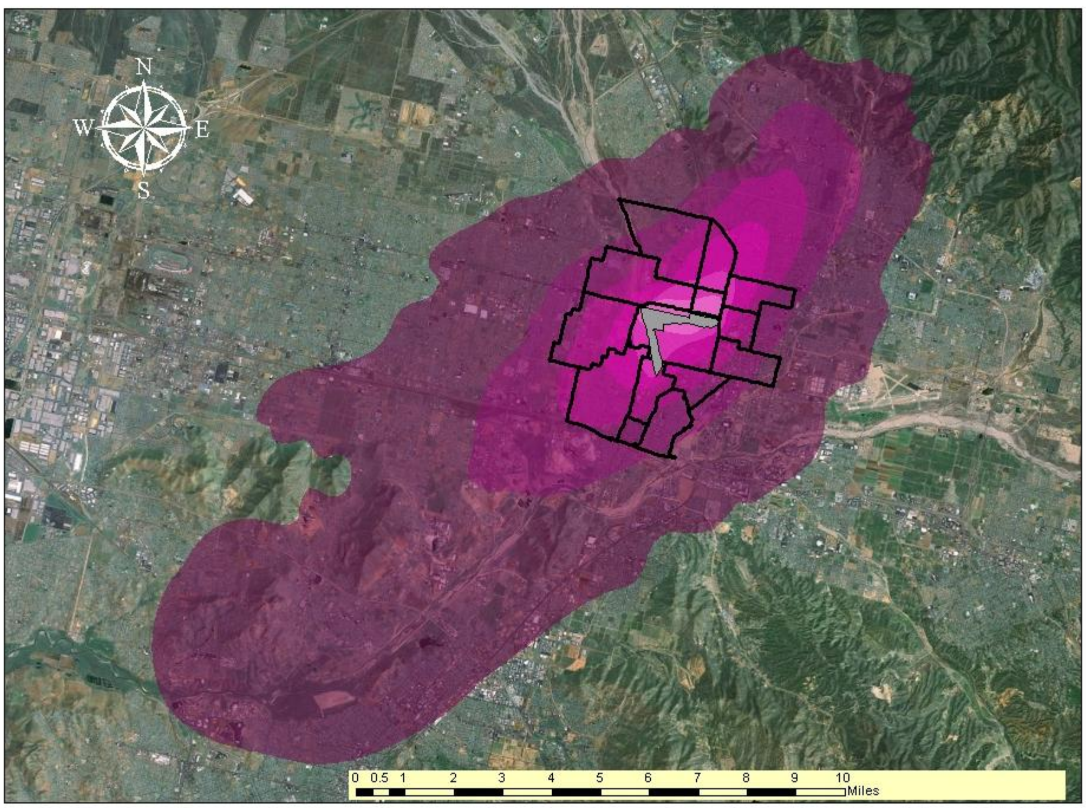

FIGURE 2-5. MAP OF THE SAN BERNARDINO RAILYARD AND ITS RISK IMPACT ZONES IN RELATION TO THE BOUNDARIES OF THE CENSUS TRACTS ON WHICH THE POPULATION-BASED CANCER ASSESSMENT WAS BASED. THE IMPACT ZONES CORRESPOND TO THE CANCER RISK RANGES PREDICTED BY THE AIR DISPERSION MODELS USED IN THE CALIFORNIA AIR RESOURCES BOARD HEALTH RISK ASSESSMENT. CANCER RISK DECREASES AS DISTANCE FROM THE RAILYARD INCREASES.

possibility that not having found a clear "dose-response" pattern was in part due to a methodological limitation in correctly modeling the actual air pollution gradient and the exposures assigned to the populations in the CTs immediately surrounding the SBR. This issue warrants further investigation.

2.4.2 Key Findings: Cancer Site-Specific

We also conducted site-specific analyses that distinguish findings for combined and dose-related railyard emission exposures for specific cancer types having different etiologic mechanisms. Next we summarized the key findings from these analyses according to the railyard exposure gradient and by major race/ethnicity groups for all 16 CTs combined.

2.4.2.1 Railyard Exposure Gradient

Although no clear evidence was found of sex-specific dose-response trends across the high-moderate-low gradient, some elevations were observed for residents in the high-exposure CTs: (1) a statistical excess of lung/bronchus cancer (SIR = 1.78; 95% CI: 1.09-2.76) among females; and (2) non-significant elevations for colon/rectum and pancreas cancers among females and males. Finding a statistically significant elevation of 78% of lung/bronchus cancer among female residents in our high exposure region near the SBR was puzzling given the lower than expected count for the same cancer among male residents and null findings among residents of the moderate and low exposure areas. However, when the data for both sexes are combined, there seems to be a pattern of non-significant but rising SIRs appears across the low-moderate-high exposure gradient for lung, colon/rectum and pancreas, suggestive of a dose-response trend (see **Table 2-5**).

2.4.2.2 Census-Tract Study Area by Sex and Ethnicity

Hispanic: Most noticeably, females showed a significant, higher occurrence of breast cancer than expected (SIR = 1.30; 95% CI: 1.06-1.59). Statistically significant elevations for females were also found for all combined cancer sites (SIR = 1.09; 95% CI: 1.01-1.17), males (SIR = 1.18; 95% CI: 1.10-1.27) and sexes combined (SIR = 1.13; 95% CI: 1.08-1.19), for all cancers combined. These risk elevations for all combined sites and for breast cancer among Hispanic residents is largely unexplained, and is consistent with the slightly higher occurrence, approaching statistical significance, of colorectal cancer among Hispanics (both sexes). Given the strong association between past tobacco use and lung and bronchus cancer occurrence, we explored past tobacco use and smoking prevalence in our ENRRICH female respondents. We used the household survey, which included questions on tobacco use, to explore smoking prevalence among our female respondents in sampling areas A and B, roughly corresponding to the high-exposure CTs, and medium and low exposure CTs, respectively, (see **Figure 2-1**). Past tobacco use among Hispanic female participants in sampling region A (high railyard exposure) was 13.8% (n = 138) compared to 13.1% (n = 175) in region B (medium-low railyard exposure). Among all female participants in the ENRRICH study, those figures were 16.7% (n = 162) and 22.9% (n = 240), respectively. Current smoking prevalence among Hispanic women was lower in the medium-low exposure CTs, 5.7% (n = 174) compared to that estimated for them in the high exposure zone: 7.2% (n = 139). To place in context, 8.4% of women in California smoke, while smoking prevalence among Hispanic women is 5.3%.[xvii] Thus we found that Hispanic females had the lowest tobacco use rates, not lending support to smoking as a causative agent. Also, it is reasonable to argue that female residents in the high-exposure region could have greater exposure to diesel emissions than males, if one assumes that males are more likely to work outside of the area while females are more likely than males to work at home.

Non-Hispanic White. Females showed elevations of lung/bronchus cancer; males for lung/bronchus cancer and for all cancers combined; and the combined sexes for all sites and lung/bronchus. Those elevations were all statistically significant and ranged from 1.15 (all cancers-both sexes) to 1.37 (lung/bronchus cancer among males). These findings reveal that female excess occurrence of lung/bronchus cancer in the railyard high region is substantially limited to non-Hispanic White residents. This group is characterized by greater than average past tobacco use.

Non-Hispanic Black. Observed counts of new cancers were similar to the expected counts and are unremarkable.

Asian/Other. Slightly fewer than expected counts for all cancer sites combined were observed among females and for both sexes combined and markedly lower than expected counts of colorectal cancer. These results are based on small numbers of counts but are consistent with lower risk of colorectal cancer reported among Asian/other California residents.

2.4.3 Limitations

The multifactorial character, different etiologies, and variable latency periods for different cancers challenge the value of using all cancer types combined as a biologically meaningful measure of the consequence of air pollution. In addition to this limitation, our findings might also be confounded by differences in presence, level, and duration of tobacco use between the sexes, race/ethnic groups, and income, education, and cultural subgroups that likely exist in the railyard exposure areas and the standard population. Although we have incorporated in our discussion estimates from the overall ENRRICH household survey, the impact of different tobacco use patterns in demographically unique segments of the population surrounding the SBR facility was not specifically assessed in this cancer investigation and is likely partly responsible for findings that appear to defy a common etiologic pattern. However, we believe that the cancer risk elevations found for Hispanic females are not easily explained by tobacco use rates alone.

A number of known factors may influence the susceptibility of the population and thus may impact population risk.[xviii] For example, socioeconomic status can be linked to psychosocial stress, influence access to health services and healthy food, or even outcomes after cancer diagnosis. Data from the ENRRICH household survey revealed that joblessness is a serious concern in the low-income communities surrounding the SBR.

[xvii] *Ibid.*

[xviii] For a discussion of factors that can affect the vulnerability of the population see OEHHA's excellent report *Cumulative Impacts Building a Scientific Foundation* (available at: http://oehha.ca.gov/ej/cipa123110.html).

Community unemployment itself can affect exposure and residency time near the railyard facility. OEHHA recommends that these types of factors be considered in the risk assessment process. Similarly, access to and utilization of cancer early detection (screening) resources likely accounts for some of the variation in occurrence and detection of the most common cancer types and was not directly assessed in our study. In addition to these limitations, our investigation did not include information on previous residence history or duration of residence in the study area or the standard population, although we have provided in this discussion some estimates of residence length, again based on the ENRRICH household survey.

Other health outcomes included in the ENRRICH project may provide more biologically meaningful and important evidence of health consequences of air pollution attributed to the BNSF facility. Further analyses that formally evaluate observed and expected counts of specific cancer subtypes that may be differentially associated with air pollution and diesel emissions, tobacco use, poverty, and differential cancer screening practices are warranted. Cancer is not an early warning marker for environmental problems. Perhaps because of long latency periods, dynamic population characteristics, complex etiologic pathways and measurement errors, environmental exposures that are reasonably deemed to be harmful are frequently never associated with unusually higher than expected cancer occurrence [69].

CHAPTER 3. COMMUNITY BASED PARTICIPATORY RESEARCH (CBPR) STRATEGY AND ADULT HOUSEHOLD HEALTH ASSESSMENT

3.1 Community Engagement Approach

The aim of the community engagement component of the ENRRICH Project was to develop an informed community response, including moving toward policy changes to reduce railyard exposures and related health impacts. In this chapter, we describe our overall CBPR strategy, including portions that have been detailed in academic publications by the ENNRICH Project team. We also present in this chapter the results from the household-level public health assessment sub-study, which was underpinned by the Project's community engagement framework and activities.

3.1.1 Contextual Framework and CBPR Strategy

When findings from the CARB's HRA Report became more widely known, local community groups raised concerns regarding air quality and its effect on residents, and challenged the Mayor of San Bernardino, local politicians, the media and researchers to look more closely at this issue. In response, community-based organizations including our partner, the Center for Community Action and Environmental Justice, with assistance from the City of San Bernardino, helped form action committees and organized informational community meetings. While many in the affected community had concerns about the impact of pollution on their health, there was also a general lack of trust in official entities, including government and research institutions such as LLU, to take appropriate action. Some residents feel that scientific studies rarely, if ever, benefit the individuals or communities being studied, which affects the community's willingness to participate in research. Compounding the situation, the high percentage of monolingual Spanish speakers in the area and resulting language barriers made discussing concerns about environmental justice and the health impacts of goods movement difficult – but these discussions were vital to soliciting community support and participation. For example, while economists refer to these goods movement health impacts simply as "externalities" of transport, residents near railyard facilities fear that these "externalities" directly harm them and affect their health and quality of life [6] —a suspicion they see as corroborated by CARB's HRA Report. As one local resident recently pleaded: "…if they know they are polluting and they're hurting people, they should do something!"

It is for this reason we decided to conduct the ENNRICH study using a collaborative approach known as community based participatory research (CBPR). CBPR is a co-learning and empowering process that involves community members in all phases of research, including identifying issues, collecting and analyzing data, developing assessment tools, designing and implementing interventions, and disseminating findings [71]. We argue that CBPR is a logical and necessary methodology to bring together the community, its stakeholders, and local researchers in a true partnership. This approach helps build trust and confidence between community and scientists by working together to collect exposure and disease outcome data. Providing the community with the tools and education to better understand study findings further strengthens that trust. CBPR is an increasingly widely used research approach in studies that involve investigating community concerns involving hard-to-reach or access communities and has shown great promise as a research tool to address EH disparities and advance EH science [72].

With CBPR principles serving as the platform to begin the research and engage community, we developed a partnership with an Inland Empire community based agency, the Center for Community and Environmental Justice (CCAEJ), which is well known in the area for its work on local issues, including environmental justice and air quality. As a team, LLU researchers have a long track record in using CBPR and other community involved research approaches in the target community in areas such as disaster preparedness, health disparities, teen pregnancy prevention, and prostate and breast cancer prevention.

3.1.2 Community-based Research Partnership

As noted earlier, our community partner for this study is the Center for Community Action and Environmental Justice (CCAEJ), a non-profit environmental justice organization whose focus is bringing people together for cooperation and participatory decision-making to improve their social and natural environment. CCAEJ's practice is to help individuals recognize their own strengths, learn new skills, and develop the confidence to use them, believing that building community capacity is crucial to long-term sustainability. For example, two of the 11 staff members who participated in the project are residents of the Westside of the City of San Bernardino and live next to the BNSF SBR railyard.

The organization has worked in San Bernardino's Westside neighborhood for more than 6 years on various environmental issues and has a membership of 400 in that community. At the time the ENRRICH study began, residents had already formed a Community Action Team (CAT) made up of 30 families that follow the day-to-day activities of the group on the railyard issue. They meet bi-monthly in a multi-agency Task Force working to reduce neighborhood exposure to the railyard emissions.

As part of data collection under the ENRRICH Project, CRPs teams were also involved in community translational and action work. They participated in local and other task force meetings and were members of action sub-committees the target community. This type of active engagement by non-academicians was appreciated by the community, which helped make our interviewing tasks, while still challenging, successful.

Some have questioned the wisdom of collaborating with a local community partner on data collection for this important health outcomes study. As investigators, we made a conscious decision to adopt a true CBPR approach and therefore to work in collaboration with community *vs*. using a traditional top-down model of investigator-driven data collection, which some would suggest would have provided for more rigor and control. We would argue however, that the scrupulous, detailed training, supervision and quality control in our partnership allowed us the best of both worlds: implementing a rigorous study in collaboration with the community that access to a usually highly closed community that otherwise likely would not have participated to the same degree due to trust concerns. Community-based research partners (CRPs) received the extensive training necessary to collect study data. First and foremost, to ground the community researchers in the basic tenets of human research and to comply with LLU Institutional Review Board (IRB) requirements, all CRPs involved in data collection were trained and certified in the ethical conduct of human subjects (HS) research before data collection began. The CRPs also received lengthy training on the study protocol and how to properly collect study data. After the CRPs were trained in data collection techniques and protocols, the teams were supervised and systematically joined by LLU researchers to observe and participate in data collection. Regular weekly meetings were held with the CRP teams to discuss study progress.

3.1.3 Human Subjects Research Training with Community Members

CBPR has evolved as a valid approach that is seen as effective in advancing research objectives while at the same time partnering with community to seek solutions to health disparities issues. CBPR involves community members in all phases of research, including identifying issues, collecting and analyzing data, developing assessment tools, designing and implementing interventions, and disseminating findings.

To ensure high quality implementation of study procedures and comply with Institutional Review Board (IRB) requirements, all participants involved with the ENRRICH study needed to be trained and certified in the ethical conduct of human subjects (HS) research. Early in this process, we realized that the conventional NIH-IRB certification methods used at LLU, which are designed for university scientists, are not well suited for community members who often face educational as well as language barriers. In response, we worked with our LLU leadership and our community partners to develop a community friendly human subjects training curriculum that met the requirements of our IRB and at the same time was well-suited to our community partners from CCAEJ, comprised mainly of monolingual Spanish speakers with varying educational backgrounds. We have drafted a manuscript of our findings and experiences, which have been accepted for publication in the journal: *Progress in Community Health Partnerships: Research, Education, Action.* The manuscript is included below. The purpose of this article was to share the experiences and lessons learned in developing and implementing a customized human subject research curriculum for our community partner, which was community friendly yet still rigorous and fulfilling our Institutional Review Board requirements.

Making Human Subject Protection Training Community Responsive: Experiences Delivering on the CBPR Promise

Authors

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Submitted to

Progress in Community Health Partnerships: Research, Education, Action.

ABSTRACT

Background: A community-based-participatory-research (CBPR) approach was used by the California-based ENRRICH Study, a partnership between scientists from Loma Linda University (LLU) and a local community organization, with the aim of assessing the health effects of exposure to emissions from a railyard on a community.
Methods/Results: To allow meaningful community participation in all study activities and to comply with Institutional Review Board (IRB) requirements, all participants involved needed to be properly trained and certified in the ethical conduct of human subjects (HS) research. Existing IRB training materials and the conventional certification methods designed for university scientists are not well suited for community members who often face educational as well as language barriers. **Conclusion:** The purpose of this article is to share experiences in developing and implementing a customized human subject research curriculum, which was community-responsive and addressed IRB requirements.

Key Words: Community-based participatory research, collaboration, IRB, human research

GRANT INFORMATION

This research was in part funded by the South Coast Air Quality Management District (SCAQMD)/BP West Coast Products Oversight Committee, LLC grant # 659005.

COMPETING INTERESTS

The authors have not published or submitted any related papers from this same study. The authors have no financial conflict of interest.

Background

Over the past few years, Community-based Participatory Research (CBPR) has shown promise as a powerful research tool in understanding and addressing persistent health disparities, while empowering vulnerable communities, especially in areas challenged by environmental justice (EJ) concerns[72-75]. Emerging evidence indicates that close residential proximity to environmental hazards results in enhanced exposures, potentially contributing to a greater community burden of disease, subsequently furthering the great health disparity divide [76-78]. EJ communities typically comprise disadvantaged and underserved populations. Compared to the general population, these residents are more likely to be exposed to multiple environmental hazards and social stressors, including poverty, poor housing quality, and social inequality [79]. The cumulative impacts of environmental exposures and social vulnerability are likely to result in greater risk for adverse health outcomes [77, 80-83]. Funding agencies have increasingly called for research to understand both the complex environmental exposures and their possible associations with adverse health effects, with many encouraging researchers to adopt CBPR approaches focused on promoting translation of research findings into sustainable positive changes in the communities most affected [84]. As a result, CBPR has increasingly emerged as an important scientific framework for environmentally related health disparities research at institutions across the U.S. Concurrently, internal institutional challenges have also increased, which at times may prevent, delay, or disrupt collaboration with community partners, such as community-based organizations (CBOs), for CBPR purposes [85-88]. Building on the previously reported IRB challenges, this manuscript highlights the difficulty of using the human subjects (HS) training curriculum required of researchers, and describes the solution for training our community partners with an educational curriculum originally designed for university personnel.

In addition to their responsibility for the approval, modification, ongoing review, suspension or termination of research involving human participants, IRBs are tasked with ensuring that investigators are trained and certified in the ethical conduct of human subjects' research. The HS training emphasizes the conduct of respectful and ethical procedures when working with humans in research, promoting the three fundamental ethical principles of the Belmont Report which include: respect for person, beneficence, and justice [89]. The principle of respect for persons includes autonomy and informed voluntary consent; the principle of beneficence involves maximizing the benefit to subjects while minimizing risk; and the principle of justice involves equitable distribution of the costs and benefits for potential participants in the research study. The development of the Belmont Report arose directly from the need to protect the rights and welfare of human subjects involved in research studies. Federal funding agencies (NIH, CDC, EPA, etc.) require human subjects training certification for all personnel involved in direct contact with participating human subjects. For research funded by non-federal sources or where the funder does not specify, the HS training requirement may be left up to the discretion of the university.

When conducting CBPR, universities may want to include all team members, including their community partner in the HS training program, to set a strong foundation for research guided by the Belmont principles. A true CBPR approach involves community members in all phases of research, if possible, even from the development of the initial research idea through data collection, analysis and result dissemination [90]. Therefore collaborating community partners should be considered a part of the research staff, and if the funder or university requires HS trainings of full-time researchers, then the training requirement should also pertain to community partners depending on their roles within the research project. Regardless of the requirement, it is helpful to encourage all personnel, whether professional researchers or community partners, to receive the HS training as a means of promoting an environment of ethical and responsible human subjects research. The difficulty of providing HS training for the community partner lies in the HS training curriculum itself. LLU has chosen the web-based training and certification program provided by the Collaborative Institutional Training Initiative (CITI). Though this training and certification should extend to community members and organizations partnering on research projects, using training materials designed for university personnel can be problematic for community members who may come from a variety of educational backgrounds. It is critical that when partnering with local community members that universities not only ensure that everyone is IRB certified and understand the ethical foundation for conducting human research, but do so in ways that are community responsive and promote true awareness for the protection of human subjects. Few resources exist in providing information on developing and delivering community-friendly HS courses [91, 92]. Having limited information available on community friendly and responsive HS training curricula for community partners becomes not only a barrier to the research partnership, but may also be seen as an indicator that preparing CBO partners in the ethical conduct of human subjects research is not viewed as important and essential.

Through our experience with CBPR at Loma Linda University (LLU), we have become increasingly aware of the difficulties in training community partners utilizing a university-targeted HS curriculum. In an effort to increase awareness and protection for human subjects, our university promotes and encourages HS training of all personnel involved with research, including community partners, regardless of any requirements of the funder. Recently, LLU received extramural funding to partner with community members and city agencies to conduct research on the health status of several thousand people living near a bustling railyard facility in San Bernardino. Successful solutions for exposure mitigation require data specific to the at risk populations and generated through research which is responsive to, and inclusive of, community-identified needs. Subsequently, we created the Environmental Railyard Research (ENRRICH) Project and partnered with local community partners to gather health data and formulate an action plan aimed at promoting cleaner air for community residents living near the railyard. Early into our partnership, it became clear that the conventional HS training and certification methods designed for university personnel are not well suited for community members who often face educational as well as language barriers. The purpose of this article is to share experiences and lessons learned in developing and implementing a customized human subject research curriculum which was rigorous yet community responsive, addressed IRB requirements, and met the needs of our mainly monolingual Latino community team members.

Development of the Overall Training Program

From the onset of our research partnership, both our LLU research team and members of our community partner organization (CP) labored under many assumptions regarding the university-based HS training and certification -- one of which was that only the LLU researchers needed to complete the HS training and obtain certification. Shortly into the IRB approval process we realized the need for *everyone* to complete the training, including CP staff and especially their personnel involved with research data collection. Both organizations expressed interest and the desire to have all Project ENRRICH research team members trained, but the challenge was how to adapt the university training for a community audience. What we had unknowingly stumbled upon was that the actual HS exam itself had become a barrier to the LLU-CP partnership. Even for somewhat experienced researchers, the basic HS web-based training and exam, while available in Spanish and English, can take several hours to complete. For community members who are not familiar with research language and who may lack computer skills, the training course can take significantly longer; it was possible that the CP staff may not pass the exam, which would have prevented them from working on this particular research project; thus the HS exam would have unintentionally created a barrier for partnering with the CBO.

After realizing the need for a HS training curriculum targeted to a lay audience with differing levels of formal education, we began to formulate an initial training plan in partnership with our university's IRB administration and our community partner. We began by discussing important barriers, with a goal of developing solutions (Table 1). We convened a meeting where we discussed potential barriers with our CP, gaining a better understanding of their needs as well as their available resources. One of the first challenges addressed was to ensure that the community partner had the resources (i.e. computers, internet access) necessary to carry out the training. We also recognized the potential language barrier, given that the majority of our CP members were primarily fluent in Spanish. Additionally we recognized the potential difficulty for some of the CP members in understanding research-specific language, whether in English or Spanish, utilized within the HS web-based training and exam program.

