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Department of Health

Associations of Short-Term Exposure to Ozone and Respiratory Outpatient Clinic Visits — Sublette County, Wyoming, 2008–2011

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Kerry Pride, J. Peel, B. Robinson, A. Busacker, J. Grandpre, F. Yip, T. Murphy

Executive Summary

Introduction

Ozone occurs both in Earth's upper atmosphere (stratosphere), where it protects against ultraviolet radiation, and at ground level (troposphere), where it can cause adverse respiratory effects. Ground-level ozone is one of the six criteria air pollutants monitored and regulated by the Environmental Protection Agency (EPA) under the Clean Air Act. The EPA considers ground-level ozone concentrations ≥75 ppb to be above the national ambient air quality standard, but health effects can occur at lower concentrations. Anyone who works, plays, or spends time outside can feel symptoms from ground-level ozone that include shortness of breath, coughing, wheezing, eye, nose or throat irritation, and pain or burning when taking a deep breath.

Ground-level ozone concentrations higher than the EPA national ambient air quality standard level of 75 ppb have occurred in Sublette County. These exceedances occurred in both 2008 and 2011 during the winter months (February and March). Residents of Sublette County have expressed concern over possible health effects from ground-level ozone and have sought information from public health officials on local adverse health effects. Until this study, objective information on adverse health effects from ground-level ozone in Sublette County was not available.

Goal

The Wyoming Department of Health (WDH) performed this public health investigation to evaluate possible associations between short-term changes in ground-level ozone and adverse acute respiratory effects among persons residing and seeking healthcare within Sublette County.

Methods

De-identified health data was obtained from the two primary care clinics in Sublette County. The Wyoming Department of Environmental Quality (DEQ) supplied the ground-level ozone concentrations, temperature, and humidity data within Sublette County. Descriptive statistics were calculated for each of the monitoring stations (mean, median, minimum, maximum, number of observation days, and standard deviation). Correlations of 8-hour max ground-level ozone concentrations between the monitoring stations were calculated to assess if concentrations at different monitoring stations were associated.

A bi-directional (before and after event) time-stratified (1-month) case-crossover (each case serves as its own control) design was used to estimate the association of ground-level ozone on clinic visits for respiratory-related illnesses. Associations between ground-level ozone and adverse respiratory-related effects were assessed for same day ground-level ozone exposure, previous day ground-level ozone exposure, two days prior ground-level ozone exposure, three

days prior ground-level ozone exposure and combined 0–3 days. Multiple sensitivity analyses were completed to evaluate whether similar results were obtained when different model assumptions were used for the analysis.

Results

During 2008–2011, data showed that 8-hour max ground level-ozone concentrations followed a similar pattern year-to-year with the highest concentrations occurring early in the year (February to April) and the lowest concentrations occurring later in the year (October to December). Eight hour max ground-level ozone concentrations between ozone monitoring stations were moderately to highly correlated (correlation coefficient range: 0.61–0.94) between ozone monitoring stations within Sublette County. Results suggest a 3% increase in the number of clinic visits for adverse respiratory-related effects for every 10 ppb increase in 8-hour max ground-level ozone the day following a ground-level ozone increase in Sublette County for the range of ground-level ozone observed (19 ppb to 84 ppb). All other ground-level ozone lags, same day, two days prior, three days prior, and lags 0–3 days combined were consistent with no association between adverse respiratory-related effects and ground level-ozone exposure.

Conclusions

The results of this study suggest an association of ground-level ozone with clinic visits for adverse respiratory-related effects the day following elevations of ground-level ozone in Sublette County. This analysis evaluated ground-level ozone across the range of concentrations observed, with the majority of days below the regulatory standards. These results are consistent with other studies in the published literature. Improved awareness and education of the public and providers of the adverse respiratory-related health effects from ground-level ozone in Sublette County should continue.

Background

Ozone is a colorless gas composed of three oxygen atoms (O_3) and is ubiquitous throughout the atmosphere.[1] Ozone occurs both in Earth's upper atmosphere (stratosphere), where it protects against ultraviolet radiation, and at ground level (troposphere) where it can cause adverse respiratory effects and is a major component of air pollution.[1] The two main classes of ozone precursors are volatile organic compounds (VOCs) and nitrogen oxides (NOx).[2] VOCs refer to all carbon-containing gas-phase compounds in the atmosphere.[2] Precursors for ground-level ozone can come from natural sources (eg. trees or volcanoes) or from man-made sources (eg. automobiles or industry). [1] Background ozone concentrations are those that would occur in the absence of human causes (anthropogenic emissions).[2] Formation of excess ground-level ozone is complex and occurs when pollutants released from cars, power plants, and other sources react in the presence of sunlight.[2-5] Ground-level ozone production varies greatly from locality to locality and is dependent on the amount and type of precursors present and meteorological conditions.[2,6]

