ENVIRONMENTAL RESEARCH
HEALTH

PAPER • OPEN ACCESS

Pollution hot spots and the impact of drive-through COVID-19 testing sites on urban air quality

To cite this article: Daniel L Mendoza *et al* 2023 *Environ. Res.: Health* **1** 045001

IOP Publishing Environ. Res.: Health 1 (2023) 045001 https://doi.org/10.1088/2752-5309/ace5cb

ENVIRONMENTAL RESEARCH
HEALTH

OPEN ACCESS

RECEIVED
1 January 2023

REVISED
1 July 2023

ACCEPTED FOR PUBLICATION
10 July 2023

PUBLISHED
31 July 2023

PAPER

Pollution hot spots and the impact of drive-through COVID-19 testing sites on urban air quality

Daniel L Mendoza[1,2,3,*], Tabitha M Benney[4], Casey S Olson[1], Erik T Crosman[5], Shawn A Gonzales[6], Mamta Chaudhari[6] and Corbin Anderson[6]

[1] Department of Atmospheric Sciences, University of Utah, 135 S 1460 E, Room 819, Salt Lake City, UT 84112, United States of America
[2] Division of Pulmonary Medicine, Department of Internal Medicine, School of Medicine, University of Utah, 26 N 1900 E, Salt Lake City, UT 84132, United States of America
[3] Department of City & Metropolitan Planning, University of Utah, 375 S 1530 E, Suite 220, Salt Lake City, UT 84112, United States of America
[4] Department of Political Science, University of Utah, 260 S Central Campus Drive, Salt Lake City, UT 84112, United States of America
[5] Department of Life, Earth and Environmental Sciences, West Texas A&M University, Natural Sciences Building 324, Canyon, TX 79016, United States of America
[6] Salt Lake County Health Department, Air Quality Bureau, Environmental Health Division 788 East Woodoak Lane, Murray, UT 84107, United States of America
[*] Author to whom any correspondence should be addressed.

E-mail: daniel.mendoza@utah.edu

Keywords: idling, $PM_{2.5}$, urban pollution, hot spots, COVID-19, drive-through

Abstract

To be successful, commitments to climate change and environmental policy will require critical changes in human behavior and one important example is driving and idling. Idling is defined as running a vehicle's motor while not in motion. Idling studies have repeatedly demonstrated that this behavior is costly, harmful to human health, and highly polluting. However, with the onset of COVID-19, the use of drive-through services to provide food, pharmaceuticals, and medical testing has increased. To understand this phenomenon further, we worked cooperatively with our government partners to compare the concentrations of $PM_{2.5}$ at three regulatory sensor locations with nearby drive-through COVID-19 testing sites during average to elevated pollution days. Salt Lake City, UT (USA), where this study was undertaken, has seen a dramatic rise in drive-through services since the onset of the pandemic and community concern is also high due to poor local air quality. More importantly, the Salt Lake Valley is home to one of the largest research grade air quality networks in the world. Fine particulate matter sensors were installed or already in place at or adjacent to COVID-19 testing sites in the area, and we used data from nearby Utah Division of Air Quality monitors to provide comparative $PM_{2.5}$ concentrations. Due to their placement (e.g., further distance from large roads and other emitting sources), we found that testing sites showed lower $PM_{2.5}$ concentrations during average air quality days despite increased idling rates. However, when urban pollution rates were elevated due to atmospheric inversions, extensive idling around testing sites led to hyper local $PM_{2.5}$ concentrations or pollution hot spots. This suggests that idling has serious compounding effects in highly polluted urban areas and policies minimizing vehicle emissions from idling and congestion could conceivably curtail pollutant exposure in a range of settings.

1. Introduction

Commitments to climate-change and other environmental problems will require critical changes in human behavior (Pearson *et al* 2016) to assure long term human health and well-being. One important example of behavior modification, which may contribute to the efforts to improve human health and the environment, is vehicle idling reduction. Idling is defined as running a vehicle's motor while not in motion (Carrico *et al* 2009). Idling studies have repeatedly demonstrated that such a habit is inefficient, damaging to the vehicle, and highly polluting (Kinsey *et al* 2007, Mendoza *et al* 2022b). Most importantly, it is harmful to human health (Vishnevetsky *et al* 2015, Breton *et al* 2016, Zhang *et al* 2018).

In addition, a range of fields have tackled this interdisciplinary problem. As a clear consensus has emerged, there appears to be a strong relationship between pollution generated by idling (Kinsey *et al* 2007, Richmond-Bryant *et al* 2009, Kim *et al* 2014, Lee *et al* 2018), interventions to reduce idling (Eghbalnia *et al* 2013, Meleady *et al* 2017, Mahmood *et al* 2019, Rumchev *et al* 2021), and the resulting impacts of idling on human health (Ryan *et al* 2013, Lynn *et al* 2014).

With the onset of COVID-19, however, the use of drive-through services for food, pharmaceuticals, and medical testing has increased (Cohen *et al* 2022). Since the scientific understanding of the dispersion of pollutants in urban areas due to idling is extremely complex and difficult to measure with precision, gaps remain in this area. As a result, few scientific studies of this phenomena exist, even with the increased use of drive-through conveniences since 2020.

In Salt Lake City, Utah, where this study was undertaken, such services have become increasingly common. At the same time, idling has been identified by local stakeholders as an area of concern (Benney *et al* 2021, Mendoza *et al* 2022a) due to the interactive effects of idling and other forms of air pollution. Since the Salt Lake Valley is home to one of the densest research grade air quality networks in the world (Mendoza *et al* 2019), air quality sensors were installed or already available at or adjacent to COVID-19 testing sites in the area. To learn more about vehicle congestion and idling at COVID-19 testing sites during the 2020–21 pandemic, a government-academic partnership was developed to consider the human health and policy implications of this phenomena. The goal of this partnership was to quantitatively evaluate if traffic and vehicle idling impacts local $PM_{2.5}$ particulate formation.