Early in the project planning process, LLU researchers met with administrators of our community partner organization to discuss the HS curriculum and how to conduct the training and certification exam. Realizing the complexity of the task, the Director of LLU's Research Protection Programs (RPP) in the Office of Research Affairs, which provides administrative support for LLU's Institutional Review Board (IRB), agreed in theory to provide the training. A meeting was arranged to meet with leaders from both LLU and our CP to discuss the details. During the meeting with the RPP Director (who also serves as IRB Administrator), the CP Program Coordinator laid out how she envisioned the HS training for their members. One concern was that many of the CP personnel were monolingual Spanish speakers, making it necessary for both the training presentation and materials to be translated into Spanish. Conducting the training in Spanish would require a Spanish translator with the IRB Administrator presenting in English. The discussion turned to whether this process in itself lacked a spirit of respect toward the non-English speaking volunteers. We ultimately agreed on an innovative, more community friendly HS training, featuring our project's bilingual Spanish speaking staff. The first step was for the IRB Administrator to provide a specialized training for the designated bilingual staff. The content addressed key points from the standard "IRB 101" lecture, along with an on-going dialog as to what points needed to be emphasized for the lay volunteers working in the field. After some brainstorming, the idea emerged to depart from the standard lecture format or on-line reading/testing and provide a less formal orientation in which "what-would-you-do" scenarios would be discussed and study-specific ethical guidance provided. Three bilingual Spanish/English speaking ENRRICH team members (two researchers from LLU and the Program Coordinator from our CP) would provide the actual community HS training. A training-the-trainers curriculum was developed, with the CP's Program Coordinator leading out to ensure appropriate content of the effort. The HS training sessions would be part of the orientation on safety and security of the community volunteers.

Development of Training Materials

The IRB Administrator provided an existing HS PowerPoint presentation that had been developed for trainings specific for LLU research personnel campus-wide. Together LLU and our CP research team members revised the existing presentation into material that was culturally and linguistically appropriate for the group, providing definitions of research terms (CBPR, human subjects, informed consent), explaining the science behind air pollution and health as it related to the project, and illustrating ethical principles with real-world scenarios team members were likely to encounter in the field. For this particular partnership, the CP Program Coordinator offered and was able to take the lead in adapting the IRB presentation for their team. Members of the LLU research team provided support to the CP Coordinator in assisting with development of the community training presentation. The overall CP training presentation was developed with the idea to make a slide show that was easy to read and understand. We used text font and colors that were easier to read and made sure to reduce the amount of words on any one slide. Table 2 includes a comparison of the similarities and differences between the content covered in the IRB and the CP presentations.

The final presentation developed for the CP was similar to the IRB training in the overall length of the presentation as well as the coverage of specific topics including: defining human subjects, previous historical events (i.e., Nazi war crimes), and research ethics (respect, beneficence and justice). However, the CP presentation differed from the existing IRB presentation on a number of points. The opening slide of the CP presentation focused on describing their CP organization's mission statement and how involvement in the research study supports their mission. The original IRB presentation opened with a description of the role of an institutional review board. After the introductory slide, the CP presentation included a slide of their main goals for the day: 1) getting to know each other better, 2) building on their existing skills and 3) understanding the basic principles of research. Next, the CP presentation included a brief background description of the research projects their organization was currently involved with and their purpose on each of these research projects. Additionally the CP training differed from the IRB training with a greater emphasis placed on the informed consent process. The IRB training had fewer slides on the informed consent process than the CP and more emphasis on the IRB review process, including: how to submit applications to IRB, deadlines for submissions, different types of IRB review (exempt, expedited, and full board review). One of the major differences between the IRB and the CP training was the inclusion of slides inviting the audience to apply the ethical principles of research through role playing potential "real world" scenarios they could encounter during data collection.

The final HS PowerPoint presentation, available in both English and Spanish, was then submitted to and approved by the IRB. The research team met with the IRB Administrator twice more to discuss the logistics of the training, finalize the agenda, and go over all relevant details. Additional training materials included: presentation handouts, study protocols, consent forms, descriptions of the role playing scenarios, role playing evaluation rubric checklist, an agenda as well as a sign in sheet. Overall it took approximately one month for all the training materials to be developed and for the specifics of the training agenda to be defined. The IRB Administrator, the CP Program Coordinator, and the LLU research team members were all in agreement and felt comfortable with the final HS training program materials and the agenda.

Convening the Community Training

Once the training materials had been created and approved by the IRB Administrator, plans were made and dates confirmed to provide the HS training at the CP's headquarters. The training took one half day to complete (approximately 4 hours). A total of 20 of our CP employees were trained and the entire training took place in Spanish to accommodate the primary spoken language of our CP; simultaneous English language translation was also provided. A CP translator with a headset and microphone translated the training into English for the one community member that spoke only English as well as for the LLU research members who were present. Both the LLU and the CP team members participated in providing the training. Figure 1 includes the agenda for the HS training day. Training began with ice breakers, transitioning into introductions and an overview of the day's agenda. Background on the overall research project, project goals, and research methods were described.

After discussion of the background on the research study, the training moved into presentation and discussion of the core ethical principles (respect, beneficence and justice) of conducting ethical research with human subjects. The CP Program Coordinator presented most of the information on the background as well as on the core ethical principles. The LLU team members focused on describing the current research studies that both the CP and LLU were collaboratively working together. Additionally LLU team members presented information on potential real world scenarios that the CP team members could encounter. The community members were asked to role play real-life situations that could occur while collecting data and to apply the core ethical principles. Examples of role playing scenarios included: approaching a potential participant and describing the research study, obtaining informed consent, and applying the core principles to data collection procedures for participating subjects. After role playing, the presenters continued with the PowerPoint slideshow and a more detailed discussion of the informed consent process and the related informed consent documents. Important emphasis was placed on accurately describing the study to potential participants and active discussions as well as hands-on practice, with an emphasis on working as objective researchers. The CP members were encouraged to actively discuss the informed consent process and how the core ethical principles can be applied, then invited to role-play potential real life scenarios in obtaining informed consent from study participants. Our CP Program Coordinator further enriched the training by adding issues related to security and how to best present oneself in the community.

In conclusion of the training day, the presenters provided a recap of the major points to remember and conducted a question and answer session. Both the CP Program Coordinator and the LLU team members responded to questions from the community members. Throughout the entire training process, breaks were frequently encouraged so that all personnel present could get up and stretch and be better able to focus on the material presented. Refreshments were provided, which helped to create a friendly and relaxed learning environment. A sign in sheet was collected and presented to the IRB Administrator for documentation of all our CP members who were present and received the training. The focus of the training day was on the ethical conduct of research and the partnership between LLU and our CP organization.

Training Evaluation

To evaluate the effectiveness of the community HS training, LLU presenters used a scoring rubric checklist to assess the community partners' knowledge of the ethical research concepts after the training; this was done via role playing of various "real world" scenarios the data collectors might encounter, such as explaining confidentiality, obtaining informed consent, etc., rather than through more traditional pre- and post-training tests. The community members appreciated the role playing technique as both a way to test their understanding of the concepts and to prepare them for their interactions in the community. All the participating CP members passed the evaluation and received human subjects' research certification from LLU.

After the training, the community partners were each asked by the IRB training presenters if the HS training helped prepare them for data collection in the field; their comments are included below:

If the HS training helped prepare them for data collection in the field:

"Yes, it helped me understand how important personal information is and to deal with confidential data." Hispanic Female

"I liked the training program…I learned about doing research the right way and how we are going to go out and collect the data." Hispanic Male

"I'm not as afraid about going out into the field and working on this research project after having the training." Hispanic Female

If the role playing of the real-world scenarios helped them to understand and apply the ethical principles of research:

"Yes, it helped us understand if we really learned the topic." Hispanic Female

"Yes, because it teaches us how to deal with a situation when needed." Hispanic Female

"Using role playing I learned more about what I'm to do in the field and how to help people be part of our study." Hispanic Female

General comments about the training:

"I really enjoyed the training. You did a great job making it fun and we learned a lot." Hispanic Female

"The role playing was the best part of the training." Hispanic Female

<u>Post-Training Debriefing and Recommendations</u>

After the HS training a post-training debriefing was convened between the LLU researchers, the community partner and the IRB Administrator to discuss the overall results and how we could improve on future trainings with CPs in general. One aspect of the training that was helpful was the role playing by our CP members of situations specific to the research study. Instead of written pre- and post testing, training knowledge was assessed throughout the several interactive role plays, questions and topical discussion, demonstrating that everyone who would be certified had an opportunity to present their acquired expertise. Not only did the scenario role playing re-emphasize the ethical principles for human subjects research, but it also helped to emphasize the study protocol and objectives. Evaluation through role playing, not only allowed evaluation of the community member's knowledge of the HS material presented, but also strengthened the relationship between our CP and LLU team members as we were encouraged to actively engage with one another. Also helpful was having multiple question and answer sessions throughout the presentation to evaluate the understanding of the information presented.

Over the entire HS training process, from development through post implementation we learned a number of important lessons. One of the major lessons learned was that all partners (IRB, LLU and CP) were vitally important to the success of an effective HS training program. Notably the IRB staff had been previously exposed to the principles of CBPR and had an active working knowledge about how community- based studies call for differing IRB approaches. Thus our IRB Administrator played a key role in facilitating ethics expectations and did so with a more complete understanding of the community needs. Another lesson learned from the training process is that the HS training materials and trainers should be culturally relevant and designed to meet community members' various educational levels. Originally the collaboration consisted of the CP partners translating the standard HS training written materials, and the IRB Administrator conducting the training at the CP's site. However, after discussion, it became apparent that it would be better to train Spanish speaking members from our research team and our CP, who would then together train the remaining CP members that will be taking part in the research project. Each HS training should be adapted to fit the needs of the specific CP and the community they serve. What works well for one CP may need to be altered to work with a different partner.

Another major lesson we learned is that university's IRB training program could adopt the resulting community-orientated HS training for university researchers working with a CP. The general availability of this model for HS training could assist other researchers on how to interact when collaborating with community partners, to promote an additional ethics layer of protection and university expectations and assure the respectful and ethical engagement with the community. An "IRB Tool Kit" is in the process of being developed and will contain a specialized IRB application for community-based research, appropriate consent templates, models for community-relevant HS training, specific ethical guidance for such research, such as suggestions from community partners on community entry and study conduct. In addition plans are underway to create a contact list of researchers willing to share their community-based research and training experiences. Other LLU researchers working on CBPR projects have since contacted our IRB Administrator to find out more information on providing community-orientated HS trainings. With our permission and encouragement, the IRB Administrator has passed along our contact information for the purpose of allowing other researchers across LLU campus to learn more about our experiences working with CBPR and to share information on providing community friendly HS trainings.

We recommend working from the beginning with one's community partner in developing the HS training material and once the training has been completed obtain feedback from them on what worked well and what to improve. Obtaining feedback will facilitate making improvements for future trainings, such as the annual re-certification and for future trainings for new or replacement staff. In addition, continuing to improve and discuss shared experiences from each other's perspective promotes the value of partnerships which is central to CBPR and strengthens the relationship with the CP.

For future collaborations between universities and local CPs it may be helpful from even the initial meetings to encourage each entity to describe their specific strengths and what they uniquely bring to enhance the quality of the research study. Continual re-emphasis on these highlighted qualities throughout all the trainings with appreciation for each organization's specific strengths helps to develop and promote respect between the two partners.

Conclusion

As CBPR expands and researchers engage more actively with the community, universities need to be prepared to provide community friendly ethical training for human subjects research which will further support CBPR partnerships. While local community partners frequently serve as the bridge to the hard-to-reach communities, universities need to be prepared to create the bridge to meet the needs of the CP. University personnel should have an awareness of potential internal barriers for collaboration with external community organizations. Strategies to overcome these obstacles are crucial in developing successful partnerships to engage underserved communities. Training programs and research studies that identify, integrate, and promotes the core human subjects principles themselves from the very beginning, will create a strong foundation for true partnership which is an essential component for increasing community trust and participation in any research study.

Table 1. Key Barriers and Solutions for Implementation of Human Subjects Training for a Community-based Organization

Need: To use local promotores to more effectively engage local, mostly ethnic minority, low income communities in research. This was a challenge since it was necessary for every data collector to be trained and certified in human subjects' protection principles, yet the existing training was designed for academicians and research.   ***Barrier – Language & Culture:*** Many of our community partner (CP) members are primarily Spanish speaking, many with low levels of education. In general, they felt more comfortable speaking in Spanish. Due to the language and cultural barriers, simply translating the training materials or even using the available Spanish training materials would not address needs in this situation.
***Solution*:** The Loma Linda University (LLU) Research Protection Program, which provides administrative support to the Institutional Review Board (IRB), helped bilingual LLU researchers and CP staff to design and conduct a culturally responsive community training utilizing adult learning principles. The selected LLU team members shared similar cultural backgrounds with community trainees and understood the challenges of implementing IRB requirements in a community setting.
Barrier -- Conventional web-based human subjects training: The human subjects training curriculum is designed for scientific researchers, not the general public. and is not community friendly. The basic IRB web-based training and exam can take even experienced researchers several hours to complete. Although the National Institutes of Health (NIH) provides a Spanish language version for human subjects' ethical training, it is simply a translation of the English training and was not designed for the lay community. For community members who are unfamiliar with research terminology, the web-based version would be too challenging and may prevent some community partners from passing the exam and taking part in data collection. . Using the web-based training also assumes that the CP will have access to and an understanding of computers as well as the Internet, which is often not the case.

Solution: Together, the IRB Administrator, LLU researchers, and CP personnel developed an on-site training program that met the university standards, which did not rely on the use of computers or existing training materials.
Barrier – LLU, which is leading the research effort, is located a distance away from the community partners, few community partners had reliable transportation, and parking at the university was a challenge.
Solution: The community-developed HS training was provided at the CP's site, which is near to the targeted community. Holding the training at their site helped put trainees at ease and made for a more relaxing environment.
Overall barriers were overcome through team work between researchers, community partners and the IRB Administrator. All worked closely together in planning, developing and implementing a community friendly, skills promoting, fun and engaging tailored human subjects training for the community members, focusing on their specific needs and requirements.

Table 2. Comparison of the IRB HS Power Point Presentation with the Community Presentation

Content Area	Description of the Content Area Information	Number of Slides included in the Content Area for the IRB Presentation (31 slides total)	Number of Slides included in the Content Area for the Community Presentation (35 slides total)
Institutional Review Board	Defining what is an Institutional Review Board (IRB).	2	0
Defining Research	Comparison of research with the practice of medicine.	3	0
CBO Background, Mission and CBPR	Describing the mission and the purpose of this particular CBO.	0	5
Training Goals	Outline of the goals to achieve through the HS training session.	0	1
CBO and Research Studies	Description of CBPR and the research projects this CBO is currently partnering with LLU on.	0	3
Human Subjects	Defining human subjects.	1	1

History	Description of previous events in history that has helped identify the need for protection of human subjects: Nazi Medical Experiments, Tuskegee Syphilis Study…etc.	5	2
Belmont Report	Detailed description of the Belmont Report.	1	0
Ethical Principles of Research	Fundamental ethical principles that guide conduct of human research including: *Respect *Beneficence *Justice.	6	7
Informed Consent	The process of conducting informed consent (oral, passive, active).	2	12
Role Playing Scenarios	Invitations to participate in role playing of various "real world" scenarios.	0	2
Types of IRB Review	Types of institutional IRB review: Exempt, Expedited and Full Board.	5	0
IRB Approval Process	Communications with the IRB. Process of obtaining approval. Tips for success in navigating the IRB process, including the LLU research affairs website. Reporting of incidents.	5	0
Conclusion and Summary	Summary of the main points of the presentation, conclusion and questions from the audience.	1	2

Figure 1. Human Subjects Training

Training Day
Agenda

March 24th
11:30 AM – 1:30 PM

11:30 - 12:00	Serve Lunch	
12:00 – 12:30	Welcome / Introductions • Ice Breaker	(Community Partner (CP)) (Loma Linda University (LLU))
12:30 - 12:45	Community Based Participatory Research • Objectives for the day • Partnership	(CP)
12:45 - 1:30	Loma Linda University Studies • Emergency Preparedness • Railyard	(LLU)
1:30 - 2:30	Principles of Research • Respect • Beneficence • Justice	(CP)
2:30 - 3:00	Group Activity: Applying the Principles of Research • Role Play in Pairs – 10 mins • Role Play Demonstration w/feedback – 20 mins	(LLU)
3:00 - 3:30	Informed Consent • It's a process • Important Elements	(CP)
3:30 - 3:45	Group Activity: Applying the Principles of Research • Role Play in Pairs – 10 mins • Role Play Demonstration w/feedback – 20 mins	(LLU)
3:45 - 4:00	Summary, Final Questions and Closing • Next Steps	(CP/LLU)

3.2 Community Perceptions

In addition to the process of developing and refining our quantitative surveys, we also collected qualitative information, in the form of key informant interviews (KIs) and focus groups (FGs), to help us to understand the challenges faced by community members living near the SBR. During our discussions with community members, it was apparent that while community members expressed concern for poor air quality, for them other, more urgent issues took priority -- jobs, neighborhood violence, and access to healthcare, to name a few. They saw railyard as both an asset and a barrier to their ability to live a better life. Participants felt that the railyard has a positive reputation and is highly valued for the jobs and economic growth it provides. However, it was also perceived as a major contributor to the already poor air quality and considered a major source of noise pollution. Several participants believe that living so close to the railyard has caused ailments in family, friends, and neighbors, as well as themselves. None of the community members participating in our study wanted the railyard to close or relocate, but many expressed a strong desire for the railyard to "step up," be a good neighbor, and make reasonable changes to help protect the surrounding community from the noise and air pollution it generates. Attendees reported feeling that the railyard does not listen to the suggestions from residents about ways to reduce the impact their facility has on the surrounding community (i.e. alternate routes; relocating the entry gate to reduce idling truck emissions and traffic burdens; using more updated, less polluting equipment). Some participants feel that they have sacrificed for the benefit of the railyard and are concerned about the health impact of life near such a busy railyard, especially for their children.

The findings from the focus groups have been included in a manuscript which has been accepted for publication in the *Journal of Environmental Health* (see below). In addition to conducting the focus groups and key informant interviews for insights into the opinions and experiences of community residents, we also included questions to the quantitative household survey to assess community needs. Residents were asked, "Is there anything that you would like to see improved within your community?", and the responses coded for recurrent themes and organized into categories. Results from the survey analysis indicated that in addition to concern for the air quality, residents living closest to the railyard had other competing interests (these findings were presented at the Annual American Public Health meeting in Boston, 2013).

While air quality and health were seen as important, people closest to the SBR expressed even stronger concerns about more immediate and tangible issues: lack of police, security, street lighting and repair; and trees and greenery. Overall, the findings from the focus groups, when combined with suggestions from community assessment surveys, indicate the community's desire for strategies to mitigate their exposure to diesel emissions, reduce the possibility of adverse health effects, and for ongoing research to confirm our findings, assess air and noise pollution as well as additional health endpoints (i.e. cognitive function, obesity).

EXPERIENCES OF A RAILYARD COMMUNITY: LIFE IS HARD

Authors

Spencer-Hwang R, Montgomery S, Dougherty M, Gleeson, P, and Valladares J.

Residential Perspective of Life Near a Railyard: A Qualitative Study Exploring the Perspective of People Living Near a Major Railyard in San Bernardino, California.

Acknowledgement

This research was funded by the South Coast Air Quality Management District (SCAQMD)/BP West Coast Products Oversight Committee, LLC grant # 659005 and also supported by NIH # 1P20MD006988.

Accepted for Publication

The Journal of Environmental Health

ABSTRACT

Background: Community groups and local air pollution control agencies have identified the San Bernardino Railyard (SBR) as a significant public health and environmental justice issue. In response, we conducted a comprehensive study with community members living in close proximity to the railyard. The purpose of this paper is to share the community's perceptions about the railyard and ideas on sustainable change.

Methods: A qualitative study was conducted with emerging themes from key informant interviews (N=12) and focus group discussions (N=5; 53 community members). Interviews were audio recorded and transcribed; analyses were conducted using inductive methods of coding and theming.

Results: Four themes emerged: "health as unattainable value," "air quality challenges," "railyard pros and cons," and "violence and unemployment ripple effect." Community participants expressed concern for poor air quality, but other challenges took priority.

Conclusions: Our findings suggest that future mitigation work to reduce air pollution exposure should not only focus on reducing risk from air pollution but address significant co-occurring community challenges. Local institutions, businesses, medical centers, public health departments and universities should work collaboratively to promote critically needed sustainable change. A comprehensive collaborative approach that puts health on the agenda is warranted in addressing impacted communities in close proximity to the goods movement industry.

BACKGROUND

The transportation of goods can both promote and adversely impact health. Goods movement activities can promote health by, for example, enabling access to employment and better services. However, transportation of goods can also degrade quality of life and damage health due to various environmental and societal impacts such as air pollution; climate change; injuries; noise; landscape disruption; diminished sense of community; stress; and anxiety [93]. Environmental health scientists are beginning to elucidate the linkages between the air pollution from international trade and goods movement and health [6, 7].

Mounting research indicates that persons living near transportation hubs and corridors are exposed to higher levels of airborne pollutants, including diesel exhaust and other emissions; the EPA has determined that diesel exhaust is “likely to be carcinogenic to humans by inhalation” [94]. Health impacts from the air pollution associated with goods movement include respiratory illnesses; increased premature death; risk of heart disease; elevated cancer risk; adverse birth outcomes; effects on the immune system; multiple respiratory effects; and neurotoxicity [95-98]; [24, 29, 99-102]. Furthermore, the strengths of associations described for traffic-related exposures are directly related to the proximity to major roadways [103, 104]. Children are especially vulnerable, and those living near freeways have been shown to have substantial deficits in lung function and development as well as exacerbation of asthma symptoms [26, 105-108]; others have linked traffic exposure to increased risk of low birth weight and premature birth [27].

Growing emissions from trucks and trains in regions with major segments of the goods movement network can add to existing air quality problems and impact specific local communities. In the City of San Bernardino, there is one such community located in close proximity to a major freight rail yard, we have identified as the San Bernardino Railyard (SBR). The SBR is one of the busiest facilities of its kind in California and a major inland hub for goods shipped from the ports of Los Angeles (figure 1). The City of San Bernardino and the railroads have been interlinked throughout the nearly 200-year history of the City, with railroad operations changing to predominately freight based operations since the 1990s. With operations running 24/7, the SBR is a crucial hub for freight and shipping for the whole country. Given the nature and intensity of the work performed at the SBR, it is not unrealistic to think air pollution levels in the immediately surrounding areas would be higher relative to other locations within the city. The potential health impacts could also be significant since the facility is close to residential neighborhoods, day care facilities, and an elementary school located within 500 yards of the railyard.

Based on the risk assessments conducted by the California Air Resources Board (CARB), the SBR facility ranks among the top 5 most polluting rail yards in California and first in terms of community health risk due to the large population living in the immediate vicinity [13]. Table 1 summarizes the key socio-demographic indicators of the community members residing within one half mile of the surrounding railyard, obtained through Census 2010 data and modeled with geographic information system (GIS) software. The population immediately around the SBR is defined primarily by young (including a large proportion of children), low income, and largely Latino members. Available health outcomes data suggest tremendous health disparities between the region's African Americans and Latinos and the Caucasian population. While the overall county's poverty rate is 15.8%, the rate for Latinos stands at 34.9%, which far exceeds the overall poverty rate for the state (14.2%), the nation (12.4%) and even California's Latino poverty rate of 28% (U.S. Census Bureau, 2005). Further limiting available support for community members was the 2012 bankruptcy of the city of San Bernardino, making this one of the area's poorest municipalities, with a disproportionate number of neighborhoods facing a host of economic, educational, health, and environmental challenges.

Fueled by the CARB report on the potential health effects for residents, some community members have voiced an urgent call to action to the City's Mayor, politicians, and local researchers to address these environmental justice issues. In response, researchers, in collaboration with residents and a local community-based organization, formed the Environmental Railyard Research Impacting Community Health (ENRRICH) Project. Using a community-based-participatory-research (CBPR) approach, ENRRICH aimed to explore the health risks of residents living in close proximity to the railyard and to support the development of a community response plan. While the overall study goals involve quantitative community and child assessments, the initial research phase used qualitative methods to better understand the context of risk experienced by the residents. As a CBPR study, ENRRICH emphasizes the significant role of community input, ownership, and concerted efforts in risk reduction to produce appropriate, innovative and practical solutions which are cost-effective and sustainable [109]. Therefore, we conducted a qualitative study to gain community members' perspectives about life near the railyard.