Because ground-level ozone can cause adverse health effects and environmental and property damage, it is one of the six criteria air pollutants monitored and regulated by the Environmental Protection Agency (EPA) under the Clean Air Act.[2] The EPA regulates criteria pollutants by developing human health-based and/or environmental-based criteria for setting permissible levels.[2] The EPA considers ground-level ozone concentrations $\geq$75 ppb for an 8-hour period to be above the level of the national ambient air quality standard. Elevations of ground-level ozone most commonly occur in urban areas during the summer months.[2]

Exposure to elevated ground-level ozone can result in a number of health effects in any person, but especially in susceptible populations such as the young, the elderly, and anyone with pre-existing respiratory health conditions.[1,7,8] Symptoms of adverse respiratory health effects can include shortness of breath; coughing; wheezing; eye, nose or throat irritation; and pain or burning when taking a deep breath. Adverse respiratory-related effects following ground-level ozone exposure have been extensively documented in numerous studies and include induction of respiratory illness symptoms, increased asthma attacks, increased hospital admissions, increased daily mortality, and other markers of morbidity.[9-12] In previous studies, adverse respiratory-related effects due to elevated ground-level ozone occur most commonly during the summer months in large urban centers.[2,13,14]

Sublette County is located in western Wyoming and is just over 4,800 square miles. This region of Wyoming has experienced a population boom; from 2000 to 2010, the population increased 73.1%, from 5,920 to 10,247 (2.1 persons/square mile).[15] Six communities are located in the county ranging from 93 persons to 2,030 persons. [15] Sublette County is an area of year-round tourism for outdoor activities including hiking, skiing, snowmobiling, and other activities. Active oil and gas development is occurring in Sublette County also; the number of drilling rigs increased from 2 in 1996 to 49 in 2006 and the number of oil and gas wells increased from 1,900 in 2000 to 10,000 in 2008 (personal communication, Wyoming DEQ, 2011).

There are two area health clinics, which provide both primary and urgent care. As Sublette County does not have a hospital, patients commonly seek care at one of the area primary care clinics; if needed ill patients are transferred out of the county to one of the hospitals in the surrounding communities. Hospitals with specialized and emergent care are located approximately 80 miles north and 100 miles south of the main population centers in the county.

Since 2005, DEQ has monitored ground-level ozone in Sublette County. During the study period of January 1, 2008 through December 31, 2011, 13 monitors recorded ground-level ozone data for varying amounts of time. Eight of the 13 monitors are part of the EPA Air Quality System and the other five monitors were part of a yearlong air toxics study in 2009–2010. In addition to ground-level ozone, some monitoring stations recorded full meteorological data including wind direction, wind speed, temperature, humidity, barometric pressure, and solar radiation in addition to ground-level ozone.

In the winter months of 2008 and 2011, there were periods when ground-level ozone concentrations that exceeded the EPA national ambient air quality standard level of 75 ppb. In response to the elevations, DEQ issued ozone notifications to protect the public's health and advise industry to take action to decrease emissions. Methodology for predicting elevated ground-level ozone for the ozone notification days changed yearly to improve the accuracy of the notifications. Studies completed in Sublette County suggest that snow cover, combined with high concentration of ground-level ozone precursors trapped within a relatively small volume of air (an inversion), could be the cause of the high wintertime ground-level ozone concentrations.[16]

Residents of Sublette County have expressed concern over possible health effects from ground-level ozone and have sought information from public health officials on local adverse health effects. Until this study, information on adverse health effects from ground-level ozone specifically in Sublette County has been lacking, although a vast literature provides strong evidence regarding the health impacts of ground-level ozone.[2] The goal of this public health investigation was to evaluate the association between short-term changes in ground-level ozone and adverse acute respiratory-related effects within persons residing and seeking healthcare within Sublette County, and to assess possible public health impacts from ground-level ozone.

Methods

Health Data

De-indentified health outcome data were obtained from electronic billing records of the only two area clinics for the period January 1, 2008 to December 31, 2011. Information collected included a unique identification number, International Classification of Diseases 9th Revision (ICD-9) diagnostic codes, and demographic information such as age, sex, and location. All visits for an adverse respiratory-related effect were included with the following primary ICD-9 diagnostic codes (all 2 digit extensions were used unless otherwise specified): acute bronchitis (466), asthma (493), chronic obstructive pulmonary disease (491–492, 496), pneumonia (480–486), upper respiratory tract infection (460–465, 477), and other respiratory (786.09) during the study period. Descriptive statistics were conducted to evaluate the distribution of visits for each respiratory case group; sex; and age distribution including mean, median, and range.