To advance this understanding, we compared the concentrations of $PM_{2.5}$ at three regulatory sensor locations with nearby drive-through COVID-19 testing sites in an urban area during wintertime average to elevated pollution days. We used data from nearby Utah Division of Air Quality (UDAQ) monitors to provide comparative $PM_{2.5}$ concentrations (Utah Division of Air Quality 2021). Due to their placement (e.g., further distance from large roads and other emitting sources), we found that testing sites showed lower $PM_{2.5}$ concentrations during average air quality days despite increased idling rates. However, when urban pollution rates were elevated due to atmospheric inversions, extensive idling around testing sites led to hyper local $PM_{2.5}$ concentrations or pollution hot spots. This suggests that idling has serious compounding effects in highly polluted urban areas and policy may need to account for these factors to protect human health and well-being. In addition, best management practices and policies minimizing vehicle emissions from idling and congestion could conceivably curtail pollutant exposure in a range of settings.

2. Methodology

This study compares the concentrations of $PM_{2.5}$ at three regulatory sensor locations with nearby drive-through COVID-19 testing sites in Salt Lake City, UT. This urban area was studied because of the ability to use high quality, regulatory and research grade sensors to enable direct measurement of the phenomena of interest. Additionally, the region's network was substantially enhanced in 2015 which allows our team to understand pre-existing conditions in an urban area during average to elevated pollution days. We used data from nearby UDAQ monitors to provide comparative $PM_{2.5}$ concentrations.

As shown in figure 1, Salt Lake County (SLCo), Utah, sits within a valley, or basin, bracketed by the Great Salt Lake (Northwest), and the Wasatch (East), Oquirrh (West), and Traverse (South) mountains (figure 1). Given the right meteorological conditions, the SLCo basin traps airborne pollutants emitted from sources, including vehicles, under an inversion layer resulting in stagnation and preventing the normal vertical mixing of warm and cool air (Whiteman *et al* 2014). Strong and weak inversions lasting over multiple days typically result in secondary particulate matter formation (Kroll and Seinfeld 2008). This results in air pollution concentrations that exceed the national ambient air quality standards (United States Environmental Protection Agency 2022) and raise the risk of aggravating certain health conditions especially in susceptible populations (Pope III *et al* 2015, Pirozzi *et al* 2018, Johnson *et al* 2021).

2.1. Study sites

The testing sites were strategically placed by the Utah Department of Health and Human Services to provide quick and efficient drive-up and drive-through access to COVID-19 testing. This arrangement provided for readily available testing coverage across the central part of SLCo and the east side of the Valley.

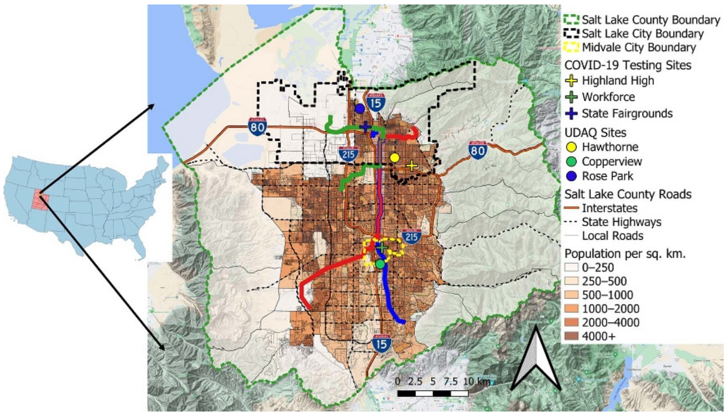

Figure 1. Salt Lake City (blacked dashed outline), Midvale city (yellow dashed outline) and Salt Lake County (green dashed outline) within Utah and the United States (left inset), are bracketed by The Great Salt Lake (Northwest), and the Wasatch (East), Oquirrh (West), and Traverse (South) mountains. COVID-19 testing sites are shown as plus symbols ('+') with comparative UDAQ regulatory air quality measurement sites in matching color circles. Interstate highways and other large roads are shown as well as population density by census block group.

Three COVID-19 testing sites were chosen because they specifically catered to vehicles (drive-through), primarily served three geographically diverse areas of the Salt Lake Valley [i.e., North (Urban/Industrial), East (Urban), and South (Urban/Commercial)], were accessible, had non-diesel/gas power sources, and exhibited high traffic and vehicle congestion where idling could occur. Site locations were characterized as urban, mixed with nearby industrial and commercial area sources. Main contributors to $PM_{2.5}$ emissions affecting the COVID-19 testing sites were the I-15 interstate corridor connecting the North–South ends of the valley (State Fairgrounds and Workforce), I-80 interstate (Highland High), industrial facilities (State Fairgrounds and Workforce), Salt Lake City International Airport and railroads (State Fairgrounds).

Figure 2 illustrates the placement of $PM_{2.5}$ sensors on the rooftops of **Highland High School** ('Highland High') (40.72365°N, −111.84300°W (Google Maps 2022), Elevation 1364 MASL (USGS TNM Elevation Tool, 2021)), **Workforce Services—Midvale** ('Workforce Services') (40.61902° N, −111.89142°W Elevation 1336 MASL), and the **Utah State Fairgrounds Wasatch BLDG** ('State Fairgrounds') (40.77237°N, −111.92126°W, Elevation 1288 MASL), (figures 2(a)–(c)).

2.2. Study timeline

The vaccination site measurement duration with the study sensors are listed in table 1.

We used data from three UDAQ sites to compare $PM_{2.5}$ readings for the entire study period and across two time periods encompassing atmospheric inversion events (Bares *et al* 2018). While the captured event was a complex inversion with 'partial mix-outs' (hence the zig zags of $PM_{2.5}$ up and back down), northerly winds were present for much of the first event from 2–14 February. The short but rapid increase in pollution between 25–28 February was associated with lighter winds and a more classic inversion. By this time, the temperatures increase due to additional sunlight, and it becomes more difficult to maintain a strong inversion. This was especially true in this instance because it was so late in the inversion season, which typically ends at the end of February.