METHODS

We conducted this qualitative inquiry using inductive Grounded Theory (GT) methods that included carefully documented participant and site observations.. A GT approach was selected because this method gives participants a "voice" allowing them to share their reality; in fact, creating a 'theory of their lives," grounded in their self-described reality. Rather than acting on our own "expert" opinions, this approach enabled discovery of the participants' main concerns and how they try to solve the challenges, without any prior preconceived hypothesis influencing the results. We collected resident feedback about their perceptions on life near the railyard through the conduct of semi-structured key informant interviews (N=12) which were coded and themed and the results used to design the validation focus groups (N=5 with 8-13 participants each). The focus groups were conducted by trained bi-lingual facilitators and lasted 60-90 minutes. Participants were selected using theoretical sampling to assure triangulation in order to draw a broad variety of perspectives (politicians, community organizers, business owners, residents who represented the local community make-up and cultural identity). More specifically, we asked residents about their lives, exploring their perceived quality of life, health challenges, including their perceptions of the potential effects of air pollution on themselves and their children, and their thoughts on the nearby railyard. Four of the focus groups (two in Spanish with monolingual Latino residents, one each in English with Latino and African American residents) were conducted at a community center near the SBR, while one (conducted in English) was convened at a nearby homeless shelter. Each participant signed informed consent forms that were approved by the university's Institutional Review Board. All interviews and focus groups were audio taped and transcribed verbatim. Once transcribed, the text was coded for emergent codes and a final codebook was developed. Transcripts were read and coded independently by several research assistants, using the coding in conjunction with a constant comparison method; emergent themes were then determined.

RESULTS

A total of 65 adults participated in the key informant interviews and focus groups. Participants included male and female community members ranging in age from 18-60+. Four major themes emerged and are described below: 1) violence and unemployment ripple effect; 2) air quality challenges; 3) pros and cons of the railyard; and 4) health as an unattainable value. Further analysis of themes led to the integration of all four into one core concept:- *Experiences of the Railyard Community: Life is Hard.* Table 2 includes a sample of quotes from the community members surrounding each of the identified themes.

Violence and unemployment ripple effect

Although we discussed other community issues and challenges in the context of air pollution and concerns regarding the railyard it is noteworthy that the high levels of violence, homelessness, and unemployment experienced by many members in this community emerged as a primary issue. At numerous points during the group discussions, the conversation turned to these topics as they clearly affected almost everyone in the community. Drug use and distribution, gang violence, and robberies were cited as daily occurrences, and the safety of family and friends were top priorities. Associated with the high unemployment and prominent in the conversations were reports of increasing numbers of individuals and entire families that were homeless. Together these reports paint a picture of a struggling community plagued with violence and poverty, conditions which some participants felt would not improve. Indeed, this affected the way many residents felt about their exposure to polluted air: while recognizing it as negative they clearly placed it further down their list of priorities compared to daily survival.

Adding to concerns about these pressing community problems was the fear that their children would become just another violence statistic. Participants reported that increasingly families are headed by a single parent who must provide for the entire family and as a result the children and youth often do not have the necessary supervision. Many saw this as a contributing factor to an increase in youth related crime and gang violence. Interviewees expressed a concern about the lack of alternatives and programs for young people in the community. The local community center was identified as the sole remaining safe and fun place to take their kids; a lone asset. Overall, safety for themselves and their families was a top priority for participants, with many expressing desperation and a general lack of control over decreasing the level of community violence.

Community infrastructure was cited as a contributing factor in violence. Since the economic downturn, the few remaining community businesses in the area include liquor and convenience stores, auto shops, bail bondsmen, payday loan stores, and nightclubs, most of which are not viewed as supportive of a healthy lifestyle or environment by the community members. Participants also reported serious problems in the city's infrastructure, such as the lack of sidewalks, faulty or non-existent street lights, increasing numbers of abandoned houses, empty lots with over grown weeds, poorly maintained parks and community centers, and businesses increasingly relocating out of the city, all of which negatively impacts their already struggling community.

As mentioned above, we conducted ethnographies and observed community life as part of our qualitative inquiry. When comparing the neighborhoods surrounding the railyard with other nearby communities, there was a tangible difference in the environment. The area is eerily grey and dusty, and feels abandoned despite its high population density. This in combination with the ever present clanging noises of the railyard creates a feeling of an industrial desert in which residents are somewhat hidden, quickly entering and exiting the homes that provide them some respite from the dust, heat, and noise. Many community members considered moving away from the area, but the low cost of living compared to surrounding communities keeps them here. Residents feel torn between keeping their families in an area where than afford to live but that exposes them to many health and safety hazards *versus* moving to a healthier but more costly area beyond their financial means.

Air Quality Challenges

A second emergent theme, air quality, was woven into the experiences of people living in the Inland Empire area, which is already known for its poor air quality. The majority of participants reported that their adult families or friends often experience poor health and disease, but few saw a link between the air pollution and poor health. For children, respiratory illnesses such as asthma, allergies, and chronic cough were reported as common, ongoing health problems, with many acknowledging that the surrounding environment likely affects their child's condition. Some community participants pointed out children's particular vulnerability, voicing concerns that poor air quality may be affecting their children's health. Even so, during the discussion about air quality, the conversation often returned to the more urgent issue of violence and safety. Many interviewees acknowledged the air quality was not the best, but felt that poor air quality was the least of their worries. They seemed resigned to their lack of control on the air quality issue, and that they are simply trying to "get by" and coexist with the problem.

Railyard Pros and Cons

A third emergent theme, Railyard Pros and Cons, was centered on interviewees' shared perceptions about life near a major railyard. For them, the railyard was seen as both an asset and a barrier to their ability to live a better life. Participants felt that the railyard has a positive reputation and is highly valued for the jobs and economic growth it provides. However, it was also perceived as a major contributor to both the surrounding poor air quality as well as the noise pollution. Several participants believe that living so close to the railyard has caused ailments in family, friends, and neighbors, as well as themselves. However, despite the fact that none of our respondents reported ever having worked or having a relative or a friend who worked for the railyard, none of the community members participating in our study wanted the railyard to close or relocate. Their own experience with unemployment makes them value the potential for jobs for others even if they themselves can't benefit. However, many expressed a strong desire for the railyard to "step up," be a good neighbor, and make reasonable changes to help protect the surrounding community from the noise and air pollution it generates. Attendees felt that the railyard does not listen to suggestions from residents (i.e. alternate routes, more updated equipment) about ways to reduce the impact their facility has on the surrounding community. Some participants feel that they have sacrificed for the benefit of the railyard and are concerned about the health impact of life near such a busy railyard, especially for their children.

More noted than air-pollution, a recurring comment from community members was the unrelenting noise emanating from the railyard, where operations are conducted "24/7." Community members expressed annoyance with the noise, specifically citing the noise of trains and semi-trucks, whistles sounding in the night, and boxcars crashing up against one another. Community members reported that the noise affected their sleep, causing side effects such as tiredness and lack of concentration at school for the kids and on the job for themselves. Many also noted that in addition to the noise the physical "rattling and shaking" has affected them as well as their homes.

In addition, the semi-trucks driving in and out of the railyard to load and unload freight were seen as major contributors to the railyard pollution. Residents noted that despite posted signs prohibiting parking and idling in residential areas, trucks continue to do so near homes and the community park. Residents report that there is little to no enforcement of these posted rules, which was validated during our ethnographies.

Health as an Unattainable Value

Our final theme centered on the idea that our participants feel that, as adults, achieving optimal personal health and gaining access to health care are, for the most part out of their reach – "unattainable"-- and is more than they can realistically expect for themselves. However, they have not yet given up hope that their children will live a better and healthier life, which includes access to routine medical services. That said, the reality for our participants is that few have health insurance or the financial resources to take their child to the physician for regular exams or even when they are sick. Many parents interviewed reported that they saw their children and a large proportion of the children in the community as chronically ill, especially with respiratory illnesses, and that they see it as inevitable that more and more will develop chronic respiratory illnesses.

Interrelationships Among the Themes

Our four emergent themes, while separate, are also clearly interwoven into a single core concept: *Experiences of the Railyard Community: Life is Hard*. The “Life is Hard” theme sums up the experiences of the residents who live adjacent to the railyard. While no one raised the issue of fairness, the residents seem somewhat resigned to their situation, especially for themselves as adults; the only resistance to the status quo came when discussing their children’s health. The theme of violence and unemployment is directly linked with health as an unattainable value, since many community participants reported that lack of jobs translates into a lack of health care access for themselves and their families. Adding to the challenge of lacking access to health care is the fact that living in close proximity to the railyard negatively impacts the respiratory health of children, exacerbating problems and further increasing the need for health care services, clearly a less than ideal situation for raising a healthy family.

DISCUSSION

Our findings indicate that members residing near the railyard live in a community with multiple, significant barriers to their quality of life, with many factors interrelated and stemming from the economic downturn. The major concerns voiced by our participants centered on the high level of community violence, serious economic problems, homelessness, railyard-related noise exposure, and lack of access to healthcare, especially for their children, many of whom suffer from poor respiratory health. Public health scientists are beginning to point to the linkages between how goods and services are accessed and distributed across the nation and various environmental and societal impacts such as air pollution, noise, stress and anxiety, loss of land, and blight that can burden local communities [93]. Increasing evidence reported by the Governor’s Environmental Action Plan, that communities near goods movement ports are subsidizing the movement of goods with their own health, highlights the need for continued intervention and policy advancement aimed at reducing exposure to diesel emissions to protect the health of the public [7].

The health of this community, particularly the more vulnerable subpopulations (i.e. children, elderly), is of great concern given the environment in which they live, their lack of access to health care, and stresses related to violence. It has well been documented that neighborhood-level conditions have a strong impact on individual health status, including morbidity and mortality [110-112]. Additionally, research suggests that disadvantaged populations who suffer from chronic stressors experience even greater susceptibility to environmental hazards [77]. In our target community, 27.6 % of residents live below the poverty line and FBI crime statistics report a per capita violent crime rate nearly 2.5 times the national average. This “double jeopardy” of life-stress and pollution related stressors points to an even greater potential vulnerability for this underserved and overlooked community.

Researchers have identified a strong association between ambient air pollution and other socio-demographically related stressors and adverse health outcomes.

Clougherty et al. (2007) have reported the synergistic effect of traffic-related air pollution and exposure to violence on urban asthma etiology. Chen et al. (2008) have reported that chronic traffic-related air pollution and stress interact to predict biologic and clinical outcomes in asthma that are stronger than either factor alone. Research conducted in southern California indicates that children from stressful households are more susceptible to the negative effects of traffic-related air pollution on respiratory health [11, 12]. Clearly, living in an area in which the adverse health effects associated with air pollution are magnified in the presence of other non-pollution related stressors highlights a critical need for routine medical services and additional support for positive community change.

In our inquiry, it became clear that many community members felt overwhelmed with the day-to-day challenge of simply surviving and providing for their families; these challenges often outweighed their concern for poor air quality, even as they acknowledged its existence. Indeed, during the focus groups some members became irritated with the discussion of air quality and suggested focusing on more pressing issues. Only a small number of participants were vocal about the health effects associated with air pollution, while most had resigned themselves to coexisting with the poor air quality. The internal pressures of day to day living can greatly influence a person's perception of the surrounding community environment and their subsequent behavior, especially given the daily burden of survival [113]. In light of the challenges faced by residents, it is not difficult to understand why air quality might rank lower on their list of priorities.

One notable exception is parents' deep concern for the health of their children. There was awareness that the numbers children diagnosed with asthma is increasing and many believed that most children in the area either already have asthma or will develop it in the future. However, only a few parents connected increased asthma incidence with exposure to pollution from the nearby railyard. As this line of discussion continued, it became apparent that some parents were angry that air pollution from the railyard may be jeopardizing their children's health or the health of children in their community. They found it deeply upsetting that railyard-related air pollution may not only increase their child's risk of developing asthma, but may exacerbate the asthma symptoms of children already diagnosed with the condition, in essence increasing the need for medical services which many families already find difficult or impossible to access. During the discussions it became evident that their children's health was a unifying issue for the community and potential mobilization point.

Implications for Change

In addition to participant feedback about their experiences, we were also able to identify suggestions for things that could be done by the railyard and by other local agencies, businesses, institutions, and medical centers to reduce pollution and their exposure to it. The suggestions focused on improvements which included increased access to medical services and routine health screenings, development of a more extensive vegetation barrier and community wide tree planting campaign, relocation of the entry gate to the railyard to remove truck traffic and related idling from the adjacent neighborhood, and provision of safe and pollution-“freer” places for their children to play. Other ideas discussed included bringing upgraded air filters to local schools and implementing community noise and pollution reduction programs. Table 3 describes the suggested changes for the area in promoting a healthier community. A report by the National Environmental Justice Advisory (NEJA) council to the EPA titled “Reducing Air Emissions Associated With Goods Movement: Working Towards Environmental Justice,” contains advice and recommendations about how the EPA can most effectively promote strategies, in partnership with federal, state, tribal, and local government agencies and other stakeholders, to identify, mitigate, and/or prevent the disproportionate burden of air pollution resulting from goods movement on communities [94]. The NEJA report encourages a sense of urgency in developing strategies and taking action, and advocates for additional research with strong community involvement and capacity building. For this underserved community there is an immediate and great need for sustainable community improvements that address air quality issues, but also consideration for the other pressing needs identified by community participants [114].

The health and environmental challenges faced by this community are likely a common phenomenon faced by communities in close proximity to major goods movement facilities across the nation. Given the gravity of the situation and their challenges, the needs of this community and similar communities should be addressed by policy leaders and advocates by taking a Health in all Policies Approach (HiAP). According to the National Association of County and City Health Officials (NACCHO) HiAP is an innovative and strategic approach through which policies are created and implemented, emphasizing the need for input and collaboration across industry and sectors to ultimately achieve common health goals [115]. The enormity and complexity of the conditions faced by community residents call for the use of a HiAP approach in addressing their health and environmental challenges. Only through a coordinated effort from surrounding key government, business, and institutional agencies will positive improvements be implemented and sustained. Linking community planning to the goals of increasing population health and decreasing exposure to harmful risk factors can be successfully implemented and sustained [116, 117]. A combined approach focusing on the goods movement communities and prevention, which addresses the variety of factors which determine health could address a problem that is drastically and negatively influencing the health trajectory of the community [114].

Limitations

Given the qualitative nature of our study, there are some noteworthy limitations. The information we gained is the opinion of a sample of our target community and may not represent the views of all community members. However, we conducted systematic theoretical sampling to recruit participants from each community stratum to accurately represent community demographics. As a result, we managed to recruit an ethnically diverse group of community participants from varying educational backgrounds and work profiles, including the unemployed and homeless.

CONCLUSION

Our inquiry was successful in providing important insights into the life of community members who live adjacent to a railyard that has been identified as a major source of pollution. Our findings suggest that future efforts to reduce exposure to air pollution must take into consideration other major community challenges, including increased access to health care and a reduction in community violence. Most importantly, there is a need for a coordinated effort of governmental and private entities to strategically address these challenges and provide support for this truly underserved and isolated community. A systematic approach should be taken by policy leaders and advocates with policy development grounded in HiAP addressing communities across the nation that are impacted by the goods movement industry. As we all are the beneficiary of inexpensive goods shipped through this and other container-yards, we have an ethical obligation to support positive community improvements for those who carry an undue health burden as a side-effect of our access to inexpensive goods.

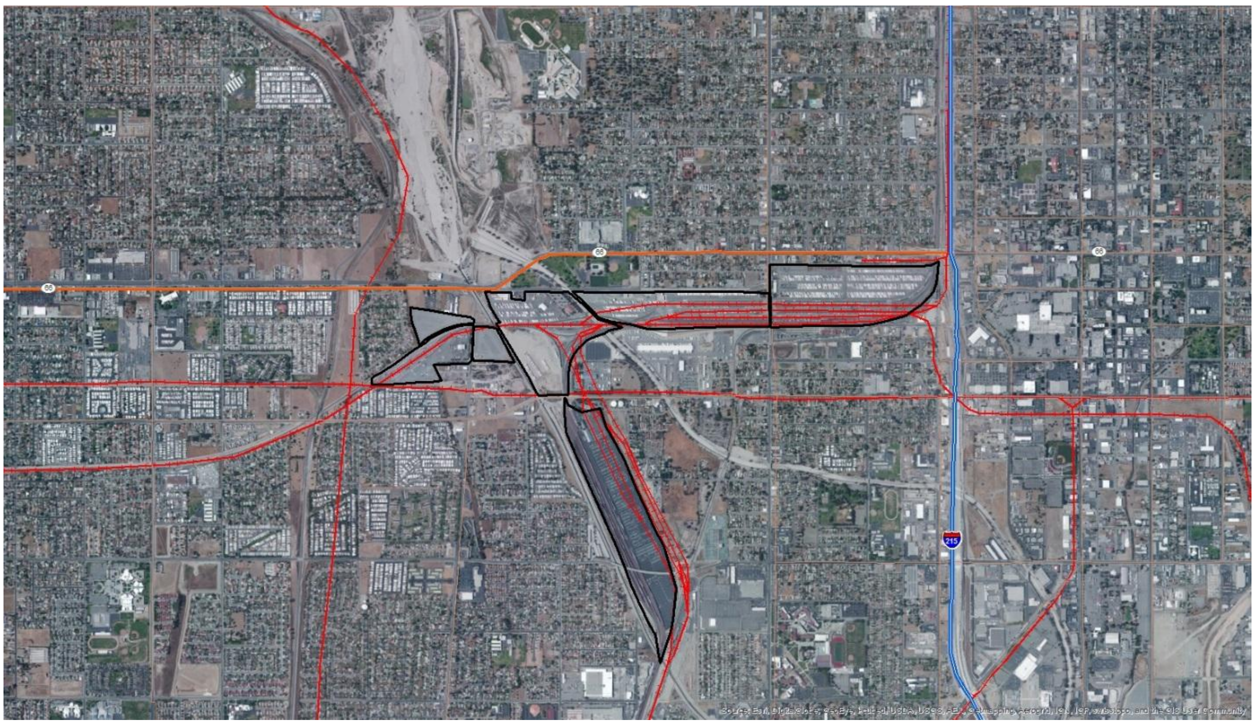

Figure 1. Aerial map of the San Bernardino Railyard and Surrounding Community

Table 1. Socio-demographic Characteristics of the Community Residing Within One-Half Mile of the San Bernardino Railyard

Socio-demographic Variables	
Total Population	7,172
Households	1,895
% African Americans	9.0
% Hispanics	82.3
% Children < 5 years of age	11.7
% Children 5 – 17 years of age	27.5
Median age (yrs.)	25.2
Average household size (persons)	3.9
Median household income	$28,214

Table 2. Community Participant Responses on the Thematic Topics Regarding Life Near A Major Railyard

VIOLENCE AND EMPLOYMENT CHALLENGES
Community violence and unemployment rates affected residents' feelings about their exposure to polluted air, ranking it lower than other, more immediate priorities related to day-to-day survival. *1) "Oh. There's a little bit of everything… People trying to rob you… You just can find yourself in the wrong place, who knows…you might come up on a nice pair of shoes and this dude comes along with a gun and they will be his." – Male* *2) "…. there's more to worry about than the actual air." – Male* *3) "We were at the park…next thing you know, my girls are seeing a stabbing and they, they don't need to see that..." – Female* *4) "….Trust me, I want good health, I want good air, I want the city to be awesome by the time my great-grandkids live here, you know what I mean? But by the same token, I think other things need to be fixed beside that." – Male* *5) "…if you're in San Bernardino and you're in the slum ain't nothing gonna change". – Male* Participants reported feeling powerless to reduce the level of violence in their area, and high levels of concern for their children's safety. *6) "I'm worried about the safety of my children…you can't just have them outside..." – Female* *7) "I think for the youths, they don't have nothing to do…. there's a lot of youngsters from all different areas that hang out right there...these*

kids need something to do with their lives." – Female

Empty lots with over grown weeds and businesses that have relocated out of the city: these are some of the factors negatively impacting the health and vitality of their community.

8) *"…There is just too many abandoned buildings…"– Female*
9) *"I've seen this community go from a family neighborhood to run-down or abandoned houses, empty lots and growing weeds." – Male*
10) *"Most of the businesses are leaving San Bernardino for other cities in the area. We used to have a mall down the street, it's all gone now." – Male*

Community members said they would like to move out of the area, but couldn't afford to.

11) *"I do not like this place, but we chose it because it was the place we could afford. I have lived here for 7 years and the city is cheap, we are here because we don't have more resources to be in another area" – Caucasian Female*
12) *"Unfortunately, this is one of the most economical places to live, but the consequences for living here is too great, not for what you pay financially, but that your health is seriously affected" – Hispanicfemale*

AIR QUALITY CHALLENGES

Participants pointed out that children are most vulnerable and voiced a growing concern that poor air quality may be affecting their children's health.

13) *"I have a nephew and he has allergies awfully bad and it's like blowing his nose and stuff 24 hours a day….. every time I see him he blowing his nose and it seems like the air is more toxic and makes it worse." – Hispanic Female*

14) *"…the people more affected are the kids because they go to school and are breathing contaminated air inside and outside the classroom…here we have one school, less than half a mile from the railyard and the number of asthma cases is increasing." – Hispanic Female*

Some community participants noted the difference in air quality at different times of the day and seasons.

15) *"I'll wake up in the mornings, like, I can't breathe." – Hispanic Female*
16) *"When the weather is the hottest, that is when we have the most kids that are sick, with little kids getting sick with a horrendous cough, like a smoker's cough." – Female*

RAILYARD CHALLENGES

Members understand that semi-truck movement around the railyard is necessary but are frustrated by spotty enforcement of truck idling laws.

17) *"… they're idling in their trucks and there are signs out there saying "do not park your vehicles there". – African American Female*
18) *"They'll park their trucks wherever they wanna park it, and there is nothing to be said about it. You got to go to the right places and get to the right people to respond, because if you don't, they ain't gonna do nothing about it" – African American Male*

Noise pollution causes sleep disturbances and other stressors, including physical "rattling and shaking" of nearby homes caused by railyard activities.

19) *"I guess it was naïve of me to think that when the traffic dies down so will the noise, but there is still a lot of noise happening within the night. I know that it's affecting me and it's also affecting others in the community because they report hearing this especially when they are sleeping." – Hispanic Female*

20) *"Yeah it's pretty loud. You hear it in the middle of the night, BOOM it wakes you up. I live about 2 blocks away and you can still hear it real loud." – African American Female*
21) *"The noise bothers me too much. I live in a mobile home and when the train passes by my house, the whole house shakes. That's where I live and it's a house that I am paying for and that is the sacrifice we are all doing." – Hispanic Female*

Participants felt that they have sacrificed overall quality of life for the benefit of the railyard, and are concerned about health impacts on their families, especially their children.

22) *"I think we like the package from where we live, what we do not like is that the railway is so close because that affects us. My husband has symptoms of asthma, and then allergies follow. My youngest daughter also gets the flu and bronchitis. We would like for the railyard to be more careful." – Hispanic Female*
23) *"I want to say that the contamination that the train brings and the type of fuel that it uses is reflected in the kids' health, for me it is obvious that they go hand in hand." – Hispanic Female*
24) *" …because they continue to use dirty equipment, then that pollutes the air which harms the neighbors. So all we want is really for them to be good neighbors, to be responsible." – Hispanic Female*
25) *"Companies are the masters of the nation and they do not listen to our concerns because for all the calls that have been done to tell them to maintain and update their equipment it appears that we have not done the petition correctly." – Caucasian Female*

HEALTH CARE CHALLENGES

Community participants view health and access to healthcare as an unattainable value for themselves, but haven't given up hope of obtaining it for their children.

