Proxy Occupational Human Health Risk Assessment on PM2.5 Exposure at Targeted International Border Ports of Entry

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Abstract: Vehicular combustion emissions constitute a significant source of fine particulate matter (PM2.5), comprising microscopic solid or liquid droplets that, upon inhalation, have been associated with both acute and chronic adverse respiratory and cardiopulmonary health outcomes. Air quality at international border ports of entry (IBPEs) is predominantly influenced by mobile source emissions from vehicles awaiting inspection. This interdisciplinary exploratory study aims at assessing exposure and health risk assessment to ambient criteria air pollutants, specifically PM2.5, using a proxy approach for personnel at IBPEs. The methodology employed proxy exposure estimation to evaluate potential health effects associated with PM2.5 exposure. A proxy exposure estimation uses indexes and indirect measurements that calculate the risk of adverse health effects of an individual or group of people. In this study, two air quality stations were strategically positioned at two targeted IBPEs within a typical breathing zone height, following EPA guidelines on outdoor exposures. Exceedances and non-cancer health risks will be calculated using 1-hour average concentrations from local monitoring stations (MiniVol and Purple Air sensors) and from nearest active Continuous Ambient Monitoring Stations (CAMS). These calculations will be compared across the IBPEs and work shifts. Monitoring stations are scheduled to monitor continuously for 24-hours at 6-day intervals from March-May 2025. The study revealed exceedances in PM2.5 concentrations across all shifts at two IBPEs in El Paso, Texas, and Las Cruces, New Mexico, with the highest exceedance rates during the afternoon shift (20.0% in El Paso and 26.6% in Las Cruces). Unlike CAMS measurements, the MiniVol LFR Sampler and Purple Air sensors recorded no exceedances. Health risk assessments indicated that all shifts measured by MiniVol and Purple Air had a hazard quotient (HQ) below 1.0, indicating low non-cancer health risk. Conversely, CAMS measurements showed HQ values of 1.0 and above, with a critical finding of an afternoon shift in Las Cruces exceeding the permissible exposure limit (PEL) by 18 times, posing significant non-cancer health risks. Significant PM2.5 variability across days and shifts at border ports of entry demonstrates that single-day sampling and regional monitoring inadequately characterize outdoor worker exposure, underscoring the need for extended, site-specific assessment approaches.

Keywords: *proxy exposure methods, human health risk assessment, occupational health, air pollution*

Introduction

PM2.5, or fine particulate matter, contributed globally to approximately 7.83 million deaths and 231.5 million disability-adjusted life years (DALYs) in the year 2021 (Fang et al., 2025). This air pollutant consists of a mixture of solid particles and liquid droplets suspended in the air coming from automobile emissions, industrial activities, and power plant facilities (Environmental Protection Agency, 2025). In the U.S., it was estimated that $1\mu g/m^3$ increase in daily total PM2.5 exposure would lead to 1 million days of work loss per year (Meng et al., 2024). This can directly impact workers in the U.S., however, there is better limited data regarding the exposure from outdoor workers.

Outdoor workers are an understudied population regarding exposures to ambient hazards. Combined data from the Occupational Information Network (O*NET) and the Bureau of Labor Statistics (BLS) Occupational Employment Projections Program indicated that there are more than 20 million outdoor workers at potential risk for occupational exposure to ambient air pollution in the U.S. (MacMurdo et al., 2025). Nevertheless, most studies on outdoor workers focus on sector specific hazards as it is in construction and agriculture. Regularly assessing exposures to work-specific hazards but not examining the risk from urban environments such as air pollution from vehicle emissions.

Additionally, personal dust monitors are used to measure exposure when conducting occupational health risk assessments. However, not all occupations allow their workers to wear such devices for safety purposes, as it is the case of Customs and Border Protection personnel. In these situations, studies have suggested using stationary environmental monitors as proxy measures to overcome the complexities and challenges of wearing personal air monitoring devices when assessing air pollutant exposure and respiratory health (Gonzalez Serrano et al., 2023). Therefore, the purpose of this study is to determine the non-cancer health risk from PM2.5 exposure among outdoor worker at targeted international border ports of entry (IBPEs) in El Paso, TX and Las Cruces, NM using proxy methods.

Methods

2.1 Participants

No human subjects participated in the conducted study since proxy measures were used to assess the occupational health risk of the outdoor workers who cannot wear personal dust monitoring devices. However, a revocable license and quality assurance project plan (QAPP) had to be submitted for review and approval prior to conducting the research project.