2.3. Instrument description

The COVID-19 testing site locations had ES-642 remote dust monitors (Met One Instruments Inc., Grants Pass, OR 97526) measuring $PM_{2.5}$ with a manufacturers uncertainty of 1 μg m^{-3} (Met One Instruments 2013) and $PM_{2.5}$ inlet sharp cut cyclones installed. The sensors used in this study are frequently used and have been rigorously evaluated against environmental protection agency regulatory sensors and cited in monitoring and research activities with a precision and accuracy similar to regulatory grade instrumentation (Mendoza *et al* 2019). The sensors were all well-maintained with proper flow rates and filter changes throughout the study. The humidity was well below the threshold (<40% humidity in this study) where particle hygroscopicity (>90% humidity) starts to have a bias effect on the laser sensors. Biases between the different ES-642 may account for part of the signal differences, however these should be less than 5% per manufacturer specifications (Met One Instruments, Inc. 2013).

Figure 2. Study area showing the sensor locations at (a) Highland High School COVID-19 testing site (East), (b) Workforce Services—Midvale COVID-19 testing site (South), and (c) Utah State Fairgrounds Wasatch BLDG COVID-19 testing site (North). $PM_{2.5}$ sensors are marked by red stars and the location of test administration by yellow circles.

Table 1. Campaign timelines including sensor availability.

Site	Start	End
Highland High (East)	1/31/2022	4/3/2022
Workforce Services—Midvale (South)	2/1/2022	4/3/2022
Utah State Fairgrounds Wasatch BLDG (North)	1/31/2022	4/3/2022

3. Results

3.1. COVID-19 testing site activity

The total daily number of COVID-19 tests administered at the testing sites is shown in figure 3. Detailed information on the testing sites, including operating days and hours, and tests by type is found in appendix.

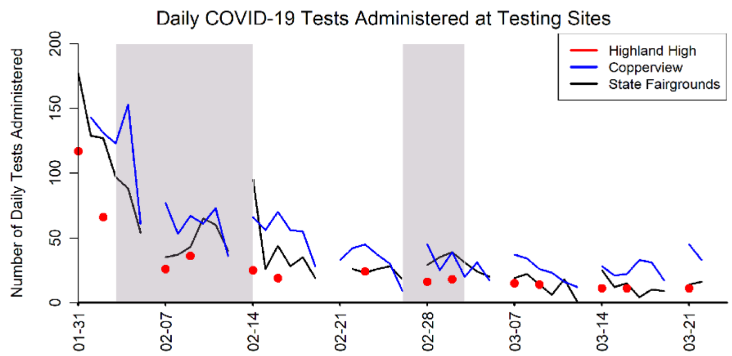

Figure 3. Daily COVID-19 tests administered at testing sites during the study period. The shaded areas represent atmospheric inversion periods.

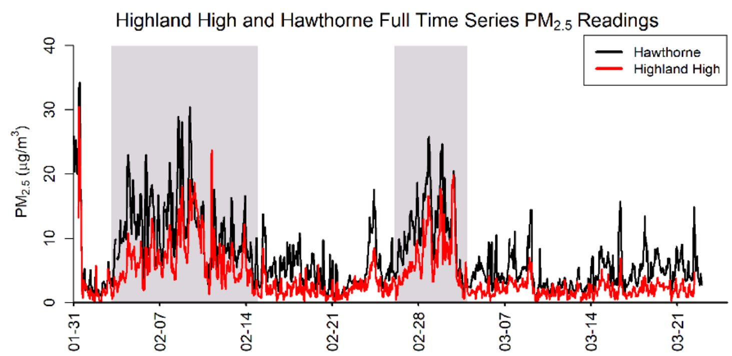

Figure 4. Highland High and Hawthorne (UDAQ) $PM_{2.5}$ timeseries comparison. The shaded areas represent atmospheric inversion periods.

3.2. Case studies

Due to the testing schedule, only the Highland High site can be studied to compare weekday air pollution on testing (Mondays and Wednesdays) and non-testing days. Both the Copperview and State Fairgrounds sites tested from Monday to Saturday which made a comparison between testing and non-testing days intractable.

3.2.1. Highland high testing site

Figure 4 shows the timeseries comparison of the Highland High COVID-19 Testing Site air quality data with the Hawthorne Elementary School UDAQ regulatory sensor data. Two inversion periods are noted spanning from early to mid-February, and late February to early March.

A statistical comparison of these data across all testing and non-testing days is shown in figures 5(a) and (b). Although Highland High $PM_{2.5}$ readings are lower than Hawthorne, on testing days (Mondays and Wednesdays) the $PM_{2.5}$ readings are proportionately higher, with a slope of 0.704, than on non-testing days (Tuesdays, Thursdays, and Fridays), which have a slope of 0.543.

The comparison of non-inversion testing days and non-inversion, non-testing days is shown in figures 6(a) and (b). During non-inversion periods, $PM_{2.5}$ concentrations were proportionately higher for the COVID-19 testing site locations during testing days (slope of 0.64) compared to non-testing days (slope of 0.366).

The analysis of inversion testing days and inversion, non-testing days is shown in figures 7(a) and (b). Although the values at Hawthorne (UDAQ) are still higher than at Highland High during inversions, the testing day $PM_{2.5}$ showed relatively higher values (slope of 0.69) than non-testing days (slope of 0.49).

The diurnal cycles during inversion testing days and inversion, non-testing days are shown in figures 8(a) and (b). During inversions the testing day Highland High $PM_{2.5}$ readings increased in the afternoon (during and after the 4–7 pm testing hours) at a greater rate than Hawthorne's (UDAQ) readings. This leads to more similar evening concentrations at both sites. On the other hand, during non-testing days, there is a larger divergence in $PM_{2.5}$ readings.