26) *"The community worries me, but first I have to worry about my family. Many of us have no health insurance and these diseases, tumors, asthma, having to constantly go to the doctor is expensive, that worries the mom, dad, children, and the whole family." – Hispanic Female*

27) *"I am a grandmother to 6 kids and I don't matter much, but the little ones do." – Hispanic Female*

28) *"The situation with children in this community is very bad. My granddaughter was not sick so often, but since she moved and lives with me she constantly gets sick. " – Hispanic Female*

Table 3. Community Challenges and Suggestions for Positive Change

COMMUNITY CHALLENGE	SUGGESTIONS FOR IMPROVEMENT
NOISE	*Our research team suggests a larger vegetation border surrounding the entire railyard perimeter would help to reduce noise pollution; researchers have found that strategic plant selection has proven effective for noise reduction [118, 119]. The railyard has contributed funding for a vegetation border on a nearby street, but a larger border would be even more beneficial. *Better insulation and thicker windows would reduce noise, especially for those residents living within a few blocks of the railyard. Quiet Solutions, a California based soundproofing manufacturer, has developed a product line that can be applied to existing walls to reduce transmission of sound [120]. Since most noise complaints were associated with close residential proximity to the railyard, one recommendation was that the SBR railyard support and assist nearby residents with the cost of improved insulation and new windows for their homes. *Participants requested that the railyard consider adjusting railyard schedules to decrease overnight traffic, when most residents are sleeping. *Our research team suggested universities and research institutions conduct systematic assessments to monitor noise pollution around the railyard and throughout the community and identify steps to mitigate impact and improve community health and quality of life.
POOR AIR QUALITY	*Currently there is a small vegetation border between the railyard and some homes. To improve air quality and reduce

	noise, a carefully planned, robust vegetation border should be planted to surround the perimeter of the railyard, especially in areas where homes share a retaining wall with the railyard. With strategic planning, urban vegetation has been shown to reduce atmospheric pollutants [121-123]. *Community members suggested moving the entrance of the SBR to a location farther away from homes. Community participants reported that this has been requested many times but has not been implemented. The relocation of the entrance to the SBR should be re-evaluated and a top priority. * Community participants suggested that the railyard take an active role in monitoring and reducing the idling of semi-trucks in residential areas. * Participants requested increased use of less polluting, "clean engines" at the SBR. Though these engines are increasingly used at the SBR, they rotate through all the Company's facilities nationwide, potentially spending less time at SBR, the railyard most closely located to a densely populated residential area. No official reporting on their use is available. The NEJAC report to the EPA advocates for accelerated introduction of existing, cleaner technologies and systems by providing needed resources using incentives, regulatory actions and technical assistance [94]. *Lastly, the research team recommends an increase in air quality monitoring throughout the residential area near the SBR and additional health research to better understand exposures and to inform strategies for exposure mitigation. The NEJAC report advocates for additional research with strong community involvement to accelerate exposure reduction activities [94]. *Policy development and exposure mitigation strategies are needed for schools and child care facilities currently residing in close proximity to a major goods movement source.
LACK OF HEALTH SERVICES	*Local medical institutions and the county public health department should help provide care, specifically targeting the railyard community. One recommendation is to provide more regular and long-term mobile clinics offering free services, especially for children. Even reduced or sliding scale fees at local clinics may cost more than many families can afford. Of

	note, recent efforts by our collaborative have brought a mobile clinic to the community on a regular basis, and though this is a step in the right direction, it does not fully address the health needs of local residents. Mobile clinics are effective in reaching underserved communities and providing cost-effective preventive health services [124].
VIOLENCE	*Participants have requested the community center offer more programs to provide young people with activities and recreation, reducing the time they spend on the streets. However, with San Bernardino's bankruptcy filing it will take major outside funding to support the infrastructure changes needed (i.e. more community programs, repaired sidewalks, increased lighting…etc.). *Participants suggested increased lighting as a way to reduce crime and make people feel more comfortable in their surroundings. Researchers have identified positive effect in use of lighting to reduce crime [125]. *Participants suggested a tree planting campaign to help encourage people to spend more time outside, making their community aesthetically pleasing and providing much-needed shade. Published studies suggest a potential association between trees in public areas and lower crime rates as well as reduced stress levels [126-128].

3.3 HOUSEHOLD-LEVEL HEALTH SURVEY OF ADULT RESIDENTS

The household-level survey was conducted to achieve two primary goals: (1) to establish baseline information on the burden of disease among adult residents in the communities surrounding the SBR, and (2) to assess the potential association between residential proximity to the SBR and the prevalence of adverse health effects. We present below a description of the methodological framework as well as the results from this sub-study.

3.3.1 Study Design

We used a cross-sectional design to assess the relationship between air pollution levels near the SBR, compared to areas outside the RIZ (see **Figure 1-2**), and adverse health effects among nearby adult residents. We collected interviews at households located at varying distances upwind and downwind across the spatial gradient of diesel PM concentrations in the areas surrounding the SBR (see **Figure 3-1**). Residential proximity to the SBR was used as a proxy of exposure. We compared the prevalence of adverse health effects among "exposed" adults—i.e., from households located near the SBR— to that among residents from the "background" areas further away. To account for the seasonal variation in local air quality we conducted two cross-sectional waves of data collection, one in the summer of 2011 and the second in the winter-spring of 2012. In all, over 1,000 households were surveyed to gather data on the prevalence of respiratory symptoms and conditions as well as two biologic outcomes: peak expiratory flow and airway inflammation.

3.3.2 Sampling Strategy

The household survey data were collected from within three sampling zones, A, B, and C, in the communities surrounding the SBR. The location and spatial configuration of the sampling regions are depicted in **Figure 3-1**. We designed these three regions to model decreasing levels of air pollution exposure, from highest (A) to lowest or background (C), away from the SBR. These sampling zones were defined across the spatial gradient of air pollution and associated health risks as presented in the CARB's HRA report (see **Figure 1-2**). As presented in the HRA Report, the gradient was originally derived through the computer-based air dispersion modeling. Cancer risk was then characterized by combining the cancer potency factor of diesel PM with the model-predicted concentrations over space. The result is the overall RIZ (see Chapter 1), within which there is an elevation in modeled cancer risk above the risk due to background impacts. The 10 isopleth, as shown in **Figure 1-2**, defines the boundary of the RIZ. Our reference region C models background exposure levels and closely follows the boundary of the RIZ. Region B roughly corresponded to the impact area contained within the 50-100 x 10^{-6} cancer risk range (**Figure 1-2**). Based on our discussions with colleagues from UCLA, we decided to modify our household sampling scheme by adding region A in order to include in our sample households in very close proximity to the SBR. We defined region A by delineating a 350-meter buffer around the perimeter of the railyard facility; we then considered for sampling purposes every house within region A. This intensive sampling approach was designed to match the sharp decline of diesel PM concentrations which was postulated to occur over a short distance from the SBR.

Within sampling regions B and C, we employed a 2-stage cluster sampling methodology to select our target households. Sixty census blocks within each sampling zone were first randomly selected and then a set of five houses within each census block was chosen. To facilitate rigor as well as ease of selection of households, we used digital street and cadastral maps of the target neighborhoods and selected households for interviews using a GIS-based random number generator tool.

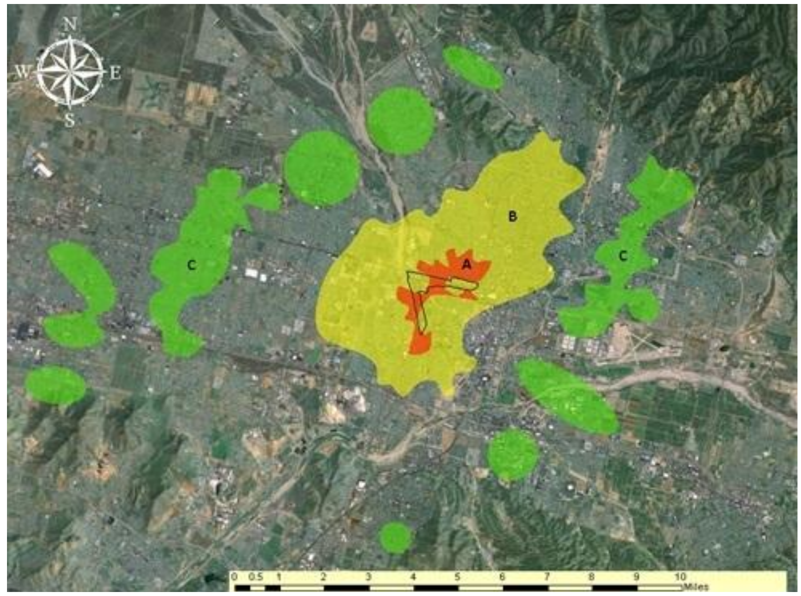

FIGURE 3-1. MAP OF STUDY AREA WITH THE RAILYARD SILHOUETTED IN THE CENTER AND THE SURROUNDING SAMPLING AREAS FROM WHICH HOUSEHOLDS WERE SELECTED FOR THE FIELD HEALTH SURVEY OF ADULT RESIDENTS: A (HIGH EXPOSURE, RED); B (MODERATE EXPOSURE, YELLOW); AND C (COMPARISON, BACKGROUND, GREEN). CROSS-SECTIONAL SUBJECT LOCATIONS ARE NOT SHOWN TO PROTECT THE PARTICIPANTS' CONFIDENTIALITY.

3.3.3 Exposure Definition

For analytical modeling purposes, we defined exposure based on our sampling regions A, B, and C, which denoted residential distance to the railyard as a proxy of exposure to diesel emissions. Three exposure categories were defined: *Exposed*, *High Exposure*, and *Moderate Exposure*. These exposure categories were assigned to participating subjects as follows. First, to define general exposure in our study population, we designated a railyard *exposure zone* (EZ), which included our sampling regions B and A. Thus, study participants who resided in the EZ were classified as *Exposed*. The average distance from subject locations within the EZ to the SBR was 1 mile. Region C served as our comparison or *background* group. The average distance from subject locations in region C to the SBR was 5 miles. *High Exposure* was assigned to study subjects who resided in sampling region A (i.e., the portion of the EZ immediately adjacent to the SBR). Subjects in the *High Exposure* zone were on average less than 0.2 miles from the railyard. *Moderate Exposure* was defined through residence in Region B. Subject locations in the *Moderate Exposure* category were on average 2 miles away from the SBR.

3.3.4 Survey Instrument

A bilingual —English and Spanish— interview instrument was developed by relying on mixed methods research successfully employed by our team and others in the field of public health, to gather information in a culturally competent and linguistically appropriate manner. The process of developing the survey instrument included an extensive literature review and discussion with scientists (LLU researchers and colleagues from UCLA) to identify an exhaustive list of variables (outcome and potential confounders) to assess; it included internal technical discussions, community feedback obtained through key informant interviews, resident focus groups, and meetings with UCLA researchers who had recently conducted a two-year air pollution sampling study in three communities near railyards in southern California: Long Beach, Commerce/East Los Angeles, and San Bernardino. This process helped us identify relevant questions (from both scientific and community perspectives) to incorporate into our household interviews, such as lived experiences as well as attitudes and perceptions regarding the health impacts of residential proximity to the SBR and possible ideas for solutions.

The survey consists of several sections that include questions pertaining to race/ethnicity, description of household SES, history of doctor-diagnosed illnesses, respiratory symptoms, hearing impairment, health history of household members, use of medications, hospital utilization, occupational and residential histories, lifetime and current stress levels, smoking status/history, perception of community noise levels, and indoor sources of air pollution. Additionally, we added questions on desired community changes focusing on air quality, social stressors, and environmental improvements.

3.3.5 Field Data Collection and Training Activities

A suite of data collection tools was procured and assembled in support of the household survey campaign. During the first phase of the study we used a mobile mapping application that combines tablet PCs, mobile GIS, and GPS. This application enabled field teams to capture the geographic location of sites visited in the field while simultaneously collecting and integrating spatial and questionnaire data without the direct input or manipulation by field staff. The basic set of field tools included ruggedized PC tablets (with integrated mobile GIS software and GPS units), peak expiratory flow meters, and NIOX MINO devices, which collect airway inflammation data via fractional exhaled nitric oxide (FE_{NO}). Detailed protocols on the use of the equipment were also developed and attached to each set of field tools.

Early in the study, and simultaneously with our IRB application, we developed the necessary training and research protocols targeted at research assistants and community partners. All field teams received IRB training as well as hands-on training on field data collection protocols as well as the use of the field equipment. Representatives from Aerocrine, the company that manufactures the NIOX MINO devices, also participated in the training sessions to ensure that all team members achieved adequate proficiency in the handling and use of the equipment. The training included all field research procedures, ranging from appropriate interviewing techniques and safety protocols to data recording. During the training sessions participants received audiovisual presentations, participated in hands-on and “mock” field exercises, and were supplied with ample written documentation in English and Spanish which detailed all research protocols and procedures. By the end of the training activities, all members of the field teams were supplied with the necessary equipment and written documentation. By the end of May 2011, the field teams had participated in several pilot tests and provided feedback from those experiences, which was used to fine-tune the survey protocols and field protocols. A final 3-day training session took place in early June in order to review and test all data collection protocols once more with the field teams. The actual data collection effort began in the last week of June, 2011.

Data on self-reported clinical symptoms and adverse health outcomes were collected via household questionnaires. After obtaining IRB approval, the first cross-sectional wave of data collection took place from July through October 2011. The second cross-sectional wave of data collection occurred from March through May 2012. During the two waves of field data collection, we collected surveys from 1,075 households: 346 in region A, 355 in region B, and 374 in region C.

We collected information on health outcomes including diagnoses of asthma by a health professional, relative frequency and severity of respiratory symptoms, health care utilization, and disease-related quality of life impact. We also assessed each study subject for airway inflammation through FE_{NO} using a portable NIOX MINO® instrument (Aerocrine AB, Solna, Sweden), which has been approved by the FDA as a diagnostic tool for airway inflammation. Nitric oxide (NO) in exhaled breath reflects the redox state of the airway and is a biomarker of lung tissue injury and inflammation. Lung function was assessed through PEF measurements using portable Mini-Wright devices (Clement Care, London, UK). The highest of three readings was used in analyses after having been transformed into the percent of the predicted PEF according to the subject's height, age, and gender.

Using GIS techniques, we created indicators of outdoor exposures. Residential proximity to the nearest major road (≤ 100 m, 100-200 m, > 200-300 m, and > 300 m) as proxy for traffic-related air pollution exposures was derived in a GIS by linking the residents' residential locations to the transportation network. To account for exposures to diesel PM emissions from local sources, we used data from the Multiple Air Toxics Exposure Study III (MATES-III), a regional emissions gridded inventory of air toxics developed by the SCAQMD [129]. A 2 km x 2 km GIS raster data set was created to store the MATES data. The combined diesel PM (kg/day) emissions from local stationary, on-road, and off-road sources, excluding emissions from the railyard, were computed for each 2-km x 2-km cell. The residents' address locations were linked to the raster data set in order to assign total diesel PM emissions to each study participant.

3.3.6 Statistical Analyses

Log-binomial regression models were used to estimate the effect of residential proximity as a proxy for exposure to SBR excess emissions on prevalence of respiratory symptoms, respiratory illness, CVD, high FE_{NO}, and low PEF, adjusting for selected potential confounders. Covariates were selected on an *a priori* basis as likely confounders based on suspected relationships. The included confounders were age, sex, race/ethnicity, season, tobacco use, exposure to ETS, time spent outdoors, neighborhood-level median household income, proximity to major roads, and exposure to diesel PM from local (mobile and stationary) sources. Regression analyses were conducted utilizing SAS version 9.3 (SAS

Institute, Cary, NC). The Multivariate Fractional Polynomial (mfp) package in R was used to assess the best transformation for the covariates included in the models.

3.3.7 Results

General Characteristics

A total of 1,075 San Bernardino adult residents from areas surrounding the SBR participated in the household survey effort conducted in 2011 and 2012 (Fig. 3). The general characteristics of our study population are summarized in **Table 3-1**. Mean age of the ENRRICH Study population was 46. Over two-thirds of participating adults self identified as Hispanics (n = 714) and female participants represented about 70% (n=755) of the adult sample population. Almost half (44%) of participants were married and 43% of the participants had lived at their current address 5 years or longer. The highest level of education achieved for 81% of the sample population combined was some college or less. More than two-fifths of the participants reported to be unemployed and less than 25% worked full time. More than one quarter of the study population reported an annual household income below $10,000.

The three sampling regions included roughly even numbers of participants. There was a recognizable trend for certain baseline characteristics across the three sampling regions coupled with increased residential proximity to the SBR, namely, race/ethnicity, marital status, and residence time, which in some cases reached statistical significance. Noticeably, the representation of Hispanic residents in the study sample increased from the background region outside the RIZ towards the SBR. In sampling region A (high exposure), the proportion of Hispanic residents reached 73%, compared to 59% in region C (background). The number of individuals who were unemployed and had an average household income < $10,000 also increased with residential proximity to the SBR. In contrast, the number of individuals who were married, employed full time, and had an average household income > $30,000 increased as distance from the railyard increased.

Environmental Exposures and Behavioral Factors

As presented in **Table 3-2**, environmental and lifestyle exposure characteristics of participating adults varied by sampling region. On average, our study population was within 3.66 km (approximately 2.3 miles) of the SBR perimeter and 4.6 km (approximately 2.9 miles) from the point of projected maximum impact on the north side of the facility. Survey participants in regions A, B, and C were on average within 283 m (0.18 miles), 3,057 m (1.91 miles), and 7,320 m (4.6 miles), respectively, of the SBR.

TABLE 3-1. DEMOGRAPHICS AND BASELINE CHARACTERISTICS[a] OF PARTICIPATING ADULTS ACCORDING TO SAMPLING REGION (A, B, C) AND CORRESPONDING EXPOSURE LEVEL.

Characteristic		All Subjects (N=1,075) No. (%)	A-*High Exposure* N=346 No. (%)	B-*Moderate Exposure* N=355 No. (%)	C-*Background (Comparison)* N=374 No. (%)
Age	*(Mean ± Std. Dev.)*	46.2 ± 58.9	44.8 ± 43.5	43.6 ± 43.0	50.1 ± 44.5
Race/Ethnicity*					
	White	101 (9.4)	17 (4.9)	33 (9.3)	51 (13.6)
	Hispanic	714 (66.4)	254 (73.4)	238(67.0)	222(59.4)
	African American	106 (9.9)	18 (5.2)	51 (14.4)	37(9.9)
	Other	13 (1.2)	1 (0.3)	6 (1.7)	6 (1.6)
Gender					
	Female	755 (70.2)	229 (66.2)	257 (72.4)	269 (71.9)
	Male	320 (29.8)	117 (33.8)	98 (27.6)	105 (28.1)
Highest Education					
	Grade School/Less	275(25.6)	84 (24.3)	106 (29.9)	85 (22.7)
	High School/Cert.	331(30.8)	116 (33.5)	109 (30.7)	106 (28.3)
	Some College	273 (25.4)	79 (22.8)	93 (26.2)	101 (27.0)
	Associates/Bachelor	73 (6.8)	18 (5.2)	28 (7.9)	27 (7.2)
	Masters/Doctoral	10 (1.0)	5 (1.4)	4 (1.1)	1 (0.3)
Marital Status†					
	Single	286 (26.6)	90 (26.0)	104 (29.3)	92 (24.6)
	Married	470 (43.7)	141 (40.8)	157 (44.2)	172 (46.0)
	Divorced/Separated/ Widowed	133 (12.4)	44 (12.7)	48 (13.5)	41 (11.0)
	Live Together	79 (7.4)	29 (8.3)	32 (9.0)	18 (4.8)
Primary Language					
	English	442 (41.1)	126 (36.4)	167 (47.0)	149 (39.8)
	Spanish	521 (48.5)	178 (51.4)	172 (48.5)	171(45.7)
	Other	9(1.0)	1 (0.3)	3 (1.0)	5 (1.3)
Time at Current Address*					
	<1 year	59 (5.5)	18 (5.2)	33 (9.3)	8 (2.1)
	1-<5 years	443 (41.2)	114 (32.9)	180 (50.7)	149 (39.8)
	5-10 years	206 (19.2)	65 (18.8)	67 (18.9)	74 (19.8)
	11+ years	251 (23.3)	102 (29.5)	58 (16.3)	91 (24.3)
	Lifetime	12 (1.1)	8 (2.3)	2 (1.0)	2 (0.5)
Employment Status					
	Unemployed	454 (42.2)	146 (42.2)	160 (45.1)	148 (39.6)
	Part time	119 (11.1)	43 (12.4)	42 (11.8)	34 (9.0)
	Full time	263 (24.5)	76 (22.0)	85 (23.9)	102 (27.2)
	Retired	89 (8.3)	27 (7.8)	37 (10.4)	25 (6.7)
	Student	34 (3.2)	9 (2.6)	14 (3.9)	11 (2.9)
Average Household Income					
	<10,000	291 (27.1)	107 (30.9)	102 (28.7)	82 (21.9)
	10,000-<30,000	356 (33.1)	120 (34.7)	119 (33.5)	117 (31.3)
	30,000-<50,000	140 (13.0)	27 (7.8)	64 (18.0)	49 (13.1)
	50,000-<74,000	41 (3.8)	8 (2.3)	15 (4.2)	18 (4.8)
	74,000+	16 (1.5)	3 (1.0)	8 (2.3)	5 (1.3)

[a] Some columns may not add to 100% due to missing data; *P < 0.05; †P < 0.1.

TABLE 3-2. EXPOSURE CHARACTERISTICS OF PARTICIPATING ADULTS ACCORDING TO SAMPLING REGION (A, B, C) AND CORRESPONDING EXPOSURE LEVEL (*HIGH*, *MODERATE*, *BACKGROUND*).

Indicator	All Subjects N=1,075	A-*High Exposure* N=346	B-*Moderate Exposure* N=355	C-*Background* (Comparison) N=374
Distance to Railyard (m)				
Mean (Std. Dev.)	3,662 (3,352)	283 (206)	3057 (1486)	7320 (2478)
Min.- Max.	3 - 16,301	3 - 1,018	465 -16,301	3,482 - 13,911
Distance to PMI[b] (m)				
Mean (Std. Dev.)	4,624 (3,465)	1,085 (589)	3,9921 (1,329)	8,453 (2,492)
Min.-Max.	79 - 16,778	79 - 2,865	1,521 - 16,778	4,567 - 15,010
Other Exposure Indicators, No. (%)				
Currently Smoking				
Yes	173 (16.1)	44 (12.7)	74 (10.4)	55 (14.7)
No	740 (68.8)	224 (64.7)	262 (73.8)	254 (67.9)
Live with a Smoker†				
Yes, currently	33 (3.1)	7 (2.0)	8 (2.3)	18 (4.8)
Yes, previously	206 (19.2)	43 (12.4)	93 (26.2)	70 (18.7)
Never	642 (59.7)	203 (58.7)	216 (60.8)	223 (59.6)
Household Heating[a]				
None	85 (7.9)	36 (10.4)	25 (7.0)	24 (6.4)
Only Fireplace	56 (5.2)	13 (3.8)	28 (7.9)	15(4.0)
Natural Gas	771 (71.7)	234 (67.6)	281 (79.2)	256 (68.4)
Other	19 (1.8)	4 (1.2)	8 (2.3)	7 (1.9)
Household Cooling[a]				
Open Windows†	318 (29.6)	92 (26.6)	105 (29.6)	121 (32.4)
*Window Unit***	302 (28.1)	136 (39.3)	100 (28.2)	66 (17.6)
*Central Air condition***	384 (35.7)	92 (26.6)	124 (34.9)	168 (44.9)
Portable/Ceiling Fan	328 (30.5)	95 (27.5)	116 (32.7)	117 (31.3)
Other	25 (2.3)	10 (2.9)	7 (2.0)	8 (2.1)
Drink Alcoholic Beverages				
Yes	261 (24.3)	79 (22.8)	100 (28.2)	82 (21.9)
No	649 (60.4)	188 (54.3)	229 (64.5)	232 (62.0)
Fruit < 3 Times/wk*				
Yes	876 (81.5)	279 (80.6)	304 (85.6)	293 (78.3)
No	75 (7.0)	22(6.4)	30 (8.5)	23 (6.1)
Eat Vegetables < 3 Times/wk*				
Yes	875 (81.4)	276 (79.8)	307 (86.5)	292 (78.1)
No	71 (18.6)	26 (7.5)	23 (3.7)	22 (5.9)

[a] Column percent may add to over 100% due to subjects answering yes to more than one category of heating or air conditioning types for their household.

[b] PIM = Point of Maximum Impact (located on the north side of the SBR).

*P < 0.05; **P < 0.0001; †P < 0.1.

Statistically significant differences across sampling regions were found for passive smoking (i.e., living with a smoker), type of house cooling system, and consumption of fruits and vegetables. Compared to regions A and B, sampling region C (background) had slightly higher prevalence of current smoking. Residents in region A, the closest to the SBR, were less likely to live or have lived with a smoker compared to regions B and C. Residents in B were the most likely to live or have lived with a smoker. The number of households with central air conditioning systems noticeably decreased with increasing residential proximity to the railyard, while the opposite is true of households with window A/C units. Consumption of fruits and vegetables falls with increased residential proximity to the SBR. The sharpest contrast with respect to alcohol and fruit/vegetable consumption patterns was between residents in regions C and B.