2.2 Measures

PM2.5 1-hour average concentrations were collected using a Purple Air® real-time low-cost air monitoring sensor and the active CAMS most proximate to each targeted IBPE. For the Purple Air®, raw data (ATM) and corrected data (CF) was used for the assessment. In addition, the EPA FRM/FEM MiniVol® LFR Sampler real-time particulate profiler (RTP), collected 5-minute PM2.5 data and was averaged into 1-hour concentrations. A total of 15 sampling events (3 months) of PM2.5 concentrations were collected at two targeted international border ports of entry, in El Paso, Texas and Las Cruces, New Mexico.

2.3 Data Collection

Data was collected through monitoring stations deployed between active IBPE booths to assess outdoor workers' exposure. A single monitoring station was randomly collocated near primary inspection booths per IBPE. The stand-alone station was set within EPA's ideal breathing zone height (3-6 feet above ground level) and data was collected for all IBPE's work shifts (Figure 3). It is important to note that (Figure 1) showcases the co-location of the different devices used to monitor PM2.5 concentrations. However, additional devices are included since this study is a portion of a parent research study. For Las Cruces, New Mexico two 8-hour shifts were assessed and for El Paso, Texas two 8-hour and one 4.5-hour shifts were examined. The shifts were labeled as either *Morning Shift*, *Afternoon Shift*, or *Evening Shift* and spanned from 6:00-14:00, 14:00-22:00, and 22:00-6:00, respectively. Data was collected using a 1-in-6 systematic random scheme.

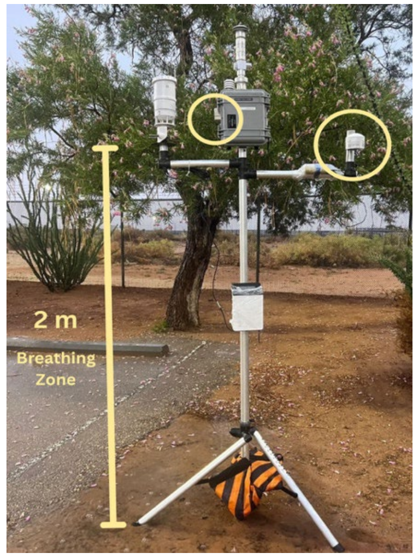

Figure 1. Monitoring station from parent research study; this project only uses MiniVol RTP® and the Purple Air® devices (circled) within the EPA breathing zone range.

2.4 Occupational Health Risk Assessment Calculations

Time-weighted averages (TWAs) and hazard quotients (HQs) were calculated to assess exceedances and the level of non-cancer health risk from PM2.5 exposure among outdoor workers who cannot wear personal dust monitoring devices at the targeted IBPE, respectively. The formula used for calculating the time weighted averages is as it follows:

$$\text{TWA} = \frac{\sum_{i=1}^{n} C_i t_i}{\sum_{i=1}^{n} t_i} = \frac{(PM2.5C_1 \times 1HR) + (PM2.5C_2 \times 1HR) + \cdots + (PM2.5C_n \times 1HR)}{Ttotalshift} \tag{1}$$

Since there is currently no set permissible exposure limit for PM2.5 ambient concentrations, the EPA's 24-hour NAAQS of 35μg/m^3 will be used instead. The formula for calculating the hazard quotient is as it follows:

$$\text{HQ} = \frac{\text{TWA}}{\text{PEL}} = \frac{\text{TWA}}{35\mu g/m^3} \tag{2}$$

2.5 Treating Missing Data

Mean imputation was performed to treat missing data. The imputation was applied when a minimum of 75% of completeness was found per variable per sampling date. If more than the 25% of the data was missing, the date was discarded from the occupational health risk assessment.

Results

The study identified exceedances in all shifts when calculating time-weighted averages of PM2.5 concentrations using the nearest active CAMS from both IBPEs, in El Paso, Texas, and Las Cruces, New Mexico. The highest percentage of exceedances was observed during the afternoon shift, with 20.0% of samples exceeding the limit in El Paso (Table 1) and 26.6% in Las Cruces (Table 2). In contrast, no exceedances were identified at any of the targeted IBPEs when using the MiniVol LFR Sampler or the Purple Air low-cost sensors, located near active primary inspection booths.

Furthermore, when assessing the non-cancer health risk from PM2.5 exposure using the MiniVol and Purple Air equipment, all work shifts from both targeted IBPEs were below 1.0 (HQ < 1.0). These results suggest a low risk for non-cancerous adverse health effects. On the other hand, all work shifts using the CAMS showed HQ ≥ 1.0 (Table 3-4). The range of non-cancer health risk was between 1 and 5 for both IBPEs. The only exception is presented in Table 2: the afternoon shift in Las Cruces detected an exposure level 18 times higher than the set PEL, suggesting a high potential for non-cancer health effects.