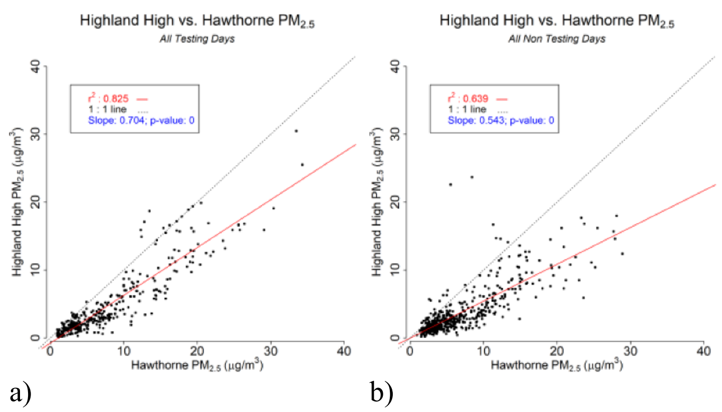

Figure 5. Highland High And Hawthorne: (a) all testing days and (b) all non-testing days.

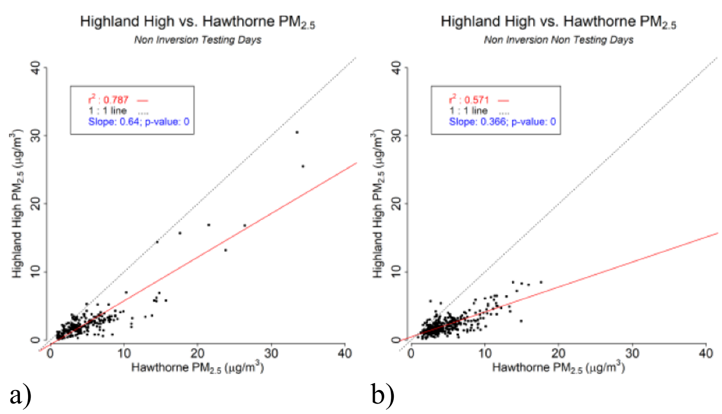

Figure 6. Highland High And Hawthorne $PM_{2.5}$: (a) non-inversion testing days and (b) non-inversion, non-testing days.

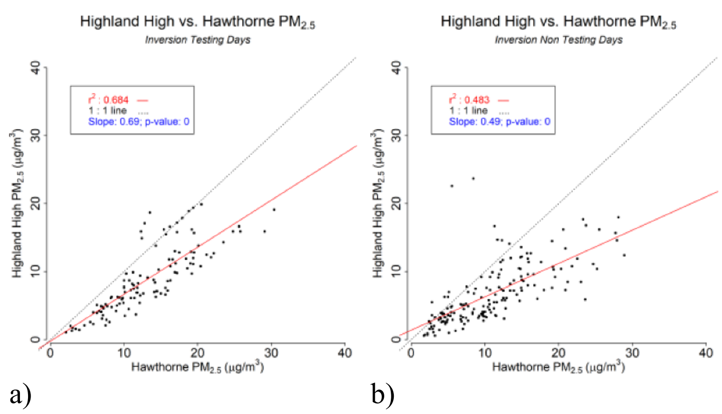

Figure 7. Highland High and Hawthorne inversion testing days $PM_{2.5}$: (a) inversion testing and (b) inversion, non-testing days.

3.2.2. Workforce testing site

Figure 9 provides a timeseries comparison of the Workforce COVID-19 Testing Site $PM_{2.5}$ data with the Copperview UDAQ regulatory sensor data.

The analysis of inversion testing days and inversion, non-testing days is shown in figures 10(a) and (b). During inversions the testing day $PM_{2.5}$ (slope of 0.972) showed substantially higher values than the non-testing days (slope of 0.645) at Workforce when compared to UDAQ data (Copperview).

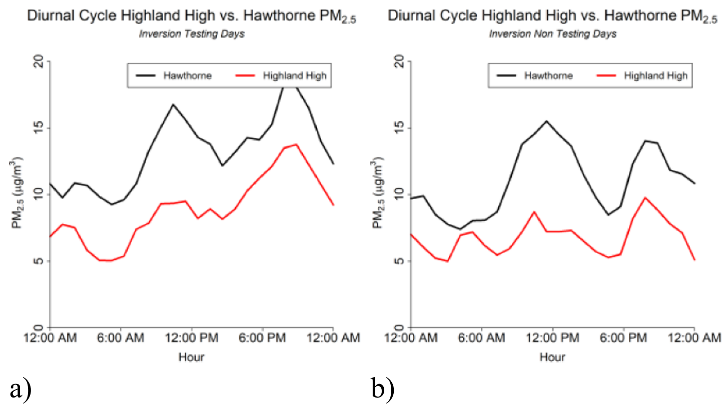

Figure 8. Highland High and Hawthorne inversion $PM_{2.5}$ diurnal cycles: (a) testing days and (b) non-testing Days.

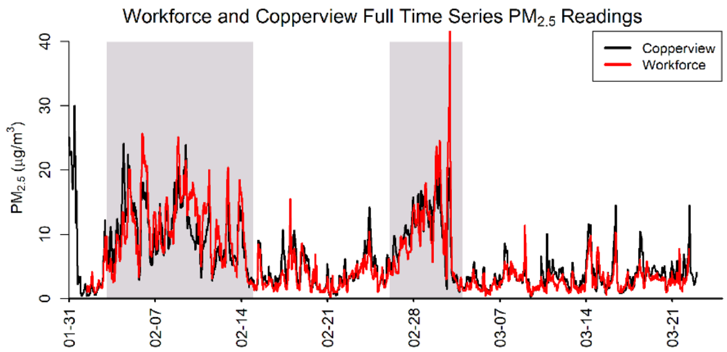

Figure 9. Workforce and Copperview (UDAQ) $PM_{2.5}$ timeseries comparison. The shaded areas represent atmospheric inversion periods.