Distribution of Respiratory and Non-Respiratory Outcomes

Data on self-reported respiratory related symptoms as well as on PEF and airway inflammation results are presented in **Table 3-3**. Respiratory tests identified 38% (n=352) of all subjects with low PEF (< 80% of the predicted value, adjusted for gender, age and height). Intermediate to high FE_{NO} values (≥ 25 ppb) were detected for 19% of study participants (n = 178). Nearly one fifth of all subjects reported a doctor-diagnosed respiratory illness (asthma, bronchial conditions, emphysema) and 10% use a physician-prescribed inhaler. With respect to self-reported respiratory symptoms, close to one-third of all subjects (n = 346) experienced frequent morning or nighttime coughing, 40% (n = 429) said they experienced shortness of breath, 27% (n = 288) reported frequent sputum or mucus from lungs, 28% (n = 303) exhibited wheezy breathing, and almost 20% (n = 210) had a doctor-diagnosed respiratory condition. No statistically significant differences across the sampling regions were found for the respiratory outcomes and symptoms. Regions A and B are relatively close to each other and in some cases region B, although slightly further from the SBR, reports worse health statistics for some of the variables than regions A and C.

The values for participants' self-reported non-respiratory related health characteristics shown in **Table 3-4** illustrate an interesting relationship between the subjects' description of their general health status and increasing residential proximity to the railyard. The number of participants who said their health status is "fair" or "poor" rose with increasing residential proximity to the railyard, while the number of those describing their general health to be "good" or "excellent" increased in the opposite direction (i.e., away from the SBR). Compared to regions B and A, region C's residents tended to report better self-described health status and access to health care services. With the exception of migraines, region C had lower proportions of chronic health conditions including high cholesterol, diabetes, high blood pressure, and allergies. These differences were statistically significant.

Perceptions of Residential Community Characteristics

We also surveyed households regarding perceptions among adult residents about the social and physical conditions of the community. Results of several community indicators are shown in **Table 3-5.** Differences across sampling regions A, B, and C, for most

TABLE 3-3. RESULTS FROM THE BIOLOGICAL TESTS, SELF-REPORTED RESPIRATORY SYMPTOMS, AND DOCTOR-DIAGNOSED RESPIRATORY CONDITIONS OF PARTICIPATING ADULTS BY SAMPLING REGION (A, B, C) AND CORRESPONDING EXPOSURE LEVEL (HIGH, MODERATE, BACKGROUND).

Outcome/Symptom	All Subjects (N=1,075) No. (%)	A-*High Exposure* (N=346) No. (%)	B-*Moderate Exposure* (N=355) No. (%)	C-*Background* (Comparison) (N=374) No. (%)
BIOLOGICAL TEST				
Peak Expiratory Flow (PEF)[a]				
< 80 % of predicted	352 (37.8)	117 (41.1)	119 (36.2)	116 (36.6)
Airway inflammation (FE_{NO})[b]				
NO ≥ 25 ppb	177 (18.9)	56 (19.6)	55 (16.6)	66 (20.7)
SELF-REPORTED RESPIRATORY SYMPTOMS AND CONDITIONS				
Frequent cough (morning/night)	341 (31.7)	106 (30.6)	127 (35.8)	108 (28.9)
Frequent sputum/mucus	288 (26.8)	95 (27.5)	105 (29.6)	88 (23.5)
Wheezy breathing	303 (28.2)	94 (27.2)	115 (32.4)	94 (25.1)
Shortness of breath	429 (39.9)	121 (35.0)	167 (47.0)	141 (37.7)
Doctor-diagnosed respiratory illness	210 (19.5)	63 (18.2)	79 (22.3)	68 (18.2)
Physician-prescribed inhaler use	111 (10.3)	29 (8.4)	46 (13.0)	36 (9.6)
Recently ER visit for respiratory/heart reasons	119 (11.1)	34 (9.8)	48 (13.5)	37 (9.9)
Recently hospitalized for respiratory/heart condition	75 (7.0)	22 (6.4)	27 (7.6)	26 (7.0)

[a] Percentages for each region are based on the number of people from each zone who were able to perform the peak expiratory flow (PEF) test: (A =285, B =329, C =317).
[b] Percentages for each region are based on the number of people from each zone who were able to perform the fractional exhaled nitric oxide (FE_{NO}) test: (A =286, B =331, C =319).

TABLE 3-4. SELF-REPORTED NON-RESPIRATORY HEALTH INDICATORS AND OUTCOMES OF PARTICIPATING ADULTS BY SAMPLING REGION (A, B, C) AND CORRESPONDING EXPOSURE LEVEL (HIGH, MODERATE, BACKGROUND).

Indicator/Outcome	All Subjects (N=1,075) No. (%)	A-*High Exposure* N=346 No. (%)	B-*Moderate Exposure* N=355 No. (%)	C-*Background (Comparison)* N=374 No. (%)
Subject's description of general health status				
Excellent	101 (9.4)	27 (7.8)	36 (10.1)	38 (10.2)
Good	417 (38.8)	119 (34.4)	160 (45.1)	138 (36.9)
Fair	357 (33.2)	133 (38.4)	104 (29.3)	120 (32.1)
Poor	74 (6.9)	21 (6.1)	32 (9.0)	21 (5.6)
Place usually go for medical visits[a]				
Don't go	209 (19.4)	72 (20.8)	70 (19.7)	67 (17.9)
Doctor's office	620 (57.7)	189 (54.6)	220 (62.0)	211 (56.4)
County clinic	130 (12.1)	43 (12.4)	43 (12.1)	44 (11.8)
Emergency Room	136 (12.7)	23 (6.6)	69 (19.4)	44 (11.8)
*Other**	7 (0.7)	1 (0.3)	6 (1.7)	0 (0.0)
Diagnosed with any of the following conditions:[a]				
High Cholesterol†	212 (19.7)	79 (22.8)	69 (19.4)	64 (17.1)
Diabetes†	152 (14.1)	52 (15.0)	56 (15.8)	44 (11.8)
Stroke	11 (1.0)	2 (0.6)	4 (1.1)	5 (1.3)
Angina	20 (1.9)	4 (1.2)	10 (2.8)	6 (1.6)
*High B.P.**	259 (24.1)	86 (24.9)	97 (27.3)	76 (20.3)
*Allergies**	182 (16.9)	56 (16.2)	74 (20.8)	52 (13.9)
Migraines	117 (10.9)	30 (8.7)	42 (11.8)	45 (12.0)
Experienced ringing one/both ears	418 (38.9)	126 (36.4)	157 (44.2)	135 (36.1)
Physician-diagnosed hearing loss	76 (7.1)	27 (7.8)	23 (6.5)	26 (7.0)
Medical services needed in past 12 months, but couldn't access†	229 (21.3)	78 (22.5)	86 (24.2)	65 (17.4)
Medications needed in past 12 months, but couldn't get	158 (14.7)	44 (12.7)	63 (17.7)	51 (13.6)

[a] Column percent may add to over 100% due to subjects answering yes to more than one category of heating or air conditioning types for their household.

*P < 0.05; †P < 0.1.

indicators were statistically significant. In general, negative community perceptions increased with increasing residential proximity to the railyard, from the comparison region C to the exposure regions B and A. This trend was particularly evident in perceptions related to community nuisances such as violence, heavy traffic, or sleep disturbance. For instance, while 44% of those surveyed in region C agree or strongly agree that violence is not a problem in their neighborhood, only 28% feel that way in region A, and 35% in region B. Conversely, the proportion of those who perceive violence as a problem reaches 47% in region A, but only 26% in region C.

Although less pronounced, the differences with respect to perceptions of neighborhood traffic across sampling regions mimic the trend observed for community violence. Almost 20% more respondents in region A, compared to region C, agree or strongly agree that heavy traffic is characteristic of their neighborhood. The proportion (43%) of those surveyed in region A who agree or strongly agree that community noise disturbs their sleep at night more than doubled the proportion (18%) of participants in region C who reported the same concern. A similar trend, with more residents perceiving more favorable conditions away from the railyard, was observed with respect to local exercise facilities and ample opportunities offered to exercise; shade afforded by trees; and availability and selection of fruits and vegetables.

Association Between Residential Proximity to the SBR and Health Outcomes

Exposed subjects, i.e., those residing in the REZ, had higher prevalence ratios for all health endpoints assessed after adjusting for age, sex, race/ethnicity, season, tobacco use, exposure to Environmental Tobacco Smoke (ETS), time spent outdoors, neighborhood-level median household income, proximity to major roads, and diesel emissions from local sources (**Table 3-6)**. The strongest associations were observed for self-reported respiratory symptoms (cough, wheeze, shortness of breath, and sputum), PR = 1.20, followed by self-reported, doctor-diagnosed respiratory illness (asthma, bronchial conditions, emphysema, or use of physician-prescribed inhaler), PR = 1.17, and CVD (angina, high blood pressure, high cholesterol, and stroke), PR = 1.15. The weakest associations overall were found for low PEF and intermediate-to-high FE_{NO} (≥ 25 ppb), PR = 1.06 and PR = 1.08, respectively. The observed associations for respiratory symptoms and CVD were borderline significant.

Suggestive of a dose-response trend, the associations strengthened with the intensification of exposure (i.e., with increased proximity to the railyard, from the *Moderate* to *High* exposure zones) for respiratory symptoms, respiratory conditions, FE_{NO}, and low PEF. However, this was not the case for CVD, as the elevation of this endpoint was greater in the *Moderate* exposure region than in the *High* exposure areas: PR = 1.14 *vs*. PR = 1.07. Across endpoints and exposure levels, elevations were modest, ranging from small (low PEF, PR = 1.06) to moderate (respiratory symptoms, PR = 1.26).

TABLE 3-5. PERCEPTION OF RESIDENTIAL COMMUNITY CHARACTERISTICS AMONG PARTICIPATING ADULTS BY SAMPLING REGION (A, B, C) AND CORRESPONDING EXPOSURE LEVEL (HIGH, MODERATE, BACKGROUND).

Indicator	All Subjects (N=1,075) No. (%)	A-*High Exposure* N=346 No. (%)	B-*Moderate Exposure* N=355 No. (%)	C-*Background (Comparison)* N=374 No. (%)
Violence is not a problem in my community**				
Strongly agree	130 (12.1)	40 (11.6)	37 (10.4)	53 (14.2)
Agree	256 (23.8)	56 (16.2)	89 (25.1)	111 (29.7)
Disagree	233 (21.7)	89 (25.7)	88 (24.8)	56 (15.0)
Strongly disagree	166 (15.4)	72 (20.8)	54 (15.2)	40 (10.7)
I often see children playing outside				
Strongly agree	239 (22.2)	70 (20.2)	88 (24.8)	81 (21.7)
Agree	439 (40.8)	149 (43.1)	142 (40.0)	148 (39.6)
Disagree	114 (10.6)	36 (10.4)	46 (13.0)	32 (8.6)
Strongly disagree	50 (4.7)	21 (6.1)	14 (3.9)	15 (4.0)
My community has heavy traffic†				
Strongly agree	182 (16.9)	72 (20.8)	62 (17.5)	48 (12.8)
Agree	252 (23.4)	77 (22.3)	90 (25.4)	85(22.7)
Disagree	249 (23.2)	73 (21.1)	82 (23.1)	94 (25.1)
Strongly disagree	57 (5.3)	18 (5.2)	15 (4.2)	24 (6.4)
A large selection of fruits and vegetables are available in my community				
Strongly agree	251 (23.3)	70 (20.2)	84 (23.7)	97 (25.9)
Agree	507 (47.2)	148 (42.8)	189(53.2)	170 (45.5)
Disagree	77 (7.2)	33 (9.5)	23 (6.5)	21 (5.6)
Strongly disagree	34 (3.2)	18 (5.2)	7 (2.0)	9 (2.4)
The trees in my community provide enough shade†				
Strongly agree	152 (14.1)	41 (11.8)	65 (18.3)	46 (12.3)
Agree	364 (33.9)	99 (28.6)	141 (39.7)	124 (33.2)
Disagree	185 (17.2)	74 (21.4)	54 (15.2)	57 (15.2)
Strongly disagree	105 (9.8)	48 (13.9)	29 (8.2)	28 (7.5)
Local facilities offer many opportunities to get exercise*				
Strongly agree	139 (12.9)	44 (12.7)	39 (11.0)	56 (15.0)
Agree	264 (24.6)	66 (19.1)	99 (27.9)	99 (26.5)
Disagree	233 (21.7)	78 (22.5)	95 (26.8)	60 (16.0)
Strongly disagree	135 (12.6)	48 (13.9)	48 (13.5)	39 (10.4)
The noise in my community keeps me awake/wakes me up at night**				
Strongly agree	110 (10.2)	67 (19.4)	22(6.2)	21 (5.6)
Agree	173 (16.1)	81 (23.4)	47 (13.2)	45 (12.0)
Disagree	381 (35.4)	86 (23.9)	169 (47.0)	128 (34.2)
Strongly disagree	184 (17.1)	29 (8.4)	64 (18.0)	91 (24.3)

*P < 0.05; **P < 0.0001; †P < 0.1.

TABLE 3-6. ADJUSTED[a] PREVALENCE RATIOS OF THE ASSOCIATION BETWEEN RESIDENTIAL PROXIMITY TO THE SAN BERNARDINO RAILYARD AND RESPIRATORY AND CARDIOVASCULAR HEALTH OUTCOMES.

	Respiratory Symptoms[b] (n = 739)	Respiratory Illness[c] (n = 739)	Peak Expiratory Flow < 80%[d] (n = 728)	FE_{NO} ≥ 25 ppb[e] (n = 712)	Cardiovascular Disease[f] (n = 739)
Railyard Exposure[g]			PR (95% CI)[h]		
Exposed	1.20 (0.97, 1.48)	1.17 (0.87, 1.56)	1.06 (0.86, 1.32)	1.08 (0.76, 1.56)	1.15 (0.96, 1.37)
High	1.26 (0.97, 1.64)	1.21 (0.85, 1.72)	1.07 (0.83, 1.39)	1.21 (0.79, 1.85)	1.07 (0.88, 1.31)
Moderate	1.17 (0.93, 1.47)	1.16 (0.85, 1.58)	1.06 (0.84, 1.34)	1.01 (0.68, 1.51)	1.14 (0.96, 1.36)
Background	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)

[a] Covariates included in the model: Age, sex, race (Hispanic/Not Hispanic), season, tobacco use (current smoking), ETS exposure, time spent outdoors, neighborhood median household income, proximity to major roads (< 300 m from major roadway) , and total diesel particulate matter (kg/day) from local (mobile and stationary) sources.
[b] Includes self-reported: Cough, wheeze, shortness of breath, and sputum.
[c] Includes doctor-told: Asthma, bronchial conditions, emphysema, or use of physician-prescribed inhaler.
[d] Measured peak expiratory flow less than 80% of predicted value based age, gender, and height.
[e] Intermediate to high measured FE_{NO} (fractional exhaled nitric oxide): ≥ 25 ppb.
[f] Doctor-told cardiovascular condition: Angina, high blood pressure, high cholesterol, and stroke.
[g] See *Methods* section for the derivation of the exposure categories: Exposed (mean residential distance to railyard = 1 mile); High (mean residential distance to railyard < 0.2 miles); Moderate (mean residential distance to railyard < 2 miles).
[h] Prevalence Ratio (95% confidence interval) per change in residential exposure category with respect to background exposure (i.e., residence in neighborhoods bordering the *railyard impact zone* as defined in the California Air Resources Board Health Risk Assessment; mean residential distance to railyard < 5 miles).

3.3.8 Discussion

We explored the health risks of living in close proximity to the SBR, a goods movement rail hub, in an urbanized area of inland southern California. Specifically, we assessed the relationship between air pollution near and further away from the facility and adverse health effects among nearby adult residents in an area already impacted by regional air pollution. Residential proximity to the railyard was used as a proxy of exposure to excess railyard diesel emissions. We collected individual-level data for a relatively large, diverse, and representative population sample in the neighborhoods surrounding the SBR. Two waves of household surveys were conducted in the summer and winter to capture the potential differential impact of exposures to regional air pollutants whose concentrations vary seasonally.

Our results show that residing in close proximity to the railyard had small but detectable effects on the prevalence of respiratory and cardiovascular outcomes in adults. Our study adds to the growing body of research that links exposure to traffic and transportation corridors and is novel because of its focus on a major goods movement railyard.

There are several limitations to our study that should be considered. Outcomes were determined and analyses were conducted cross-sectionally. Therefore a cause-effect relationship cannot be established. Another limitation is that residential proximity, i.e., distance to the SBR estimated from the subjects' street address, acts as a surrogate measure for diesel exhaust concentrations, which may lead to the possibility of misclassification of railyard-related air pollution exposure. However, this was the most feasible way of characterizing exposure in our large population sample and in the absence of a dense network of air monitors across our sampling regions, and any non-differential misclassification would tend to bias our results toward the null.[xix] Our definitions of respiratory disease and symptoms were based on self-report, which may also result in misclassification, but questionnaire-based reporting of asthma and other respiratory conditions is widely established in epidemiological studies of respiratory risk.[xx] In addition to self-reported health endpoints, we also collected data on two biological outcomes, PEF and FE_{NO}, which were directly measured on each subject.

The adult outcomes are not as clear and strong as those observed in our study of childhood respiratory health risk. However, there is a trend toward higher prevalence of adverse respiratory health endpoints among persons living in the railyard exposure zone in comparison with the background region further away. Despite its relatively small size (approximately 11,500 acres), we detected variations in the prevalence of the

[xix] Bias towards the null implies that if there is an association between exposure to railyard emissions and a given health outcome, it tends to minimize it regardless of whether it is a positive or negative association. See Vogel C, Gefeller O. Implications of nondifferential misclassification on estimates of attributable risk. Methods Inf Med. 2002; 41(4):342-8.

[xx] On the issue of using questionnaires for asthma assessments, see for example: Remes ST, Pekkanen J, Remes K, Salonen RO, Korppi M. In search of childhood asthma: questionnaire, tests of bronchial hyperresponsiveness, and clinical evaluation. Thorax. 2002 Feb;57(2):120-6.

outcomes within the REZ. There was a trend of increased prevalence of self-reported respiratory outcomes, low PEF, and intermediate-to-high $F_{E_{NO}}$ from the *Moderate* to the *High* exposure regions. In contrast, the prevalence of CVD was higher in the *Moderate* exposure zone than in the *High* exposure region. As noted earlier, the results were not statistically significant, although some of the associations were borderline significant.

Pervasively high levels of background, transported air pollution and emissions from local sources, together with underlying respiratory health challenges and relative socioeconomic/ethnic homogeneity, define an overall exposure setting within which it may be difficult to find a distinct pattern of adverse outcomes with respect to residential proximity to the SBR. We nevertheless were still able to detect elevations with respect to increasing proximity to the SBR, which were consistent across outcomes. This trend appears to fit the expectation of enhanced exposures in the areas near the facility. The SBR is the largest local emitter of diesel PM. In addition, emerging results from a study recently conducted by UCLA scientists indicate that pro-oxidant activity (i.e., cellular oxidative stress), which will lead to adverse health effects, was greater in ambient air samples collected near the SBR compared to samples taken at the Long Beach and Commerce railyards. This finding implies increased toxicity of the air pollution to which local residents near the SBR are exposed.

Our models adjusted for relevant confounders, including age, sex, race/ethnicity, neighborhood-level household income, exposure to ETS, tobacco use, time spent outdoors, proximity to traffic, and diesel emissions from local (mobile and stationary) sources. The fact that even after analytical adjustments we still found modest to moderate elevations across health endpoints does not appear to support the basic hypothesis of no association between residential proximity to the railyard and adverse health outcomes.

CHAPTER 4: SCHOOL-BASED ASSESSMENT OF RESPIRATORY HEALTH

To more comprehensively understand how proximity to a major goods movement rail facility may impact the respiratory health of nearby residents we also conducted a respiratory health assessment of children. Young children have developing respiratory systems and are likely more sensitive to the impact of the additional air pollution from the railyard.

To reach large numbers of children for both exposure and background locations, we conducted health assessments with children at two elementary schools—one located in the high exposure region, adjacent to the SBR, and a socio-demographically matched comparison school several miles away, outside the RIZ. The target school is under the jurisdiction of the San Bernardino City Unified School District (SBCUSD), while the comparison school is under the jurisdiction of the Fontana Unified School District (FUSD). The main purpose of the school assessment was to gather data on the prevalence of respiratory disease and symptoms as well as on biologic outcomes (peak expiratory flow and airway inflammation). All children who attended one of the schools and had active parental consent to participate were included in the study. The start of the school health assessment work was delayed from its planned start date due to unexpected problems with the approval process by one of the school districts. By early December 2011, however, both school districts involved had approved their participation in the health study without reservation. Data collection for the two schools was aligned in time (winter season) to assure similarity in seasonality and weather. Data collection took place on Feb 21-24 at the exposure school and during Feb 27-29 at the comparison school. We decided to collect data in winter since this is usually the “good” air quality season, and thus would give us conservative estimates of impacts of the regional air pollution on the children’s health. The school screenings were carried out in partnership with the San Bernardino County's Arrowhead Regional Medical Center Breathmobile® Program. Children who required follow up medical care were referred to the Breathmobile® asthma program.

4.1 Biological Outcomes Assessment

Once the health screening data from the two participating elementary schools were collected and the resulting data set augmented with potential confounding variables, we analyzed results to assess if the proximity of school children to the major railyard increases the likelihood of adverse respiratory health outcomes. The findings from the assessment of the biological tests (including PEF and FE_{NO}) have recently been submitted as a manuscript to *Environmental Health Perspectives*, detailing the results. We have inserted the full manuscript below. In addition to the submitted text, we have also included an additional section on respiratory health endpoints obtained through the school assessment.

Schoolchildren's Respiratory Health and Proximity to a Major Goods Movement Railyard: The ENRRICH Project

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SHORT RUNNING TITLE

Railyard Proximity and Children's Respiratory Health

KEY WORDS: air pollution, children, respiratory, railyard, goods movement

ACKNOWLEDGEMENTS

This research was funded by the SCAQMD/BP West Coast Products Oversight Committee, LLC grant # 659005 and by NIH # P20MD006988. We thank the Arrowhead Regional Center Breathmobile® for collaborating with Project ENRRICH and the Aerocrine Corporation for donating additional NIOX tests. We are also grateful to Drs. J. Ospital and T. Chico, from the SCAQMD, for providing the MATES emissions data.

COMPETING INTERESTS

The authors have not published or submitted any related papers from this same study. The authors have no financial conflict of interest.

Abstract

Background: Inland Southern California is a region of public health concern, especially for children, given the area's perennially poor air quality and increasing sources of local pollution. An elementary school is located only a few hundred yards from the San Bernardino Railyard, one of the busiest goods movement facilities in California, potentially increasing respiratory problems.

Objectives: Through the ENRRICH (**En**vironmental **R**ailyard **R**esearch **I**mpacting **C**ommunity **H**ealth) Project, we assessed the association of proximity to a major railyard with respiratory health in schoolchildren.

Methods: With parental approval, we provided respiratory screening for children at two elementary schools: one in close proximity to the railyard and a socio-demographically matched comparison school seven miles away. Screening included testing for airway inflammation (FE_{NO}) and lung function (peak expiratory flow, PEF). Parental questionnaires collected demographic and other information. Log-binomial and linear regression were used to assess association.

Results: Compared to children in the comparison school, children attending school near the railyard were more likely to exhibit airway obstruction with higher prevalence of abnormal PEF (<80%): Prevalence Ratio (PR) = 1.59 (95% CI: 1.19-2.12). The association with inflammation was less clear. While children at the exposure school, who had lived for at least 6 months at their current address, were more likely to have values suggesting inflammation (FE_{NO} >20 ppb) (PR=1.44, 95% CI: 1.02-2.02), an elevation but no significant association found through linear regression.

Conclusion: Our findings suggest children attending school and residing in close proximity to a major railyard have significantly higher airway obstruction and possibly increased airway inflammation.