Table 1. Identified PM2.5 exceedances (bold) using CAMS in El Paso IBPE.

Sampling Event	Morning Shift	Afternoon Shift	Evening Shift	Percent
1	**179.0**	**153.3**	**134.9**	**Morning Shift** 6.7%
2	16.0	34.3	8.3	
3	14.4	32.2	31.1	
4	4.9	8.7	8.5	
5	27.5	**93.0**	31.8	
6	8.8	6.1	5.1	**Afternoon Shift** 20.0%
7	10.9	13.2	12.2	
8	13.4	**71.6**	6.3	
9	9.8	12.6	6.0	
10	9.6	29.4	11.3	
11	14.6	31.5	9.3	**Evening Shift** 6.7%
12	10.0	8.8	11.1	
13	9.3	13.1	7.5	
14	21.8	17.4	17.4	
15	32.4	18.0	27.3	

Table 2. Identified PM2.5 exceedances (bold) using CAMS in Las Cruces IBPE.

Sampling Event	Morning Shift	Afternoon Shift	Percent
1	**35.0**	3.7	**Morning Shift** 20.0%
2	**194.3**	**640.4**	
3	**63.6**	**60.4**	
4	**48.0**	14.5	
5	**37.0**	**129.2**	
6	**49.4**	9.5	
7	9.3	9.1	
8	10.5	**69.9**	**Afternoon Shift** 26.7%
9	4.9	5.7	
10	16.5	27.7	
11	8.2	34.5	
12	7.2	6.7	
13	7.2	6.9	
14	13.4	9.5	
15	15.7	15.8	

Table 3. HQ of PM2.5 exposure using CAMS in El Paso IBPE (bolded HQ≥ 1.0).

Sampling Event	Morning Shift	Afternoon Shift	Evening Shift
1	**5.11**	**4.38**	**3.85**
2	0.46	0.98	0.24
3	0.41	0.92	0.89
4	0.14	0.25	0.24
5	0.78	**2.66**	0.91
6	0.25	0.17	0.15
7	0.31	0.38	0.35
8	0.38	**2.04**	0.18
9	0.28	0.36	0.17
10	0.27	0.84	0.32
11	0.42	0.90	0.26
12	0.29	0.25	0.32
13	0.26	0.37	0.21
14	0.62	0.50	0.50
15	0.93	0.51	0.78

Table 4. HQ of PM2.5 exposure using CAMS in Las Cruces IBPE (bolded HQ≥ 1.0).

Sampling Event	Morning Shift	Afternoon Shift
1	**1.00**	0.1
2	**5.55**	**18.3**
3	**1.82**	1.7
4	**1.37**	0.4
5	**1.06**	**3.7**
6	**1.41**	0.3
7	0.26	0.3
8	0.30	**2.0**
9	0.14	0.2
10	0.47	0.8
11	0.24	**1.0**
12	0.21	0.2
13	0.21	0.2
14	0.38	0.3
15	0.45	0.5

Concluding Remarks and Future Directions

This study shows variability on a day-to-day and work-shift basis for PM2.5 TWA concentrations at targeted IBPE in El Paso, Texas, and Las Cruces, New Mexico. The study exhibits that the generalization of exposure to PM2.5 concentrations using the nearest active CAMS can overestimate the risk and does not necessarily show the most accurate representation of exposure among outdoor workers at IBPEs. In addition, close attention is given to exceedances, which can be potentially relevant for more vulnerable and sensitive groups. Thus, we highlight the importance of sampling for more than a single day of exposure and using proxy methods to assess exposure among workers who cannot wear personal dust monitors. Particularly since there are no standardized methods to assess the health risk in this type of environment, pollutant, and occupation.

Even though we understand that this set of results only shows 3 months of data collection, while environmental sampling is recommended to be conducted for at least 3 to 5 years, this exploratory study intends to emphasize the importance of conducting health risk assessments for more than a single day among occupations conducted outdoors to account for the variability of the pollutant exposure. This understanding will allow for better assessment of the level of exposure in this understudied population, leading to tailored mitigation strategies to prevent reduction of work loss days and its effects on productivity.

In future studies, our research group will focus on gaining a deeper understanding of assessing non-cancer risk and seasonality by sampling for at least one year of exposure using the same sampling scheme. This understanding is essential for designing better methods to conduct occupational health risk assessments among outdoor workers who have no set standards for exposure to PM2.5 and cannot wear personal dust monitors.

This research emphasizes that safeguarding outdoor workers requires a shift from convenient approximations to rigorous, site-specific, multi-day exposure characterization. Furthermore, the tools and standards necessary to achieve this effectively are still under development, requiring practitioner engagement and innovation.

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