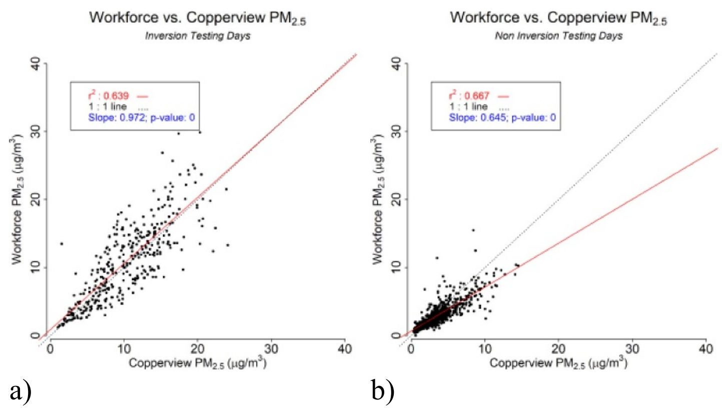

Figure 10. Workforce and Copperview testing days $PM_{2.5}$: (a) inversion days and (b) non-inversion days.

3.2.3. State fairgrounds testing site

Figure 11 displays a timeseries comparison of the State Fairgrounds COVID-19 Testing Site $PM_{2.5}$ data with the Rose Park (UDAQ) regulatory sensor data.

The analysis of inversion testing days and inversion, non-testing days is shown in figures 12(a) and (b). Similarly, to the Copperview site, during inversions the testing day $PM_{2.5}$ (slope of 0.988) showed relatively higher values than non-testing days (slope of 0.661) at State Fairgrounds compared to Rose Park (UDAQ).

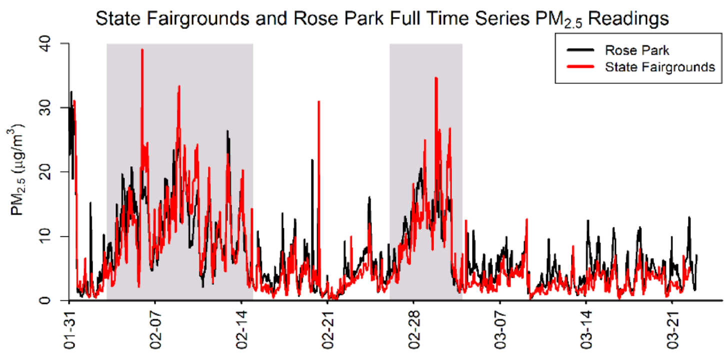

Figure 11. State fairgrounds and rose park (UDAQ) $PM_{2.5}$ timeseries comparison. The shaded areas represent atmospheric inversion periods.

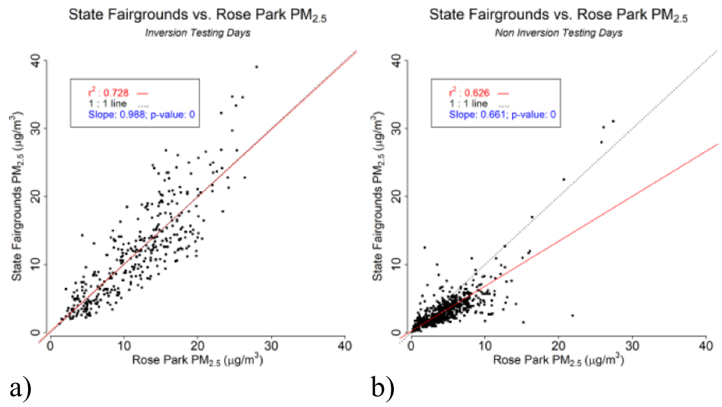

Figure 12. State fairgrounds and Rose Park testing days $PM_{2.5}$: (a) inversion days and (b) non-inversion days.

4. Discussion

4.1. Key findings

On days when the COVID-19 testing sites were closed, we found consistently lower $PM_{2.5}$ concentrations compared to their corresponding UDAQ sites. This is primarily due to the proximity of UDAQ sites to high-emitting sources, including interstate highways and industrial facilities. However, during testing days, this difference was reduced, due to the addition of local pollution emissions from vehicles traveling to the testing sites and idling while waiting in line. It is well-known that high-traffic areas in cities are subject to increased pollution levels compared to areas away from roads (Chen *et al* 2022). During inversion stagnation events, when the local emissions from vehicles traveling and idling were able to build up more, relative to non-inversion days, the concentration difference between testing and UDAQ sites was further narrowed. Looking at the diurnal cycles of $PM_{2.5}$ concentrations, the inversion-driven pollution build-up is particularly apparent in the late afternoon and evening hours, when testing lines and, therefore, idling levels, were highest. This suggests that the evening nocturnal surface inversion works to maximize the relative signal of hyper-local emissions from added car traffic and idling cars at the testing sites.

Staff working at the testing sites mentioned a final rush during the last 30 min of testing hours. Hourly business patterns of COVID testing sites on Google.com appears to support this pattern in some locations as the busiest times were found to be at the end of the testing site's hours of operation. In other locations, post 9am—5pm business hours were found to also be high traffic periods, and this further supports the patterns found in our study. Therefore, the compounded effects of multi-day and nocturnal surface inversions in the meteorology and the late afternoon maximum in vehicular emissions from the testing site are hypothesized to both be important factors to explain this phenomenon. For the evening surface inversion, the most notable example is at Highland High as testing hours were from 4–7pm.

Because the number of daily tests administered at the testing sites is relatively small and stable over time, (figure 1, appendix tables A1–A3), it is apparent that vehicular idling while waiting in line for testing was a substantial contributor to $PM_{2.5}$ concentrations. As a result, it is likely that the main source of emissions may be attributed to the additional local traffic associated with the vehicles arriving at the testing site as well as both idling and the associated behavior of stopping and restarting while waiting in line. During inversion events, when pollutants easily accumulate and do not ventilate well, even a small amount of additional contaminants can cause a sustained effect.