Background

The overall impacts of international trade and the accompanying nationwide movement of goods are generally seen as positive as they are believed to promote employment opportunities and cheaper goods. Relatively little attention has been given to possible health threats to the communities crisscrossed by segments of the complex goods movement system. Residents living near major transportation hubs and corridors are likely to be exposed to high levels of airborne pollutants, which have been associated with the exacerbation of airway inflammation and respiratory disease [130]. Scientific evidence has linked exposure to traffic-related air pollution to reproductive and cardiovascular disease effects, as well as increased respiratory symptoms, increased asthma-related hospitalizations, and higher incidence of asthma [95-97, 131, 132]. Exposure to diesel exhaust in particular has been associated with adverse respiratory symptoms and clinical outcomes [31, 133, 134]. Health risks are even greater for children, a subpopulation considered especially vulnerable to the health effects of air pollution with respect to the exacerbation and initial development of childhood asthma [29, 135, 136].

In California, many minority or low-income children live near transportation corridors and hubs [7]. The California Air Resources Board (CARB) has recently conducted a series of health risk assessments focusing on 18 major freight railyards, which ranked the San Bernardino Railyard (SBR) first in California in potential cancer risk, due to the large population living in the immediate vicinity, and fifth in terms of emissions [13]. The SBR is a component of the massive Los Angeles-Long Beach port complex and its associated inland trade centers, distributing nearly half of the nation's imported goods to the rest of the country.

In light of concerns regarding the enhanced risk of exposure to particulate matter (PM) and other harmful air pollutants among children growing up near the SBR, the primary aim of this research was to explore the association between respiratory function and airway inflammation in schoolchildren relative to their proximity to the facility.

Materials and Methods

Study setting. The SBR is located in a densely populated area in inland southern California characterized by notoriously poor air quality for ozone and particulate pollution. This region has dynamic demographic growth even while facing severe social challenges and a weakened economy. The areas which surround the SBR are home to predominantly young, low-income, Hispanic populations.

Emission sources at this 24/7 railyard facility include locomotives, on-road and off-road machinery, and vehicles. Diesel PM (DPM) is the dominant toxic air contaminant although other air toxics (e.g., benzene and 1,3-butadiene) are also emitted in small amounts [13]. CARB has estimated the SBR's combined DPM emissions and other significant non-railyard (mobile and stationary) sources within a one-mile radius of the facility at 33 tons per year (t/yr) [13]. As depicted in Figure 1, 65% of the facility-wide emissions occur along the northern yard. The total area impacted by DPM emissions encompasses approximately 62,000 acres surrounding the SBR. Within this impact zone, DPM concentrations are greatest near the SBR and gradually subside over distance (see Figure 1).

Study design. We used a cross-sectional design to compare two socio-demographically matched schools: the exposure school (ES), located 500 meters downwind from the SBR, and the comparison school (CS), located seven miles west, which was selected after a GIS-based spatial query outside of a CARB-identified railyard impact zone (RIZ) (see Figure 1). The school closest to the same rail lines crossing the SBR was selected from among a group of candidates located in neighborhoods that matched the GIS-derived socio-demographic signature of the community feeding into the ES. Potential confounders were assessed through a number of different methods including: parental survey, Census 2010 data, as well as additional traffic and emission databases. Potential confounding variables were included if they changed the main effect by 10% or more. A description will follow of the covariates that were included.

After obtaining Institutional Review Board (IRB) and school district approval, an explanatory letter, consent form, and a short questionnaire were sent to the parents of children. To start off the study, an assembly in the form of a theatrical play was conducted at each school. School-based respiratory health screenings were conducted in February 2012 with students from grades K-5.

Questionnaire. The parental questionnaire contained questions on socio-demographic variables; home addresses; residential history; potential indoor environmental exposures (tobacco smoke, pets, and types of heating system used in the home); and level of the child's outdoor play. In addition, there was information about the child's respiratory symptoms and past health history.

Screening clinics. Using trained and standardized technicians, children's peak expiratory flow (PEF) and fractional exhaled nitric oxide (FE_{NO}) measurements were collected, as were anthropometric measurements to determine each child's body mass index (BMI). The screenings were conducted in partnership with the County's mobile clinic Breathmobile® Program. All children who exhibited respiratory values outside normal PEF range or had a parental survey indicating their child had asthma received additional spirometry testing by the medical staff of the Breathmobile® and were offered follow-up medical care through the mobile clinic.

Peak expiratory flow. PEF was assessed using a peak flow meter (Mini Wright, Medline, Mundelein, Illinois). The highest of three readings was used in analyses after being transformed into the percent of the predicted PEF according to the child's height based on manufacturer's guidelines.

Exhaled nitric oxide determination. Nitric oxide (NO) in exhaled breath reflects the redox state of the airway and has been proposed as a biomarker of lung tissue injury and inflammation [137]. FE_{NO} was measured once with the child in a sitting position using a NIOX MINO® instrument (Aerocrine AB, Solna, Sweden), which has been approved by the FDA as a diagnostic tool for airway inflammation.

Potential confounders. Identification of potential confounders was done through literature review and included:

1) *Confounders considered relevant and included on the parental questionnaire.* Sex (male/ female); age (years); grade; race (non-Hispanic White, non-Hispanic Black, Hispanic, Other); furry pets in the home (yes/no); time spent outdoors (<12 hrs. per week, 12-24 hrs. per week, 24+ hrs. per week); exposure to environmental tobacco smoke (yes/no); type of home heating system (gas, wood burning stove/fireplace,

coal/oil, other); length of time at current address (months); BMI (underweight, normal, overweight and obese); and lack of access to medical care (yes/no).

2) Neighborhood characteristics. Using GIS, we created several variables to characterize population density, housing indicators, and household income at the census block group (BG) level using Census 2010 figures and definitions. These neighborhood-level indicators were assigned to study subjects from both schools according to their residential BG.

3) Traffic exposure. We modeled proximity to major roadways as a proxy for residential and school exposure to traffic emissions. Distance between subjects' residential and school locations to nearest major roads (freeway, highway, and arterials) was estimated through GIS mapping methods described previously [103, 138-140].

4) DPM exposure variables. To account for exposures to DPM emissions from local sources, we used data from the Multiple Air Toxics Exposure Study III (MATES-III), a regional emissions gridded inventory of air toxics developed by the South Coast Air Quality Management District (SCAQMD) [129]. A 2 km x 2 km GIS raster data set was created to replicate the spatial coverage and resolution of the MATES-III inventory. The combined DPM (kg/day) emissions from local stationary, on-road, and off-road sources, were computed for each 2-km x 2-km cell. The geocoded student addresses were linked to the raster data set in order to assign total DPM emissions to each subject. DPM emissions were categorized into 3 groups: 0 to < 7; 7 to <9; and greater than 9 kg/day.

Statistical Analysis. Descriptive and summary estimates were assessed and compared between the two schools using Chi-square and t-tests. The association of school location with the two respiratory health measures, PEF and FE_{NO}, was studied separately using linear regression as well as log-binomial regression models for dichotomous outcomes (using established cut-off levels for PEF (< 80% vs 80+) and recommended cut-off levels to assess airway inflammation for FE_{NO} (>=20 vs < 20 ppb), which allowed the calculation of prevalence ratios (PR) and 95% confidence intervals (95% CI). The final model in addition to the school variable included age, gender, race/ethnicity, environmental tobacco smoke (ETS), time spent outdoors, median household income, proximity to nearest major road, and total diesel pollution from local sources. Other covariates described as potential confounders above did not noticeably change the effect of the main exposure and were not included in the final model. An additional set of sensitivity analyses was conducted limiting the study population to students who had lived 6+ months at their current address (N=765). All analyses were conducted utilizing SAS version 9.3 (SAS Institute, Cary, NC).

Results

Of 1,440 children attending the two schools, the parents or guardians of 1,066 (74%) children provided consent for the children to participate and presented themselves for testing; 531 attended the ES and 535 the CS. Two-thirds of participating children lived within < 0.6 miles of their campus and most were Hispanic (83%). Schools were similar with respect to gender, race/ethnicity, BMI category, and time spent outdoors. Of the 1,066 participating students, 1,065 had acceptable and reproducible PEF data and 1,052 had acceptable and reproducible $F_{E_{NO}}$ data. A total of 877 children (ES, n = 435; CS, n = 442) had complete information on all variables that went into the final analytical model and thus constitute our study population (Table 1). Overall 21% of students had PEF results below 80% of the predicted value and 16.3% had high $F_{E_{NO}}$ values, indicative of airway obstruction and/or lung inflammation, respectively.

The association between respiratory outcomes and proximity to the railyard are shown in Table 2. Both the linear regression and log-binomial regression analysis revealed consistent findings across the crude, adjusted, and sensitivity analysis models, indicating that children from the ES exhibited an increased prevalence of poorer PEF results compared to the comparison school. After adjusting for age, sex, race/ethnicity, ETS, time spent outdoors, median household income, proximity to nearest major road, and local DPM emissions, the ES children experienced a significant 59% increase in the prevalence of reduced PEF compared to the CS children (PR= 1.59, 95% CI: 1.19-2.12). Sensitivity analyses with students who resided 6 months or longer at their current address confirmed the earlier PEF results (PR= 1.41, 95% CI: 1.03-1.92). The findings for $F_{E_{NO}}$ were less clear: no association was found using the linear regression model. However, when using the recommended cutoff of 20 ppb, the children in the ES were 33% more likely to have an abnormal value (PR=1.33, 95% CI: 0.95-1.85) compared to the CS. When limiting the analyses to those who had resided at their current address for at least 6 months, the estimate became stronger and statistically significant (PR=1.44, 95% CI: 1.02- 2.02).

Discussion

This research was part of the ENRRICH Project, developed by LLU researchers, to understand how proximity to a major goods movement rail facility may impact the respiratory health of nearby residents and their children. Specifically, we examined the question of whether pollution density near the railyard had an adverse effect on children's respiratory health, in an area already impacted by regional air pollution, by comparing an elementary school in close proximity to the railyard with a socio-demographically matched school several miles away. Our findings of compromised respiratory function among the children attending the school located close to the source of significant DPM pollution are in line with findings by others [141-144]. Through screening we found that children from the ES had poorer test results (26% with PEF <80% of predicted and 18% with $F_{E_{NO}} \geq$ 20ppb) compared to children from the CS (17% PEF <80% of predicted and 15% $F_{E_{NO}} \geq$ 20ppb), suggestive of reduced lung function and increased airway inflammation respectively. Sensitivity analyses suggest a 41% increase in prevalence of low PEF, indicating a significant increase in airway obstruction and a 44% increase in PR with respect to airway inflammation in children attending the ES. This pattern of adverse effects suggests that proximity to the railyard enhances respiratory risk for children.

Together, both biological respiratory tests provide important information that is not compromised by self-report. Others have used PEF when studying traffic-related air pollution and ambient PM and found significant decreases in PEF values for children associated with increase in air pollutants [145-147]. Additionally, $F_{E_{NO}}$ has been used in assessing traffic related air pollution and ambient PM [145, 148]. FE_{NO} also has been found to be a sensitive screening method for early respiratory risk of asthma and for assessing asthma aggravation in asthmatic children [149, 150]. Dales et al (2008) found that it may, in fact, be a more sensitive indicator of adverse air pollution effects than traditional measures of ventilatory function [151]. Nickmilder (2007) found signs of inflammation using exhaled nitric oxide even at levels slightly below the current air quality standards in Belgium [152]. In a recent study where children (ages 7-10) were followed for 3 years, those in the highest FE_{NO} quartile had more than a two-fold increased risk of new-onset asthma compared to those with the lowest quartile (hazard ratio 2.1, 95% CI 1.3-3.5) [153]. The effect of elevated FE_{NO} was most apparent among those without a parental history of asthma. Our FE_{NO} average results are higher than those reported by the University of Southern California Children's Study (13.3 ppb vs 10.9 ppb in the USC study) [154].

In gauging the observed differences in PEF and FE_{NO} between the schools, we must ponder four key issues:

(1). Pollutants, sources, and associated health effects. A fundamental issue to be examined is the evidence that the pollutants from freight railyards can be linked to detrimental health effects. Given previous research we expect that our ES children would be exposed to diesel exhaust, a complex mixture of pollutants composed of vapors, gases, and fine particles [155]. In a railyard study in northern California, researchers measured sulfur, very fine metals, and soot, as well as coarse particles in soil samples and polycyclic aromatic hydrocarbon (PAH) species [156]. They found that coarse PM had high concentrations of diesel-associated particles, petroleum-derived *n*-alkanes, and PAHs, and ultrafine (UF) particles and chemical components associated with exhaust had higher downwind concentrations. Ambient PM and DPM have been associated with a variety of respiratory and cardiovascular problems [18, 19, 24, 157, 158]. In addition, traffic emissions and diesel exhaust have been associated with increased risk of adverse respiratory health in children [26, 135, 159, 160].

(2) Mechanisms of action. Diesel exhaust particles are by mass largely less than 2.5 microns ($PM_{2.5}$) and thus are readily respirable, can penetrate deep into a growing child's lungs, and eventually enter systemic circulation. They have also been shown to promote the release of allergic and inflammatory response mediators in the upper and lower airway [161]. Moreover, particles from incomplete combustion of engine fuels and lubricating oils can bypass the body's defense mechanisms, gain entry to cells and tissues, and alter or disrupt normal cellular function [23]. Emerging evidence indicates that the primary etiologic agents from fossil fuels are pro-oxidant pathways and electrophilic activity that leads to irreversible binding with proteins and DNA [162, 163]. Quinones found in DPM have been identified as being highly reactive and seem to play a critical role in eliciting oxidative stress-dependent cellular toxicity in human pulmonary tissue [162].

(3) Pollutant characterization and population exposure. Our exposed setting is complex, resulting from the intersection of local and regional air pollution processes and conditions. For example, the concentration of quinones, the key agents in the toxicity of PAHs, increases significantly eastward from the harbor areas toward the inland valleys of southern California. Additionally, 90% of quinones at receptor sites inland have been found to be photochemically formed during atmospheric transport, thus increasing their toxicity [164]. This implies that children living near our ES may be at greater risk due to the combined exposures to transported regional air pollutants and railyard emissions. The SBR is the largest source of emissions in the immediately adjacent areas, with an estimated 22 tons of DPM emitted annually, doubling the 10.8 t/yr from all other off-site (mobile and stationary) sources together [13].

(4) Confounding. We carefully socio-demographically matched our CS to our ES and further adjusted for individual-level confounders known to influence respiratory health, such as exposure to ETS in the home and the amount of time the child spends outside. We also assessed the children's ability to access medical care. Finally, we adjusted for potential neighborhood differences that might exist and took into account proximity to traffic and emissions from other local sources.

Strengths and limitations. Our study has a number of strengths. The screening was offered to all children with parental consent from both schools and we had a high participation rate (74%). We used objective biological measurements from participating children, including PEF and $FE_{NO,}$ to assess respiratory health. The CS school was socio-demographically matched to the ES to allow for robust comparisons. Both schools were subject to virtually the same levels of regional air pollution, allowing us to assess risk in an environment already burdened by poor air quality. The data collection was conducted during a winter month when ambient air pollution is lowest in the inland areas of Southern California.

Our research also had some limitations. School location was used as a proxy of exposure and no monitoring data of ambient air pollution levels were available for this study. Future research studies should attempt to collect individual exposure measurements such as equipping children with backpacks that measure air pollution [105, 165], arguably a challenging but important next step. Another limitation was the difficulty of isolating the exposures to railyard-related emissions given the presence of other off-site sources of pollution in the community. However, previous research had already established that the railyard accounts for 66% of the on- and off-site DPM emissions [13]. Although adjustments were made to take these off-site sources into account, it is possible that other sources may have contributed more to the pollution than modeled. Another limitation, which may provide a conservative bias, is that the sickest children might not have been included in the study because they were absent from school during the screening. Lastly, the study results could be influenced by self-report bias for some of the covariates as well as residual confounding.

Public health implications. Freight logistics systems are considered a vital component of modern societies, and are generally seen as beneficial [1]. However, such benefits should not obscure the potential for societal impacts such as air pollution, noise, stress, loss of land, and blight that can burden local communities [2-4]. Only recently have scientists begun to point to the linkages between goods distribution and environmental and societal impacts [5]. The prospect that residents, especially children, who live near ports, rail yards, distribution centers, and along high-traffic corridors could be disproportionally impacted by higher levels of ambient air pollution has prompted the State of California to implement emission reduction strategies specifically focused on international goods movement [6]. Our study represents one of the first investigations into the concerns about the health effects of railyard-related emissions in children. Our findings are consistent with previous exposure studies which indicate that proximity to traffic sources can negatively impact respiratory health in children. Current CARB guidelines recommend avoiding construction of new schools and homes within a mile of a railyard. In 2003, the California Legislature passed SB 352, which requires that a school district verify that any railyard within a quarter mile of a new school will not present a public health threat. However, decades ago when the schools were built, little was known about the health effects of air pollution and the nearby roadways, rail lines and facilities were not nearly as busy as they are today. Even though some older schools are not covered by these guidelines and legislation, public health professionals have a responsibility to consider the impact of these environmental conditions on growing children, especially on children from low income, minority households, where the main focus is on day-to-day survival. Emerging evidence suggests that children from stressed households are even more susceptible to the respiratory health effects of traffic-related air pollution [11, 12]. Other prospective studies, which include enhanced exposure assessment designs, are needed to verify our current cross-sectional findings.

Conclusion

The results from this study support the hypothesis that proximity to a busy goods movement railyard negatively impacts the respiratory health of children, even in an area already afflicted by poor air quality. Previous research and subsequent regulatory efforts have focused on ports and roadways and not goods movement rail facilities. More research is needed from prospective studies to assess the long term impact of rail facilities on children's respiratory health as well as other health outcomes. Ultimately, our findings lend support to the proactive direction taken by the state in instituting and promoting measures aimed at protecting residents of communities near the goods movement network.

Figure 1. Map of the study area, illustrating the location of the San Bernardino Railyard (SBR), and the two participating elementary schools in relation to the transportation infrastructure (railroads and roadways). The inset map displays the full geographic extent of the impact zones in relation to the study area (rectangle).

Table 1. Basic characteristics and main outcomes of participating children

		By School of Enrollment	
	All Subjects (n = 877)	Exposure School (n = 435)	Comparison School (n = 442)
Age, yr, mean ± SD	7.96 $\pm$ 1.8	7.97 $\pm$ 1.8	7.95 $\pm$ 1.8
Race/Ethnicity, n (%)			
Non-Hispanic White	42 (4.8)	19 (4.4)	23 (5.2)
Hispanic	732 (83.4)	356 (81.8)	376 (85.1)
African American	48 (5.5)	32 (7.4)	16 (3.6)
Other	55 (6.3)	28 (6.4)	27 (6.1)
Gender, male, n (%)	414 (47.2)	201 (46.2)	213 (48.2)
Grade, n (%)			
Kindergarten	128 (14.6)	74 (17.0)	54 (12.2)
1st	145 (16.5)	57 (13.1)	88 (19.9)
2nd	161 (18.4)	77 (17.7)	84 (19.0)
3rd	139 (15.9)	71 (16.3)	68 (15.4)
4th	156 (17.8)	81 (18.6)	75 (17.0)
5th	148 (16.9)	75 (17.2)	73 (16.5)
BMI, n (%)			
Underweight (<18.5 kg/m^2)	39 (4.5)	28 (6.4)	11 (2.5)
Normal (18.5 - 24.9 kg/m^2)	481 (54.8)	233 (53.6)	248 (56.1)
Overweight (25.0 - 29.9 kg/m^2)	144 (16.4)	71 (16.3)	73 (16.5)
Obese ($\geq$30 kg/m^2)	213 (24.3)	103 (23.7)	110 (24.9)

Time spent outdoors, n (%)			
< 12 hours	359 (40.9)	183 (42.1)	176 (39.8)
12 – 24 hours	368 (42.0)	187 (43.0)	181 (41.0)
> 24 hours	150 (17.1)	65 (14.9)	85 (19.2)
Lived with smoker, n (%)	188 (21.4)	103 (23.7)	85 (19.2)
Distance to major road			
< 100 m	295 (33.6)	190 (43.7)	105 (23.8)
100 – 200 m	179 (20.4)	76 (17.5)	103 (23.3)
200 – 300 m	180 (20.5)	80 (18.4)	100 (22.6)
> 300 m	223 (25.4)	89 (20.5)	134 (30.3)
Peak Expiratory Flow (PEF)*			
Mean ± SD (L/min)	207 ± 61.8	201 ± 60.5	214 ± 62.4
< 80 % of predicted, n (%)	188 (22.4)	112 (25.8)	76 (17.2)
Exhaled nitric oxide FE_{NO}#			
Mean ± SD (ppb)	13.3 ± 15.1	13.7 ± 15.6	12.9 ± 14.6
≥ 20ppb, n (%)	141 (16.3)	76 (17.5)	65 (14.7)
Median household income, mean ± SD	43,726 ± 13,679	38,755 ± 12,704	48,618 ± 12,826
Diesel exposure, kg/day, mean± SD	7.96 ± 1.47	7.73 ± 1.81	8.19 ± 0.98

* Sample size = 840. # Sample size = 867

TABLE 2. LINEAR REGRESSION AND LOG BINOMIAL MODELING. RESULTS OF CHILDREN AT THE EXPOSURE ELEMENTARY SCHOOL (ES) EXPERIENCING ADVERSE RESPIRATORY RELATED HEALTH OUTCOMES IN CONTRAST WITH THE COMPARISON ELEMENTARY SCHOOL (CS)

	All Subjects				Sensitivity Analysis**		
Linear Regression Analyses			Crude	Adjusted*			Adjusted*
Health Outcomes	N	Events	β (95% CI)	β (95% CI)	N	Events	β (95% CI)
PEF Test Results	877	188	-12.8 (-21.0, -4.66)	-14.9 (-22.2, -7.58)	765	161	-13.0 (-20.8, -5.20)
FE_{NO} #	867	141	0.00 (-0.10, 0.11)	-.01 (-0.13, 0.11)	759	129	0.03 (-0.10, 0.16)
Log Binomial Analyses			Crude	Adjusted*			Adjusted*
Health Outcomes	N	Events	PR (95% CI)	PR (95% CI)	N	Events	PR (95% CI)
PEF Test Results < 80%	877	188	1.50 (1.16, 1.94)	1.59 (1.19, 2.12)	765	161	1.41 (1.03, 1.92)
High FE_{NO} $\geq$20ppb	867	141	1.19 (0.88, 1.61)	1.33 (0.96, 1.86)	759	129	1.44 (1.02, 2.02)

3

Abbreviations: β = regression coefficient; 95% CI = 95% Confidence Interval
* Model=school, age, gender, race, environmental tobacco smoke (ETS), time spent outdoors, medium household income, proximity to nearest major road, total diesel pollution.
**Sensitivity analysis included only subjects residing more than 6 months at their current address.
Log of FE_{NO} + 1

4.2 Parent-Reported Outcomes and Symptoms

In addition to the PEF and FE_{NO} outcomes reported in the submitted paper, we also conducted parallel analyses using log-binomial and logistic regression modeling (see below). Briefly, as in the analyses of the submitted paper above, we used the analyses on children at the exposure school who are experiencing adverse respiratory health and symptoms in contrast with the comparison school and compared endpoints using the two different analyses techniques (log binominal and logistic regression). The endpoints considered were: parent-reported asthma or inhaler use (PRA/Inh); parent-reported asthma or low PEF or high FE_{NO} (SA); cough; wheeze; and parent-reported child visit to Emergency Department for respiratory related problems within last year (ED). Low PEF was defined as < 80% of predicted value based on the age and height of child. High FE_{NO} (airway inflammation) was defined as ≥ 20 ppb NO. For reference, we have included in the same graph the log-binomial and logistic regression results obtained for PEF and FE_{NO} (see Table 2 immediately above). All models were adjusted for age; sex; race; exposure to ETS; time spent outdoors; neighborhood median household income; proximity to nearest major road; and total diesel PM from local (mobile and stationary sources).

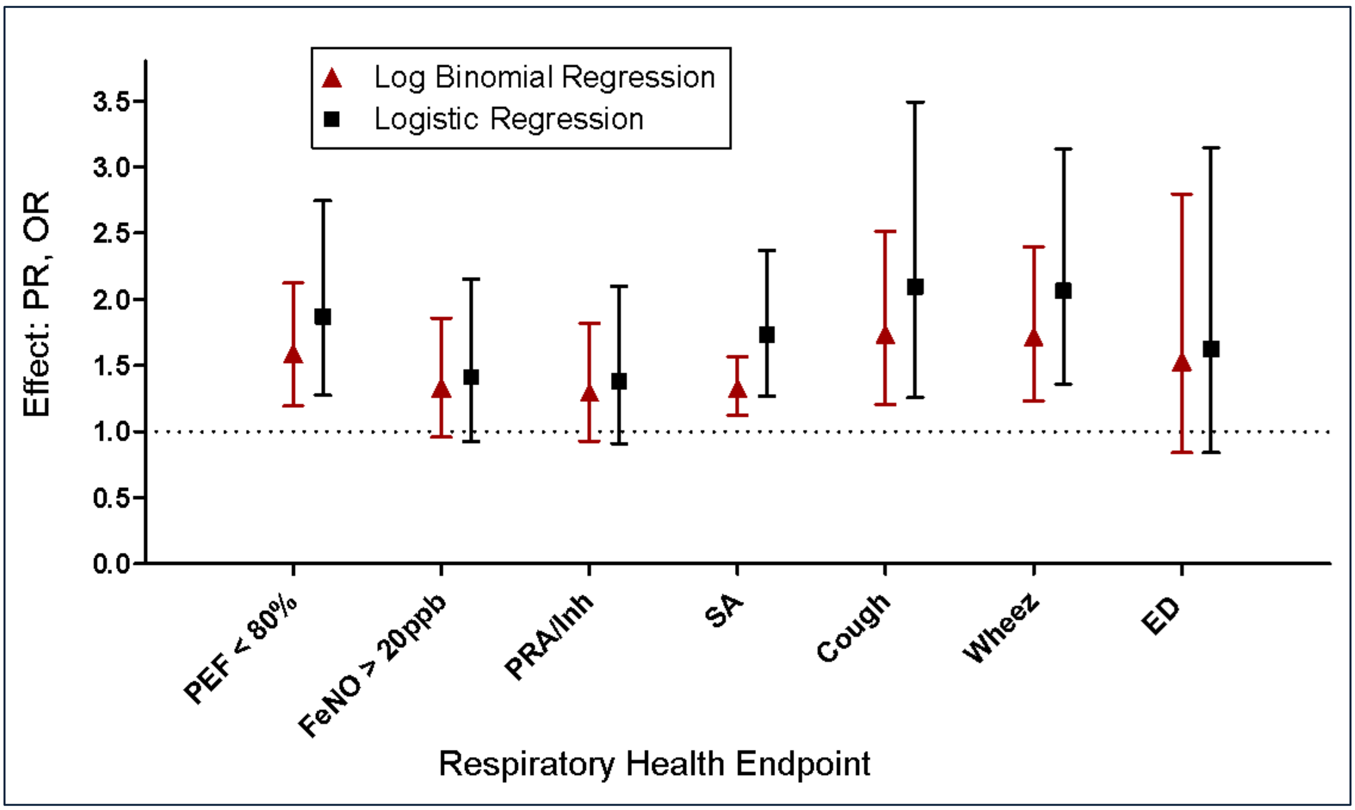

FIGURE 4-1. ADJUSTED PREVALENCE AND ODDS RATIOS OF ASSOCIATION BETWEEN SCHOOL EXPOSURE AND SELECTED RESPIRATORY HEALTH ENDPOINTS

Cough (PR = 1.74/OR = 2.09), wheeze (PR = 1.74/OR = 2.06), and parent-reported asthma/low PEF/high FE_{NO} (PR = 1.33/OR = 1.73) were significantly elevated according to either regression approach. Non-significant elevations were observed for parent-reported asthma/inhaler use and ED utilization for respiratory related problems, PR = 1.30/OR = 1.40, PR = 1.53/OR = 1.63, respectively. Noticeably, log-binomial regressions produced more precise estimates, as indicated by the narrower 95% confidence intervals, compared to the logistic models.

CHAPTER 5: DISSEMINATION & MITIGATION STRATEGIES

5.1 Dissemination Activities

According to a most telling definition, the goal of public health is "to find ways to make people healthy before they are wealthy, and then keep them that way." In order to increase the visibility of our project and enhance its sustainability, while supporting its environmental justice dimension, we adopted a project name that reflected this intention and commitment, Project ENRRICH. ENRRICH is the abbreviation of **En**vironmental **R**ailyard **R**esearch **I**mpacting **C**ommunity **H**ealth. This name was selected from among more than 60 entries submitted by public health graduate students at our school. The adopted project name has been also used to designate the study's web site, which is available at http://www.enrrich.org. The web site contains information about the study and includes mechanisms for visitors to leave feedback and suggestions.

Since early in the study, research team members engaged in various outreach and dissemination activities. For example, the co-principal investigators participated in a roundtable event on the LLU campus organized by the LLU Center for Christian Bioethics. The topic of discussion at the roundtable was the BNSF San Bernardino Railyard as Case Study in Environmental Justice. In addition to the co-principal investigators, participants included San Bernardino City Mayor Patrick Morris, Dr. Tom Dolan, Executive Director of the Inland Congregations United for Change, and representatives of BNSF.

The co-principal investigators, who are members of the AQMD-sponsored San Bernardino Clean Communities Plan Working Group, have delivered special presentations on the ENRRICH Project at meetings of both groups where key stakeholders are represented. The ENRRICH Project has been also featured in a video interview conducted by AQMD with Dr. Beeson, a co-investigator in the study.

Coinciding with the beginning of the household survey data collection effort, we scheduled a press conference in collaboration with the City of San Bernardino. The event was intended to serve as the official launching of the study and to heighten awareness about the project among local residents. The press conference was held on June 8, 2011, at the Ruben Campos Community Center, which is located immediately adjacent to the SBR, and received wide media coverage on local, regional, and national media, including CBS, FoxNews, ABC and Univision, National Public Radio, The San Bernardino Sun, The Riverside Press Enterprise, The Los Angeles Times, and The New York Times. Television coverage featured live footage of the event and interviews with LLU research, officials, and residents. Among the City and County officials who participated in the event were Mayor Patrick Morris, LLU President, Dr. Richard Hart, and San Bernardino County 5th District Supervisor Josie Gonzales, who called on residents to join in the study and assist researchers in their efforts. and

Several members of the research team have also disseminated information about the ENRRICH study, including oral papers and posters, at several professional meetings. We list some of these activities below (a complete list can be found in the project references):

- Title: *Making the IRB Training Community Responsive: Project ENRRICH Experiences in Delivering on the CBPR Promise.* Conference: One Community One Environment Environmental Justice Conference, Detroit, Michigan, August 23-26, 2011.
- Title: *Community Perceptions of Living Next to a Major Railyard: The ENRRICH Project*. Conference: Annual Conference of International Society for Environmental Epidemiology, Barcelona, Spain, September 15-19, 2011.
- Title: *Environmental Justice for Railyard Communities:* A *CBPR Approach*. Conference: Annual Conference of the American Public Health Association, Washington DC, October 29, 2011.
- Title: *Community Health Impact Assessment: The ENRRICH Project.* Conference: Healthy Communities by Design Summit, Loma Linda, California, November 14 and 15, 2011.

5.2 Policy Development and Mitigation Activities

Important to a CBPR approach is the collaboration with community members to develop a sustainable response plan. Through focus groups, survey information, and adult and child health assessments, we have developed a platform for policy and mitigation activities based on the identified challenges and health needs among community members.

5.2.1 Policy Recommendations

For residents in areas such as west San Bernardino, near the SBR, the existing infrastructure can disproportionately affect residents' health. Regulation of interstate road and railway pollution has been traditionally under the Inter-State Commerce Clause and EPA regulations, though specific state laws provide scope for state and local agencies to implement mandates. However, this has led to only limited enforced regulations, especially near residential areas. While zero emissions should remain a working goal, interim steps in reducing diesel pollution are urgently needed. Project ENRRICH is advancing several policy recommendations that can address these needs when implemented through a collaborative effort of agencies at the local, state and federal levels.

5.2.1.2 Federal Policy Recommendation

The 1990 Clean Air Act provides a foundation for national emission standards. Exempt from applicability of such laws are railway locomotives, which are subject to separate EPA regulations for US emission standards for locomotives; applicable in two tiers: tier 0-2 standards for those manufactured from 1973, and tier 3-4 standards (effective from 2015). Data suggest that such general standards may not appropriately protect residents in close proximity to railyards, such as those living near the SBR. New standards to cover nearby residential areas are needed. Tier 3-4 standards require newly built or remanufactured locomotives to use exhaust gas after-treatment technologies which would help to protect residents, but few are used; existing locomotives need stricter regulations, especially when near residential areas. Currently BNSF has purchased several so-called "clean" engines. And while they are a step in the right direction, these cleaner engines are not necessarily *consistently* located in railyards with high potential residential impact. To reduce exposure experienced by local community residents, we suggest 1) retrofitting existing engines with emission control systems, and/or 2) replacing more existing engines with newer models that have more protective technology or use natural gas engines, and 3) placing restrictions on the operation of existing equipment.

5.2.1.3 State Policy

In addition to federal policy recommendations, Project ENRRICH recommends enabling the Federal government to provide broader authority for state and local authorities in regulating railways as per US Health and Safety Code Section 4300 (c) and 43000.5 (d and e). There is a need to promote environmental justice as an integral part of public health, thus expanding the state's role under the 14th amendment of the U.S. Constitution, allowing local agencies broader authority to protect public health and safety. We recommend mandating new zero/low emission technologies on all locomotives of California, as well as mandating the use of Advanced Locomotive Emissions Control Systems. We also suggest more stringent land use and zoning policies to prevent the construction or expansion of freight hubs in residential areas. For existing rail facilities, we suggest implementing stricter zoning laws, including efforts to mitigate air pollution affecting local residents as well as regulations limiting business license allowances based on emission standards. To encourage zero emission locomotives we recommend providing incentives, tax benefits, etc., for the use of these improved engines locomotives, which may be complicated by state or federal tax codes; however, it is important to make financially attractive for railway companies to upgrade their diesel locomotives to a "healthier" fleet.

5.2.1.4 Local Policy Recommendations

In addition to the Federal and state policy recommendations, there is the need to design, get approved and implement local policies that are more proactive in protecting the public's health. Because it is not realistic or reasonable for residents to move or for the railyard to move, we suggest investing in carefully planned, tiered vegetation/tree barriers as borders between the railyard and the local community. Currently there are no buffer zones between the two, and only recently, based on community concerns and pressure, has there been some movement toward such a vegetation buffer. As some mitigation efforts are beginning (BNSF has recently given some funding for a vegetation border for a limited section along their fence) we also suggest to putting in place a longitudinal monitoring system for health outcomes near high burden sites as well as directly monitoring the ambient air quality in several residential areas close to the railyard. There are too few monitoring stations to create a complete picture. All information collected through the monitoring data, as well as results from research studies and their implications for policy change, should be widely disseminated to community residents.

Noise pollution was an often noted concern by residents. There is the need to mandate stricter hours of operation to reduce continuous emissions and noise pollution. Residents who participated in focus groups and interviews were highly vocal about the noise from the railyard. As noted above, it would be helpful to build fences and walls, and plant vegetation borders wherever the railyard abuts residential areas to help buffer noise and block some pollutants. Since these efforts require funding and potentially changes in local regulations (or enforcement of existing ones) that may make the conduct of business more challenging in an area in dire needs for jobs, one should consider raising generalized license fees (area-wide) to assist the residential areas that pay for our access to cheap goods with their health. Similar to the tobacco tax, such a fee could then be used to benefit affected areas adjacent to railyards to help enact public health safety measures.

Clearly there is much to do and it is important to do this in partnership with the community and the railway industry. Residents are very supportive of industry; they simply would like to be healthy *and* able to work and support their families. Therefore there is the need to involve industry in efforts to protect affected communities. Recently, the ENRRICH team held a community meeting with the San Bernardino Rotary Club, which includes members of local businesses, to discuss the development of a vegetation border at the elementary school a few blocks from the railyard. A report by the National Environmental Justice Advisory (NEJA) council to the Environmental Protection Agency (EPA) titled “Reducing Air Emissions Associated With Goods Movement: Working Towards Environmental Justice,” contains advice and recommendations about how the EPA can most effectively promote strategies, in partnership with federal, state, tribal, and local government agencies, and other stakeholders, to identify, mitigate, and/or prevent the disproportionate burden on communities of the air pollution resulting from goods movement [94]. Only through a coordinated effort from key government, business, medical and institutional agencies as well as support from impacted communities will improvements be implemented and sustained.

The health and environmental challenges faced by the community, which was the target of our study, are likely a common phenomenon faced by other communities, which are located near major goods movement facilities. Given the gravity of the situation and their challenges, the needs of these communities should be addressed by policy leaders and advocates, taking a Health in all Policies Approach (HiAP). According to the National Association of County and City Health Officials (NACCHO), HiAP is an innovative and strategic approach through which policies are created and implemented, emphasizing the need for input and collaboration across industry and sectors to ultimately achieve common health goals [115]. The enormity and complexity of the conditions faced by community residents support this approach to addressing their health and environmental challenges.

With this in mind we propose the following:

Reduce pollution at the San Bernardino railyard by developing and implementing a plan with target dates for:

- Converting trucks to alternative fuels
- Converting railyard equipment to alternative fuels
- Installing advanced new “cleaner” railyard technology and engines

In the immediate present, reduce residents’ exposure from railyard pollution by-

- Creating buffer zones – walls and fencing
- Establishing truck routes away from densely populated areas
- Move the railyard entry gate away from the local community center and two local schools
- Expand current plans for a green vegetation border to trap emissions
- Continue to retrofit homes and schools with air filters and new windows

Though prevention efforts are critical and should be pursued through policy and legislation, we have identified significant health challenges for the most vulnerable in the community. Therefore, to improve health outcomes, we recommend that free asthma and respiratory health screenings and referrals for treatment be offered for young children. And while our adult health data findings were less clear, we recommend that free or reduced cost screening and health services are made available for residents, as well as health care for those requiring treatment.

To make this goal a reality, both LLU researchers and our community partners are committed to systematic planning and coalitioning efforts toward these outcomes. This includes:

- Developing a platform for action to address diesel pollution and health impacts.
- A task force of stakeholders, including representatives from 12 local, regional, and state agencies will continue to meet regularly.
- Develop and finalize intervention plans for reducing pollution levels and assign task force members to implement.
- A health response team with at least 4 health agencies will meet regularly and develop a health intervention plan.
- Also, in the next year, CCAEJ will begin work on a demonstration project to address air pollution and its health impacts in the west side neighborhood of the City of San Bernardino. The group plans to inform and engage local residents and continue outreach efforts to educate and inform 300 community members about health impacts from the railyard. Work with local health researchers/experts to develop clear, well-written educational materials in lay language that explain current research findings on the health impacts of particulate pollution.

5.2.2 Mitigation Strategies

Community Intervention

As part of the qualitative, community-based research methods employed by the Project ENRRICH team, we conducted a series of focus groups and key informant interviews to understand the community's needs and wishes, and also to inform the household survey which would be used in data collection. Residents were asked questions such as, "Is there anything you would like to see improved in your community?" Responses were then coded for recurrent themes and organized into categories. Results from the survey analysis showed that while air quality and health were concerns, residents had more immediate and tangible problems – issues with law enforcement, street lighting and repair, and the lack of trees and greenery. In the focus groups, community members gave several suggestions for improving their neighborhoods, which mirrored the findings from the household surveys.

The following are recommendations from community residents who participated in focus groups and completed household surveys:

Railyard Related

- Move the entrance of the SBR further away from homes. Participants reported this has been requested multiple times but no action has been taken. This issue was considered top priority.
- The railyard should take an active role in reducing the practice of semi-trucks idling in residential areas.
- San Bernardino Police should enforce existing ordinances prohibiting idling trucks in residential areas.
- Increase the use of less polluting, “clean engines” at the SBR.
- Implement regular air quality monitoring in the community, especially around the railyard.

Medical Services

- Provide greater access to regular and long-term free medical services in the community.

Community Programs

- Offer more programs at community centers to provide young people with activities and recreation, reducing the time they spend on the streets.

Increased Lighting

- Increase lighting as a way to reduce crime and make people safer in their surroundings.

Tree Planting Campaign

- Plant trees to encourage people to spend more time outdoors, improve aesthetics, and provide much-needed shade. Trees will also help block both noise and air pollutants.

Community-supported Activities

Through the ENRRICH Project we were able to work with the local community and to support needed and desired community improvements. The following includes a detailed description of the various community engagement activities:

Arrowhead Regional Medical Center Mobile Clinic Outreach. Through focus groups conducted with community members living near the railyard, we saw a strong desire for medical services in this underserved community. ENRRICH investigators facilitated the signing of a Memorandum of Understanding (MOU) between the San Bernardino County Arrowhead Regional Medical Center (ARMC) and City officials. Under this agreement, the ARMC’s Mobile Clinic has established a regular schedule of monthly visits to the neighborhoods near the SBR to provide needed medical services and preventive care. The Mobile Clinic started providing free medical services on March 2013 at the Ruben Campos Civic Center, near the SBR. CCAEJ and ENRRICH continue their close involvement with this initiative.

Arrowhead Regional Medical Center Breathmobile®. Through the respiratory screening conducted in our two participating elementary schools, the research team saw first-hand the large number of local children with respiratory illness, or the risk of it.

As part of the group of organizations that made up Project ENRRICH, the Arrowhead Regional Medical Center Breathmobile® Clinic (BC) conducted the asthma and respiratory health screening at the two elementary schools which participated in the study. This mobile clinic currently provides medical care for respiratory health issues at a few schools in the Inland Empire; however, neither of the ENRRICH study schools were on the BC's schedule. Typically, a school nurse or other medical professional at the child's school will identify children suffering from asthma and recommend that the parents bring the child to the BC. The interior of the BC resembles a doctor's office, and is staffed with a licensed registered nurse, a respiratory therapist, a patient service worker and at times, a nurse practitioner or pediatric immunologist. Medical treatment provided by the BC personnel includes physical exams, free medications, spirometry, skin testing, and peak flow meter testing. Families are also educated on the proper use of medications, metered dose inhalers, peak flow meters, spacing devices, and nebulizer treatments as well as ways to make the home more "asthma friendly" through environmental control measures. Evaluation studies have demonstrated dramatic health improvement for patients treated by the BC, including fewer emergency room visits, improved pulmonary function, decreased school absenteeism, and improved quality of life. After the ENRRICH screening project, the BC offered to the exposure school near the SBR to their regular schedule. The school now receives regular visits from the BC.

Figure 5-1. Inside the Arrowhead Regional Medical Center Breathmobile Clinic

Parent Training for Asthma Management. As part of the ENRRICH screening effort at the two target elementary schools, all parents were contacted with the results of their child's respiratory tests. In addition, parents from both elementary schools were invited to informational sessions, conducted in English and Spanish, on how to manage their child's respiratory condition. Parent training sessions were held at both schools in the spring of 2013. The ENRRICH team also also provided asthma training to bilingual community health workers, *promotores de salud,* who are skilled at connecting with hard to reach populations, enabling them to provide information to parents on an ongoing basis. The *promotores* trainings took place on February 12, 2013.

Asthma Award for School Principal. For his support and work with Project ENRRICH, the project team nominated Mr. Luis Chavez-Andere, at the time Principal of the elementary school near the SBR, for the 2012 Air Health Award of Achievement for his work in promoting an asthma friendly school. *California Breathing*, a California Department of Public Health asthma program, gives the Air Health Awards. He was one of 12 elementary school principals selected across the State of California to receive the award, which was presented during a City of San Bernardino City Unified School District Board meeting. LLU researchers also presented him with a check for $1,500 raised through a silent auction held at the LLU School of Public Health. The funds were to be used for any school-related need or project the principal chose.

LLU SPH First 5 Riverside Asthma Program. Building on the experience gained through the ENRRICH project, some members of the research team developed a comprehensive asthma screening and educational program, which was submitted for funding to First 5 Riverside County; the proposal received a four-year contract (2012-2016) for $1.6 million. For this program, we elected to partner with a local community organization, El Sol Neighborhood Educational Center, which utilizes community members for health education presentations. These *promotores de salud,* or health promoters, are especially effective in providing vital health information to hard-to-reach and/or language isolated, underserved segments of the population. Through the program we are expecting to screen thousands of children for asthma and connect them to needed health care services.

The LLU SPH Asthma Education Program (AEP) is a comprehensive, wrap-around package that includes respiratory health screenings for some of the most geographically "risky" children (due to proximity to local air pollution sources) combined with education for the children, their parents/guardians, child care and medical providers about the risks and how to avoid further progression of disease. Using GIS, we have targeted services geographically to "risky" areas with high Emergency Department (ED) utilization, high concentrations of children under 5 years of age, and poor air outdoor quality (i.e. high monitored pollution levels, near traffic and other local pollution sources, etc.). Our overall program design strategically includes four major asthma intervention and educational training components including: 1) asthma education (for children, parents, and child care givers; 2) asthma screening of high risk children with medical referral for those in need; 3) child care facility "asthma friendly" site assessments; and 4) sustainability and policy development. The AEP is aimed at training both children and adults. Children attending a child care facility receive education about asthma through an age appropriate entertaining play and/or puppet show at the child care facility and augmented by educational materials. Children are then participate in asthma health screening and if identified to be at risk, are referred to follow-up medical care. The parents of children identified as having high risk for asthma, are invited to participate in an after-school educational program about follow up preventive care and tips to avoid progression while managing the disease more optimally, thus avoiding crisis episodes. We also provide asthma training to child care facility personnel to better understand asthma, including common triggers and basics about asthma management. Each participating child care facility receives an indoor environmental evaluation to determine if they are an “asthma friendly” site. LLU provides certification to the schools recognizing them as meeting the “asthma friendly” requirements. A subsample of the child care facilities, namely those located in the areas of highest pollution exposure will receive more in depth indoor and outdoor facility site assessments, including air pollution monitoring, to evaluate them for potential environmental triggers and develop plans with the respective Center Directors to help them mitigate their facilities’ exposures. Process and outcome data from all parts of our wrap-around program will be used to determine the effectiveness of the individual program components and to support policy development toward childhood asthma prevention and management.

A unique aspect of the program is the theatrical education component involving stage plays as well as puppet shows. We developed a creative theatrical program to promote a variety of health topics in an educational, but entertaining way. Research indicates that children tend to pay greater attention to what puppets say even when they might not pay attention to a teacher. They also tend to take to heart the things a puppet/or character says more so than when it comes directly from an adult. The play is intended to not only educate the children about asthma, but to also provide information on a healthy lifestyle. Depending on the size of the area at each of the child care centers, the theatrical play can also be adapted to be presented as a puppet show as well. The LLU copyrighted play “Captain Jack Snuffles and the Coughing Crew”, is about pirates with asthma and written for an audience of young children. The play can be conducted in either English or Spanish depending on the needs of the community observing the performance.

FIGURE 5-2. CAPTAIN JACK SNUFFLES’ EDUCATIONAL PLAY PRESENTED AT AN ELEMENTARY SCHOOL IN SAN BERNARDINO. THE PLAY TEACHES CHILDREN AND ADULTS THE A-B-C’S OF ASTHMA AND AIR QUALITY.

Early childhood interventions are critical to address the explosion of asthma related diseases that are costly to individuals, families and government. Only an intentional coordinated approach that leaves behind supportive policies, expertise, and responseready individuals promises some containment of individual suffering and health care costs associated with asthma.

Support for a Vegetation Border. With information gained through focus groups and key informant interviews we identified the desire to develop a vegetation border for the ENRRICH exposure school near the SBR to help potentially block air and noise pollution from reaching the school grounds. **Figure 5-3** below shows the school playground, which is the closest part of the school to the SBR. Positive input was received from the school principal, parents, community members and community stake holders, supporting a school based plan targeting air pollution exposure reduction through use of a vegetation border. On June 6th, 2012 a group of health educators with the ENRRICH Project presented to the local Kiwanis Club, group of many local businesses, on the vegetation border development. They were very keen on supporting the project and asked to be appraised regularly on the progress. A number of additional meetings have been convened to support development of a vegetation border:

- Cal Poly Pomona Department of Landscape Architecture: An expert offered advice and special considerations for effectiveness and aesthetic aspects of the border.
- UC Riverside Botanical Gardens: Experts provided recommendations for the most child-safe tree and plant species.
- We also presented a poster with work on the vegetation border development at the NIH health disparities conference 2012.

FIGURE 5-3. THE RAMONA ALESSANDRO ELEMENTARY SCHOOL PLAYGROUND YARD, WHICH IS CLOSEST TO THE RAIL YARD, IS BORDERED BY A METAL FENCE.