The Highland High site is sufficiently removed from large emission sources that even during inversions the testing site does not approach the Hawthorne UDAQ pollution levels. However, the Workforce and State Fairgrounds sites show similar $PM_{2.5}$ concentrations as their corresponding UDAQ sites (Copperview and Rose Park) during inversion testing days. During non-inversion testing days, the testing site $PM_{2.5}$ levels are far below UDAQ site levels. This underscores the strong local impact of inversions on pollution levels. As the atmospheric boundary layer lowers, the $PM_{2.5}$ levels increase and remain elevated overnight into the early morning hours.

4.2. Policy implications

Our findings suggest that drive-through facilities may have serious compounding effects in highly polluted urban areas and policy may need to account for these factors in an effort to protect human health and well-being. Hyperlocal pollution may also unnecessarily increase the health risks for health care workers (COVID-19 testers) in such conditions as well as staff in drive-through facilities. This study was conceived after receiving reports of long wait lines of up to four hours at COVID-19 testing sites in early January 2022. Although this effect had largely subsided by the time this study took place, there could be some improvements to reduce the impact of these sites on local air quality if another surge occurs. Since the benefits of turning the engine off vary by emission type (Gaines *et al* 2012), instead of drive-through settings for testing, for example, when testing lines extend beyond the ten minute mark (when net harm is maximized), large parking lots could be provided and patients could be required to walk up to the protected testing sites. This would not only protect workers and patients, but also maximize the net benefits of efficiency and pollution control. Additionally, this would improve the local air quality, be more cost effective, and would be considered more humane by reducing worker exposure overall.

While this study focused on drive-through COVID-19 testing sites, the amount of drive-through facilities, including food establishments, banks, and pharmacies, among others, is non-trivial and this number has increased as a result of the COVID-19 pandemic. As important as it is to focus on ambient air quality impacts, the health of the workers staffing these facilities must be taken into consideration as well. Many of these businesses have windows that open to facilitate customer interaction and exchanges (e.g. food pick-up) and expose the staff to elevated pollution levels stemming from vehicles, especially during inversion periods.

5. Conclusions

This study quantified $PM_{2.5}$ concentrations at three COVID-19 testing sites and compared them against regulatory air quality sensors nearby. Although, the testing sites were generally farther away from large pollution sources than the regulatory sensors and generally read lower $PM_{2.5}$ concentrations, on testing days during atmospheric inversion periods, the $PM_{2.5}$ readings became comparable. Our findings suggest that traffic-related emissions, from both idling and added traffic to and within the COVID-19 testing sites are the cause of the observed increased $PM_{2.5}$ concentrations. The impact of stagnating pollution from hyperlocal sources is a concern, particularly for staff working at high traffic facilities, including drive-throughs.

Data availability statement

No new data were created or analysed in this study.

Acknowledgments

The authors would like to thank Juli Miller from the Utah Department of Health, the staff at the Utah State Fairpark, Highland High School, and Workforce Services for their support installing the $PM_{2.5}$ sensors, Charles Snow for technical assistant on this project, and Tony Tran for providing testing site activity information.

Funding information

This study did not receive funding and investigators donated their time pro bono.

Table A1. Highland high operating days, hours, and number of tests administered by type.

Date	Time	Rapid	PCR-AN	PCR-SALIVA	Total tests
1/31/2022	4pm–7pm	61	56	0	117
2/2/2022	4pm–7pm	29	37	0	66
2/7/2022	4pm–7pm	0	25	1	26
2/9/2022	4pm–7pm	0	36	0	36
2/14/2022	4pm–7pm	0	25	0	25
2/16/2022	4pm–7pm	0	19	0	19
2/23/2022	4pm–7pm	0	24	0	24
2/28/2022	4pm–7pm	0	16	0	16
3/2/2022	4pm–7pm	0	17	1	18
3/7/2022	4pm–7pm	0	15	0	15
3/9/2022	4pm–7pm	0	14	0	14
3/14/2022	4pm–7pm	0	11	0	11
3/16/2022	4pm–7pm	0	11	0	11
3/21/2022	4pm–7pm	0	10	1	11
3/23/2022	4pm–7pm	0	14	0	14
3/28/2022	4pm–7pm	0	6	0	6
3/30/2022	4pm–7pm	0	4	0	4
Grand total		90	340	3	433

Appendix . Testing Site Information

The testing site operating days and hours, as well as the number of tests administered by type are shown for Highland High (table A1), Workforce (table A2), and State Fairgrounds (table A3).

Table A2. Copperview operating days, hours, and number of tests administered by type.