Figure 5-3 shows the scarcity of trees on the school grounds. Shade cover is minimal and the majority of the playground is open grass. It is important to note that the playground is on south side of the school, closest to the SBR. Figure 5-4 illustrates the close proximity to the SBR from the school campus.

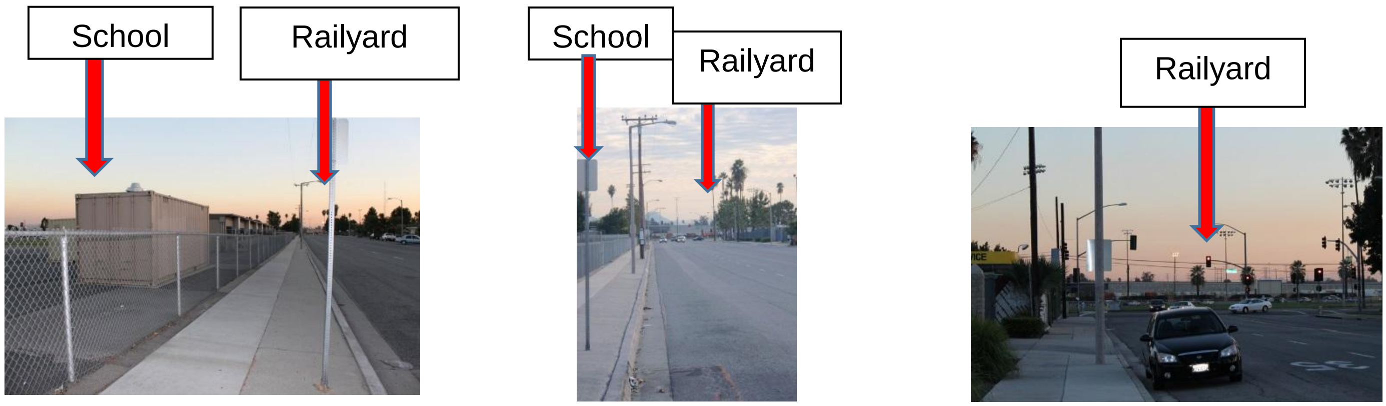

FIGURE 5-4. THREE PHOTOGRAPHS ILLUSTRATING THE CLOSE PROXIMITY OF RAMONA ALESSANDRO ELEMENTARY SCHOOL (LEFT) TO THE BNSF RAILROAD

Other Ongoing Initiatives. BNSF has donated $250,000 towards a traffic-calming project on the street immediately north of the railyard. Two genset switch locomotives have been funded by CARB under the U.S. EPA Diesel Emission Reduction Act. Also, in 2010 the SCAQMD launched the ambitious *Clean Communities Plan* to address exposure to air toxics at the community level and develop plans and solutions involving technology and policy actions through cross-sector partnerships and collaborations. The City of San Bernardino was chosen as one of the two pilot studies where AQMD staff is engaging with community stakeholders to identify and develop solutions community-specific to air quality issues. The ENRRICH Study itself is framed within the overall *Clean Communities Plan.*

CHAPTER 6: DISCUSSION & CONCLUSION

Concerns about health risks associated with elevated exposures to diesel air pollution near goods movement hubs prompted a pollution reduction agreement between CARB and the major rail companies operating in the State. The agreement was launched in 2005 with the goal of achieving diesel emissions reductions in areas near the major California railyards (**Figure 6-1**). As part of the agreement, HRAs were conducted at 18 major railyards in the State, including the one located in the City of San Bernardino. The ENRRICH Project was established out of concerns stemming from the release of the CARB's HRA, which pointed to the potential for enhanced health risks among residents near the SBR.

HRAs —based on a combination of empirical environmental data, toxicity information, and mathematical modeling— are estimates of the potential health impacts on a population at large. HRAs however do not collect data on specific individuals or residents to assess the burden of disease. Together, the ENRRICH study findings shed light on the potential relationship between increasing proximity to the BNSF Railyard and likelihood of experiencing adverse health outcomes.

FIGURE 6-1. DESIGNATED RAIL YARDS UNDER THE CALIFORNIA RAILROAD POLLUTION REDUCTION AGREEMENT.

The study region is an area notorious for long-standing poor air quality and health disparities. A comparison of reported asthma diagnosis for our entire study population, both children and adults, with asthma prevalence statistics reported for the entire San Bernardino County and the State of California, reveals increased adverse respiratory health burden across the ENRRICH Project populations (**Table 6-1**). In comparing the percentage of parents reporting that their child had a physician diagnosis for asthma, the overall asthma prevalence inferred from our study (12.8%) is higher than both the prevalence for San Bernardino County (12.2%) and California (11.6%) [166]. For adults, 12.6% of our study population reported a physician diagnosis for asthma compared with only 7.6% prevalence for both San Bernardino County and the State. These statistics suggest that residents in the ENRRICH study region experience respiratory health challenges. However, despite these shared challenges faced by our study populations, findings from our analysis by exposure site suggest that the community members living in closer proximity or attending school near the SBR may be experiencing an even greater health burden when compared to residents in areas further away. We recapitulate and discuss below the key findings from the three sub-studies of the ENRRICH Project: population-based cancer assessment; household health survey of adults; and elementary school-based assessment of respiratory health of young children.

TABLE 6-1. SELF-REPORTED, PHYSICIAN DIAGNOSIS FOR ASTHMA FOR ADULT PARTICIPANTS IN THE ENRRICH STUDY COMPARED WITH STATE AND COUNTY PREVALENCE.

	Region					
			ENRRICH Study			
	California	San Bernardino County	Total Population (n = 119)	High Exposure (n = 42)	Moderate Exposure (n = 38)	Background (n = 39)
Asthma Prevalence	7.6%	7.6%	12.6%	14.3%	11.3%	12.3%

6.1 Population-based Cancer Assessment

Our assessments of observed and adjusted expected counts of new cancers among residents of the SBR exposure areas identified mixed findings of deficits, no difference and excesses in observed counts of new cancers compared to expected numbers in some race/ethnic groups and by sex. Some of the observed elevations were small and non-significant while we also found statistically elevated numbers of observed new cancers. Disparate findings for the race/ethnic groups and between the sexes and contradictory findings for the three excess exposure zones do not provide clear evidence that exposure to airborne emissions from the SBR elevate cancer occurrence in the surrounding community.

The most remarkable findings were the higher than expected counts of new cancers identified among Hispanic females and males and for non-Hispanic white males for the combined railyard exposure area, and the decreased risk among Asian/Other residents of this combined exposure area are worthy of further exploration. Factors such as residence times, differential past/current smoking and socioeconomic patterning may account for some of the observed excess cancers, particularly among non-Hispanic Whites and Asian/Other groups. However, findings for higher than expected observed counts for new cancers among Hispanic males (all cancers) and females (all cancer sites combined and breast cancer) is largely unexplained and may provide the strongest evidence that excess air pollution emissions from the SBR could contribute to an excess in observed cancer counts.

Overall, the significant elevations that were observed would be considered to be weak (SIRs < 1.5) to moderate/strong (SIRs > 1.5) by conventional epidemiologic standards, but they are not trivial from a public health perspective and in tune with the magnitude of effect observed in a good number of environmental epidemiologic analyses. As a general principle, while it is true that the greater the magnitude of risk, the less likely the association is to be spurious or due to confounding bias, a causal association should not be ruled out simply because a weak association is observed.

The picture that emerges from our cancer assessment is certainly complex, including both intuitive and not altogether intuitive findings. Its multifactorial character, different etiologies, and variable latency periods make cancer a challenging biological endpoint in air pollution health assessments. Our findings might also be confounded by differences in presence, level, and duration of risk factors such as tobacco use between the sexes, race/ethnic groups, and according to income, education, and cultural subgroups that likely exist in the railyard exposure areas and the standard population.

In addition, a number of known factors may influence the susceptibility of the population and thus may impact population risk. Our investigation did not include information on previous residence history or duration of residence in the study area or the standard population, although we have provided in this discussion some estimates of residence length, based on the ENRRICH household survey, which seem to point towards residential stability among Hispanic and non-Hispanic white residents.

In spite of its limitations and the intricacies inherent to the exposure setting, our design included adjustments for age, race, sex, and population size changes. A clear-cut, unambiguous association between exposure to excess emissions from the SBR and elevated cancer risk among nearby residents cannot be firmly establish from our analysis. However "no risk has been shown" is not a statement that can be made either, mainly, in light of the findings for Hispanic residents.

6.2 Adults—Community Health Assessment

We explored health risks of living in close proximity to the SBR, a goods movement rail hub, in an urbanized area of inland southern California. Specifically, we assessed the relationship between air pollution near the SBR and outlying areas further away from the facility and adverse health effects among nearby adult residents in an area already impacted by regional air pollution. Our results suggest that residing in close proximity to the railyard had small but detectable effects. The results were not statistically significant, although some of the associations were borderline significant.
The magnitude of the effect across endpoints increased with closer proximity to the railyard within the REZ, from the *Moderate* to the *High* exposure region, suggesting a dose-response trend.

There are several limitations to our study. Outcomes were determined and analyses were conducted cross-sectionally. Therefore a cause-effect relationship cannot be established. Another limitation is that residential proximity was used as a surrogate measure for exposure to diesel emissions, which may lead to the possibility of misclassification of railyard-related air pollution exposure. Any non-differential misclassification of exposure however would be likely to bias our results toward the null.[xxi]

[xxi] Bias towards the null implies that if there is an association between exposure to railyard emissions and a given health outcome, it tends to minimize it regardless of whether it is a positive or negative

Our models adjusted for relevant confounders including age; sex; race/ethnicity; neighborhood-level household income; exposure to ETS; tobacco use; time spent outdoors; proximity to traffic; and diesel emissions from local (mobile and stationary) sources. Notwithstanding its methodological limitations, we believe that the public health implication of our investigation is that adult residents near major goods movement hubs should be protected from potentially damaging exposures.

6.3 Children−Elementary School Assessment

Our school-based study found that children attending school closer to the SBR were more likely to exhibit adverse respiratory health outcomes. Our findings revealed that children attending school near the railyard exhibited higher airway inflammation measured by FE_{NO} (PR = 1.33, 95% CI: 0.96, 1.86); findings were stronger among children who had lived at least 6 months at their current address (PR = 1.44, 95%CI: 1.02, 2.02). Significant effects were also seen for airway obstruction measured by PEF among children attending school near the railyard (PR = 1.59, 95% CI: 1.19, 2.12). Overall, the association with inflammation was less clear. While children at the exposure school, who had lived for at least 6 months at their current address, were more likely to have values suggesting inflammation (FE_{NO} >20 ppb) (PR=1.44, 95% CI: 1.02-2.02), linear regression analysis did not show this to be statistically significant. That said, additional log-binomial and logistic regression analyses revealed that children attending the exposure school were more likely to be diagnosed with asthma or experience adverse respiratory symptoms; they also were more likely to be taken to the emergency room for a respiratory event. Together the findings indicate that children attending school near the SBR are more likely to exhibit adverse respiratory health outcomes than children attending a socio-demographically matched elementary school located seven miles away in a similar urban setting. **Table 6-2** presents statistics comparing asthma prevalence among children attending the ENRRICH study schools to the prevalence childhood asthma in San Bernardino County and California.

TABLE 6-2. PARENT-REPORTED, PHYSICIAN DIAGNOSIS OF ASTHMA AMONG CHILDREN IN THE ENRRICH PARTICIPATING SCHOOLS COMPARED WITH STATE AND COUNTY PREVALENCE DATA.

	Region				
			ENRRICH Study		
	California	San Bernardino County	Total Participants (n = 136)	Exposure School (n = 77)	Comparison School (n = 59)
Asthma Prevalence	11.6%	12.2%	12.8%	14.5%	11.0%

association (see Vogel C, Gefeller O. Implications of nondifferential misclassification on estimates of attributable risk. Methods Inf Med. 2002; 41:342-8).

6.4 Key Points for Discussion of Observed Associations

The most fundamental question residents, local authorities, public health agencies, and scientists wonder about is whether or not the railyard facility contributes to overall disease burden in the areas surrounding the SBR. Underlying such question there are in turn two interrelated questions that need to be ascertained. First, is there evidence of increased adverse health outcomes among residents in close proximity to the SBR, compared to the populations in the background regions outside the RIZ? Second, is it conceivable that the SBR contributes to excess health risks in adjacent areas? We consider these two key questions next.

A negative answer to the first question (i.e., “no risk has been shown”) would suggest that further examination of the second question is not warranted. An affirmative answer to the first question however need not be automatically ensued by a “yes” to the second question. There is the possibility that a greater burden of disease among residents might be associated with factors or conditions (e.g., smoking prevalence) unrelated to excess diesel emissions but which also intensify in magnitude towards the railyard.

Pervasively high levels of background, transported air pollution and emissions from local sources, together with underlying respiratory health challenges and relative socioeconomic/ethnic homogeneity, define an overall exposure setting within which, *a priori*, it might be difficult to find a distinct pattern of adverse outcomes with respect residential proximity to the SBR. Despite this, we were still able to detect consistently elevations with respect to increasing proximity to the SBR. Not unexpectedly, the health effects were stronger for children than for adults, but, overall, the consistent trend across endpoints appears to fit the expectation of enhanced exposures in the areas near the SBR facility. Data collected through ENRRICH suggest that some community indicators to improve away from the SBR and degrade with proximity towards it, including factors such as income, unemployment, access to health care, or ambient noise. Therefore, it could be argued that the observed higher prevalence of adverse health outcomes is not associated with excess emissions from the railyard but with conditions such as economic disadvantage, residential instability, or even lifestyle factors such as tobacco use, which has been traditionally with lower socioeconomic status. . However, we controlled for as many of these potential effects as possible thus limiting the potential for these assumptions to drive our findings.

Furthermore, we have already discussed in this report that, according to our household survey data, residential stability was comparable across our sampling zones and that other relevant factors such as exposure to ETS, or past and current tobacco use, actually decrease towards the SBR. It is well known that smoking, a critical risk factor for cancer, respiratory, and cardiovascular health, confounds the associations with air pollution. However, again, as suggested by our household survey data, our exposed zone does not appear to be an area characterized by higher smoking prevalence compared to the background regions. These self-report data are further validated by consumer data from the U.S. Bureau of Labor Statistics from the year 2010. Using these data, we have estimated that per capita annual expenditures on smoking products in the REZ (i.e., near the SBR) amount to $63, compared to $110 in San Bernardino County at large. In summary, the elevations in risk in children and adults were identified against a general setting of residential stability and low smoking prevalence. Elevations remained after analytical adjustments for tobacco use, exposure to ETS, and for socioeconomic differences across the study population.

Although a cause-effect relationship cannot be established given the cross-sectional nature of our study, it is legitimate to assess whether reasonable correlational evidence exists. In gauging the increased adverse health outcomes identified through the ENRRICH, our results should be considered in light of the following considerations: 1) the SBR as a putative source of emissions vis-à-vis the potential contributing role of other local sources; 2) biological plausibility; 3) patterns of enhanced exposure and toxicity in the SBR region; and 4) confounding. We have already discussed these issues in some detail in the context of the three sub-studies presented in Chapters 2, 3, and 4. We summarize below the key points.

1. The SBR, a major local source of diesel PM. Although the SBR was identified as a source of hazardous air pollutants through the SRPRA (see *Introduction* section), the question as to why this goods movement hub has been singled out in the ENRRICH Project continues to be posed by many. It is therefore important to contextualize the SBR vis-à-vis the local setting of air pollution sources. As presented in Chapter 1, a variety of stationary and mobile sources are found in the immediate region surrounding the SBR, therefore contributing to the overall levels of air pollution in San Bernardino. However, the SBR is the largest local emitter of diesel PM. The emissions attributable to the SBR represent 67% of the total diesel PM emissions arising from all stationary and mobile sources within one mile of the railyard facility. This high onsite-to-offsite emissions ratio is unique to SBR. At the other major California rail facilities, onsite emissions tend to pale in comparison to those attributable to nearby offsite sources. Based on data for the other 17 SRPRA railyards, we have estimated that railyard-related diesel emissions represent on average 22% of all diesel emissions at a given facility. In addition, the absolute amount of diesel emissions, 22 tons annually, attributed to the SBR ranked fifth among the 18 California railyards assessed by CARB. Thus, the plausibility that the SBR may represent a health hazard for the local populations can be predicated on its relative and absolute contribution to local air pollution, in combination with its location in a densely populated area in San Bernardino.

2. Biological plausibility. Given the status of the railyard facility as a major local source, the next fundamental issue to consider is whether there is the evidence that the emissions associated with freight railyards exert detrimental human health impacts through plausible physiological mechanisms. Diesel exhaust is the dominant TAC that has been associated with SBR and the other railyards assessed by CARB. Diesel exhaust is a complex mixture of pollutants composed of vapors, gases, and fine particles. As presented in the *Introduction* section and in Chapters 3, 4, and 5, emerging epidemiologic evidence is establishing that ambient PM and diesel exhaust particles are associated with a variety of respiratory and cardiovascular problems and increased risk of adverse respiratory health outcomes in children.[xxii] The physiological mechanisms underlying the health effects of diesel PM are gradually being elucidated. Current evidence indicates that inhalation of diesel particles enhances allergic and inflammatory airway responses [161]. Because of their small size, diesel particles can enter systemic circulation and gain entry to cells and tissues, altering or disrupting normal cellular function. Emerging evidence indicates that the primary etiologic agents from fossil fuels are pro-oxidant pathways, which induce cellular oxidative stress, and electrophilic activity that leads to irreversible binding with proteins and DNA [162, 163]. The immunologic evidence and the proposed cellular mechanisms fit well with the epidemiologic evidence indicating that exposure to diesel pollution is likely to enhance the risk for adverse health effects.

3. Patterns of enhanced exposure and toxicity in the SBR region. The SBR represents a unique, complex setting where local and regional air pollution processes intersect. It is important to assess how concentrations and relevant pollutant properties vary in space from sources and in ambient air, and the implications of such variations for exposure in local populations. Recent evidence demonstrates a distinct spatial gradient within the South Coast (Los Angeles) Air Basin with respect to the content of certain organic species found in diesel particles. Specifically, the concentrations of quinones, which play a critical role in eliciting oxidative stress-dependent cytoxicity in human pulmonary tissue, seem to increase significantly eastward from the coast towards the inland valleys of southern California. Not only do these concentrations increase eastward, but also it has been established that the vast majority (90%) of the quinones that can be measured at inland locations are photochemically formed during atmospheric transport [164]. This implies that the region where the SBR is located is at greater risk due to the oxidation of the organic species, which enhances their toxicity, as they travel inland. The plausible scenario is that residents near the railyard are likely to receive the combined exposures from the diesel-related pollutants traveling inland and the local emissions arising from the SBR. Nearly half of the participants from the elementary school near the railyard reported residential locations within 600 m of the northern sections of the SBR, where most emissions occur, and immediately south of the school campus. In addition, emerging results from a study recently conducted by UCLA scientists indicate that pro-oxidant activity, which will lead to adverse health effects, was greater in ambient air samples collected near the SBR compared to samples taken at the Long Beach and Commerce railyards. This finding implies increased toxicity of the air pollution to which local residents near the SBR are exposed, compared to other goods movement railyards further west in the Basin.

4. Confounding. To control for confounders or other factors, which can increase, decrease, or obscure attribution of the health effects from the ambient exposures, our models adjusted analytically for economic differences across our sampling zones; age; sex; race; smoking status and ETS exposure; time spent outdoors; exposure to local (stationary and mobile) sources of diesel PM and residential proximity to busy roads. Also, in the children's (school) study we identified a comparison elementary school, which was socio-demographically with the communities

[xxii] See for example references 19, 24, 26, 135, 157, 159, 160, 167, and 168.

neighboring the SBR. Like with the household-level study of adults, we further adjusted for individual-level confounders that are known to influence respiratory health, such as exposure to ETS in the home and the amount of time a child spends outside. Through the parental survey we also assessed the difference among the children from the two schools in their ability to access medical care and found no significant differences. Within our modeling strategy, we also adjusted for potential neighborhood-level income differences that might exist, even though the schools are only seven miles away from each other. Finally, we also took into account air pollution from other local sources, including the nearby roadways and other local sources.

In summary, with respect to the first key question ("is there evidence of increased adverse health outcomes among residents in close proximity to the SBR, compared to the populations in the background regions outside the RIZ?") posed at the start of this section, the findings from the ENRRICH Study point to elevations in the prevalence of adverse health outcomes among adult residents in the neighborhoods in close proximity to the railyard. Children attending school and residing near the SBR are more likely to exhibit evidence of respiratory dysfunction. With respect to the second key question ("is it conceivable that the SBR could contribute to excess health risks in adjacent areas?"), we have established the status of the SBR as the largest local emitter; the biological plausibility for adverse health effects of diesel exhaust; and the existence of patterns of enhanced exposure and toxicity in the SBR region.

6.5 Community Perceptions

In addition to the quantitative data collected through the school and community assessments, the collected qualitative information also provides insight into the challenges faced by community members living in close proximity to the SBR. When conducting the key informant interviews and focus group discussions with community members, it became quite apparent that though the community members expressed concern for poor air quality, for most of them other challenges took priority (i.e. jobs, providing for families, access to healthcare). For them, the railyard was seen as both an asset and a barrier to their ability to live a better life. Participants felt that the railyard has a positive reputation and is highly valued for the jobs and economic growth it provides for some. The reality is however, that few jobs are held by residents living in close proximity to the railyard. On the other hand local residents are indeed frustrated by the railyards role as a major contributor to the noise pollution as well as its potential role as a major contributor the surrounding poor air quality. Several participants believe that living in such close proximity to the railyard has caused ailments in family, friends, and neighbors, as well as themselves. None of the community members participating in our study wanted the railyard to close or relocate. Many expressed a strong desire for the railyard to "step up," be a good neighbor, and make reasonable changes to help protect the surrounding community from the noise and air pollution it generates. Attendees felt that the railyard does not listen to suggestions (i.e. alternate routes, more updated equipment) from residents about ways to reduce the impact their facility has on the surrounding community. Some participants feel that they have sacrificed for the benefit of the railyard and are concerned about the health impacts of life near such a busy railyard, especially for their children. Many participants had positive sustainable suggestions for improvements to their community and are eager and hopeful to see the changes implemented and sustained.

6.6 Conclusion

The results from the population-based cancer assessment were not conclusive and in some cases they defied a straightforward interpretation. However some of the findings for all cancers combined and for site-specific cancers, such as the statistical risk elevations for breast cancer among Hispanic residents near the SBR, warrant further investigation. The ENRRICH study has also identified a significant association with increasing proximity to the local railyard and adverse respiratory health outcomes among children, in an area already plagued with poor background air quality. Although not significant, results for adults follow the same trends toward negative associated adverse health endpoints in the *Moderate* and *High* exposure regions closest to the railyard. Our models adjusted for relevant confounders, and the fact that even after analytical adjustments we still found modest to moderate elevations across health endpoints does not appear to support a basic hypothesis of no association between residential proximity to the railyard and adverse health outcomes among local residents. We cannot exclude the possibility that the lack of statistical significance for the findings for our adult study population may simply be the reflection of insufficient statistical power. While not statistically significant, we feel that these findings for adults should be considered relative to their public health significance. As we have noted throughout the report, the described associations cannot be interpreted as representing a cause-effect relationship due to the cross-sectional nature of our design. Future research is warranted with follow-up studies assessing individual-level exposures and the long-term health risks associated with chronic exposure in order to confirm/disprove the associations suggested by our analyses.

Under complex scenarios at the interface of science and policy, such as the one concerning the ENRRICH Project, the criteria for practical action do not always match the scientific opinion or consensus on causality. Public health authorities are faced with the difficult task of determining, given the available evidence, if the exposure is sufficiently widespread and the health consequences serious. In the spirit of prevention, as mandated by their role to protect the public's health, public health authorities may be justified under certain circumstances to implement specific action even when faced with moderate, rather than conclusive, evidence.[xxiii] Notwithstanding its methodological limitations, we believe that the public health implication of our investigation is that residents near major goods movement hubs should be protected from potentially damaging exposures.

[xxiii] Using an analogy from the field of statistics: this would be the equivalent of emphasizing Type II error (i.e., a false negative) over Type I error (i.e., false positive), given the potential for negative public health consequences. In contrast, statistical analyses tend to emphasize Type I error.

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