Date	Time	Rapid	PCR-AN	PCR-SALIVA	Total tests
2/1/2022	12pm–6pm	85	54	4	143
2/2/2022	12pm–6pm	84	47	0	131
2/3/2022	12pm–6pm	75	48	0	123
2/4/2022	12pm–6pm	92	61	0	153
2/5/2022	9am–1pm	34	27	0	61
2/7/2022	11am–5pm	0	76	1	77
2/8/2022	11am–5pm	0	49	4	53
2/9/2022	11am–5pm	0	65	2	67
2/10/2022	11am–5pm	6	55	0	61
2/11/2022	11am–5pm	0	68	5	73
2/12/2022	9am–1pm	0	36	0	36
2/14/2022	11am–5pm	3	61	2	66
2/15/2022	11am–5pm	0	56	0	56
2/16/2022	11am–5pm	0	70	0	70
2/17/2022	11am–5pm	0	56	0	56
2/18/2022	11am–5pm	0	55	0	55
2/19/2022	9am–1pm	0	28	0	28
2/21/2022	9am–1pm	0	33	0	33
2/22/2022	8am–6pm	0	42	0	42
2/23/2022	8am–6pm	0	44	1	45
2/24/2022	8am–6pm	0	37	0	37
2/25/2022	8am–6pm	0	29	1	30
2/26/2022	9am–1pm	0	9	0	9
2/28/2022	8am–6pm	0	43	2	45
3/1/2022	8am–6pm	0	25	0	25
3/2/2022	8am–6pm	0	39	0	39
3/3/2022	8am–6pm	0	20	0	20
3/4/2022	8am–6pm	0	29	2	31
3/5/2022	9am–1pm	0	16	1	17
3/7/2022	8am–6pm	0	36	1	37
3/8/2022	8am–6pm	0	32	2	34
3/9/2022	9am–6pm	0	26	0	26
3/10/2022	8am–6pm	0	22	1	23
3/11/2022	8am–6pm	0	16	0	16
3/12/2022	9am–1pm	0	12	0	12
3/14/2022	8am–6pm	0	27	1	28
3/15/2022	8am–6pm	0	21	0	21
3/16/2022	8am–6pm	0	21	1	22
3/17/2022	8am–6pm	0	32	1	33
3/18/2022	8am–6pm	0	29	2	31
3/19/2022	9am–1pm	0	14	3	17
3/21/2022	8am–6pm	0	44	1	45
3/22/2022	8am–6pm	0	30	3	33
3/23/2022	8am–6pm	0	26	0	26
3/24/2022	8am–6pm	0	23	0	23
3/25/2022	8am–6pm	0	11	0	11
3/26/2022	9am–1pm	0	10	1	11
3/28/2022	8am–6pm	0	26	0	26
3/29/2022	8am–6pm	0	12	0	12
3/30/2022	8am–6pm	0	15	0	15
3/31/2022	8am–6pm	0	25	0	25
4/1/2022	2pm–8pm	0	14	1	15
4/2/2022	7am–11am	0	2	0	2
Grand Total		379	1804	43	2226

Table A3. State fairgrounds operating days, hours, and number of tests administered by type.

Date	Time	Rapid	PCR-AN	PCR-SALIVA	Total tests
1/31/2022	11am–5pm	112	65	0	177
2/1/2022	11am–5pm	79	45	5	129
2/2/2022	11am–5pm	76	50	1	127
2/3/2022	11am–5pm	61	36	0	97
2/4/2022	11am–5pm	59	29	0	88
2/5/2022	9am–1pm	31	23	0	54
2/7/2022	11am–5pm	0	35	0	35
2/8/2022	11am–5pm	0	37	0	37
2/9/2022	11am–5pm	0	43	0	43
2/10/2022	11am–5pm	33	32	0	65
2/11/2022	11am–5pm	18	41	1	60
2/12/2022	9am–1pm	7	33	0	40
2/14/2022	11am–5pm	39	56	0	95
2/15/2022	11am–5pm	0	26	0	26
2/16/2022	11am–5pm	0	38	6	44
2/17/2022	11am–5pm	0	28	0	28
2/18/2022	11am–5pm	0	34	1	35
2/19/2022	9am–1pm	0	19	0	19
2/22/2022	11am–5pm	0	26	0	26
2/23/2022	11am–5pm	0	23	0	23
2/24/2022	11am–5pm	0	25	1	26
2/25/2022	11am–5pm	0	28	0	28
2/26/2022	9am–1pm	0	18	0	18
2/28/2022	11am–5pm	0	29	0	29
3/1/2022	11am–5pm	0	35	0	35
3/2/2022	11am–5pm	0	39	0	39
3/3/2022	11am–5pm	0	30	1	31
3/4/2022	11am–5pm	0	24	0	24
3/5/2022	9am–1pm	0	20	0	20
3/7/2022	11am–5pm	0	19	0	19
3/8/2022	11am–5pm	0	22	0	22
3/9/2022	11am–5pm	0	14	0	14
3/10/2022	11am–5pm	0	6	0	6
3/11/2022	11am–5pm	0	18	0	18
3/12/2022	9am–1pm	0	1	0	1
3/14/2022	11am–5pm	0	25	0	25
3/15/2022	11am–5pm	0	12	0	12
3/16/2022	11am–5pm	0	15	0	15
3/17/2022	11am–5pm	0	4	0	4
3/18/2022	11am–5pm	0	10	0	10
3/19/2022	9am–1pm	0	9	0	9
3/21/2022	11am–5pm	0	14	0	14
3/22/2022	11am–5pm	0	14	2	16
3/23/2022	11am–5pm	0	15	0	15
3/24/2022	11am–5pm	0	12	0	12
3/25/2022	11am–5pm	0	11	0	11
3/26/2022	9am–1pm	0	5	0	5
3/28/2022	11am–5pm	0	15	0	15
3/29/2022	11am–5pm	0	11	0	11
3/30/2022	11am–5pm	0	15	0	15
3/31/2022	11am–5pm	0	7	0	7
Grand Total		515	1241	18	1774

ORCID iDs

Daniel L Mendoza https://orcid.org/0000-0002-7884-7362
Tabitha M Benney https://orcid.org/0000-0001-5800-8919
Erik T Crosman https://orcid.org/0000-0002-0047-384X
Shawn A Gonzales https://orcid.org/0009-0003-9973-6324

References

Bares R, Lin J C, Hoch S W, Baasandorj M, Mendoza D L, Fasoli B, Mitchell L, Catharine D and Stephens B B 2018 The wintertime covariation of CO_2 and criteria pollutants in an urban valley of the western United States *J. Geophys. Res.* **123** 2684–703
Benney T M, Cantwell D, Singer P, Derhak L, Bey S and Saifee Z 2021 Understanding perceptions of health risk and behavioral responses to air pollution in the State of Utah (USA) *Atmosphere* **12** 1373
Breton C V *et al* 2016 Prenatal air pollution exposure and early cardiovascular phenotypes in young adults *PLoS One* **11** e0150825
Carrico A R, Padgett P, Vandenbergh M P, Gilligan J and Wallston K A 2009 Costly myths: an analysis of idling beliefs and behavior in personal motor vehicles *Energy Policy* **37** 2881–8
Chen Y, Gu P, Schulte N, Zhou X, Mara S, Croes B E, Herner J D and Vijayan A 2022 A new mobile monitoring approach to characterize community-scale air pollution patterns and identify local high pollution zones *Atmos. Environ.* **272** 118936
Cohen J F W, Posluszny H, Falbe J, Mueller M P, Gearhardt A N, Leung C W and Wolfson J A 2022 Restaurant dining during the COVID-19 pandemic among adults with low-income in the United States *Appetite* **173** 105976
Eghbalnia C, Sharkey K, Garland-Porter D, Alam M, Crumpton M, Jones C and Ryan P H 2013 A community-based participatory research partnership to reduce vehicle idling near public schools *J. Environ. Health* **75** 14–19 (available at: www.jstor.org/stable/26329619)
Gaines L *et al* 2012 *Which Is Greener: Idle, or Stop and Restart* (Argonne National Laboratory, US Department of Energy)
Google Maps 2022
Johnson S A, Mendoza D L, Zhang Y and Pirozzi C S 2021 Effects of short-term air pollution exposure on venous thromboembolism: a case-crossover study *Ann. Am. Thorac. Soc.* **18** 1988–96
Kim J Y, Ryan P H R, Yermakov M, Schaffer C, Reponen T and Grinshpun S A 2014 The effect of an anti-idling campaign on indoor aerosol at urban schools *Aerosol Air Qual. Res.* **14** 585–95
Kinsey J, Williams D C, Dong Y and Logan R 2007 Characterization of fine particle and gaseous emissions during school bus idling *Environ. Sci. Technol.* **41** 4972–9
Kroll J H and Seinfeld J H 2008 Chemistry of secondary organic aerosol: formation and evolution of low-volatility organics in the atmosphere *Atmos. Environ.* **42** 3593–624
Lee Y-Y, Lin S-L, Yuan C-S, Lin M-Y and Chen K-S 2018 Reduction of atmospheric fine particle level by restricting the idling vehicles around a sensitive area *J. Air Waste Manage. Assoc.* **68** 656–70
Lynn J, Oppenheimer S and Zimmer L 2014 Using public policy to improve outcomes for asthmatic children in schools *J. Allergy Clin. Immunol.* **134** 1238–44
Mahmood L, Abrams D, Meleady R, Hopthrow T, Lalot F, Swift H and Van de Vyver J 2019 Intentions, efficacy, and norms: the impact of different self-regulatory cues on reducing engine idling at long wait stops *J. Environ. Psychol.* **66** 101368
Meleady R, Abrams D, Van de Vyver J, Hopthrow T, Mahmood L, Player A, Lamont R and Leite A C 2017 Surveillance or self-surveillance? Behavioral cues can increase the rate of drivers' pro-environmental behavior at a long wait stop *Environ. Behav.* **49** 1156–72
Mendoza D L *et al* 2022b Air quality and behavioral impacts of anti-idling campaigns in school drop-off zones *Atmosphere* **13** 706
Mendoza D L, Bayles M, Contreras J R, Bares R, Olson C S, Crosman E T and Forrest R T 2022a Idle-free campaign survey results and idling reductions in an elementary school *Vehicles* **4** 865–902
Mendoza D L, Crosman E, Mitchell L, Jacques A, Fasoli B, Park A, Lin J and Horel J 2019 The TRAX light-rail train air quality observation project *Urban Sci.* **3** 108
Met One Instruments, Inc. 2013 ES-642 dust monitor operation manual
Pearson A R, Schuldt J P and Romero-Canyas R 2016 Social climate science: a new vista for psychological science *Perspect. Psychol. Sci.* **11** 632–50
Pirozzi C S, Jones B E, VanDerslice J A, Zhang Y, Paine R and Dean N C 2018 Short-term air pollution and incident pneumonia. A case–crossover study *Ann. Am. Thorac. Soc.* **15** 449–59
Pope C A III, Muhlestein J B, Anderson J L, Cannon J B, Hales N M, Meredith K G, Le V and Horne B D 2015 Short-term exposure to fine particulate matter air pollution is preferentially associated with the risk of ST-segment elevation acute coronary events *J. Am. Heart Assoc.* **4** e002506
Richmond-Bryant J, Saganich C, Bukiewicz L and Kalin R 2009 Associations of $PM_{2.5}$ and black carbon concentrations with traffic, idling, background pollution, and meteorology during school dismissals *Sci. Total Environ.* **407** 3357–64
Rumchev K, Lee A, Maycock B and Jancey J 2021 Reducing car idling at primary schools: an intervention study of parent behaviour change in Perth, Western Australia *Health Promot. J. Aust.* **32** 383–90
Ryan P H *et al* 2013 The impact of an anti-idling campaign on outdoor air quality at four urban schools *Environ. Sci.: Process. Impacts* **15** 2030–7
United States Environmental Protection Agency 2022 NAAQS table
USGS 2021 TNM elevation tool
Utah Division of Air Quality, Utah Division of Air Quality 2021 2020 Annual report
Vishnevetsky J, Tang D, Chang H-W, Roen E L, Wang Y, Rauh V, Wang S, Miller R L, Herbstman J and Perera F P 2015 Combined effects of prenatal polycyclic aromatic hydrocarbons and material hardship on child IQ *Neurotoxicol. Teratol.* **49** 74–80
Whiteman C D, Hoch S W, Horel J D and Charland A 2014 Relationship between particulate air pollution and meteorological variables in Utah's Salt Lake Valley *Atmos. Environ.* **94** 742–53
Zhang X, Chen X and Zhang X 2018 The impact of exposure to air pollution on cognitive performance *Proc. Natl Acad. Sci.* **115** 9193–7