Ozone and Weather Data

Daily maximum 8-hour ozone and 24-hour average temperature, and humidity data were obtained from DEQ. In order to calculate a maximum 8-hour average ozone per day, a monitor had to have a minimum of 18 rolling 8-hour average measures to be deemed as a valid monitoring day.[17] Completeness of ozone, temperature, and humidity data for the study period varied between monitors. Ground-level ozone, temperature, and humidity data were collected at the Daniel and Boulder monitoring stations for the whole study period, while the other monitoring stations had varying amounts of data available. Descriptive statistics were calculated for each of the monitoring stations (mean, median, minimum, maximum, number of observation days, and standard deviation). In addition, correlations of 8-hour max ground-level ozone concentrations between the monitoring stations were calculated to assess if concentrations at different monitoring stations were associated.

The Boulder and Daniel monitoring stations had the most complete ground-level ozone data for the study period, but the Boulder monitoring station is closest to the oil and gas field and a low proportion of the Sublette County population reside near the monitor. After review and analysis of the air data, the Daniel monitoring station was selected to represent the ground-level ozone exposures for Sublette County for a number of reasons. First, the Daniel monitoring station had the most complete data for not only ground-level ozone concentrations, but also temperature and humidity for the study period of January 1, 2008 to December 31, 2011. The Daniel monitoring station was highly correlated with other monitoring stations in population centers with less available data (such as the Pinedale monitoring station). Lastly, the use of central monitoring stations in other ozone health effect studies have been shown to be a good surrogate measure for ground-level ozone exposures for the population of an area.[2]

Statistical Analysis: Bi-directional Time-Stratified Case-Crossover

A bi-directional time-stratified case-crossover design was used to estimate the association of ground-level ozone and clinic visits for respiratory-related illnesses. Case-crossover analysis uses conditional logistic regression to compare the exposure on the case-day with the weighted average of the exposure on the selected control-days to estimate adjusted odds ratios.[18-20] The case-crossover study design inherently controls for factors that do not vary within person (e.g., age, sex, genetics) and adjusts for confounding by longer term trends and meteorological factors.[18-20]

Case-days were designated for each person who visited either of the two area clinics for one of the defined respiratory disease diagnoses and represent the day of the clinic visit. For the case-crossover analysis, a month was chosen as the strata to minimize confounding by weather, seasonality, and other factors that have longer-term variations. Control-days were matched to case-days by day of week within the same month of the case-day (e.g., if the case-day was on the second Tuesday in January, the selected control-days were all other Tuesdays in January). Repeat visits within seven days (2,790/15,532) were not included as separate case-days. There were 12,742 case-days (individual clinic visits for defined respiratory disease diagnoses) and 43,285 control-days.

Adjusted odds ratios (aORs) and 95% confidence intervals (95% CIs) were estimated using conditional logistic regression. The lag structures evaluated in this study included an unconstrained distributed lag 0–3 days and single lags including 0, 1, 2, and 3 days. A lag effect is when there is a delay in time between the exposure (ground-level ozone) and the health event (adverse respiratory-related effect). An unconstrained distributed lag allows the ability to evaluate the cumulative effects of individual lags over a few days (lag 0, lag 1, lag 2 and lag 3), with the lag days 0–3 assessed as a group and not separated out individually. Models with temperature and humidity variables coded with quadratic, cubic, or spline terms were run to determine the best model fit. The temperature and humidity included in the models were same day (lag 0) 24-hour temperature, lag 0 temperature squared, and same day (lag 0) humidity.

Interactions (factors that modify the association between exposure and health effect) by sex and age group were evaluated. Age groups were defined as child (<18 years of age), adult (18–65 years of age) and senior (>65 years of age).

In addition to the above analyses, the following sensitivity analyses were performed: exclusion of ozone notification days (19 days); exclusion of the day after a notification day (19 days); and exclusion of days with ground-level ozone ≥75 ppb (6 days for the Daniel monitoring station). Models with alternative adjustment for temperature (average, minimum, and maximum) and humidity were evaluated to assess the robustness the model. All sensitivity analyses were completed using both the unconstrained distributed lag 0–3 days and single lags of 0, 1, 2, and 3 days. Sensitivity analyses were also evaluated using ground-level ozone data from the Boulder monitoring station. Sensitivity analyses were completed to evaluate whether similar results were obtained when different model assumptions were used for the analysis. Sensitivity analyses test the robustness of the model.

Approval for this study was obtained from the Institutional Review Board from the Wyoming Department of Health.

Results

<u>Ground-Level Ozone Data</u>

Figure 1 shows the locations of the ozone monitoring stations, towns, and the locations of the oil and gas wells around Sublette County.[21] Table 1 displays the results of the descriptive analyses of the 13 monitoring stations.

Figure 1: Monitoring Stations, Towns, and Wells Sublette County, Wyoming[21]

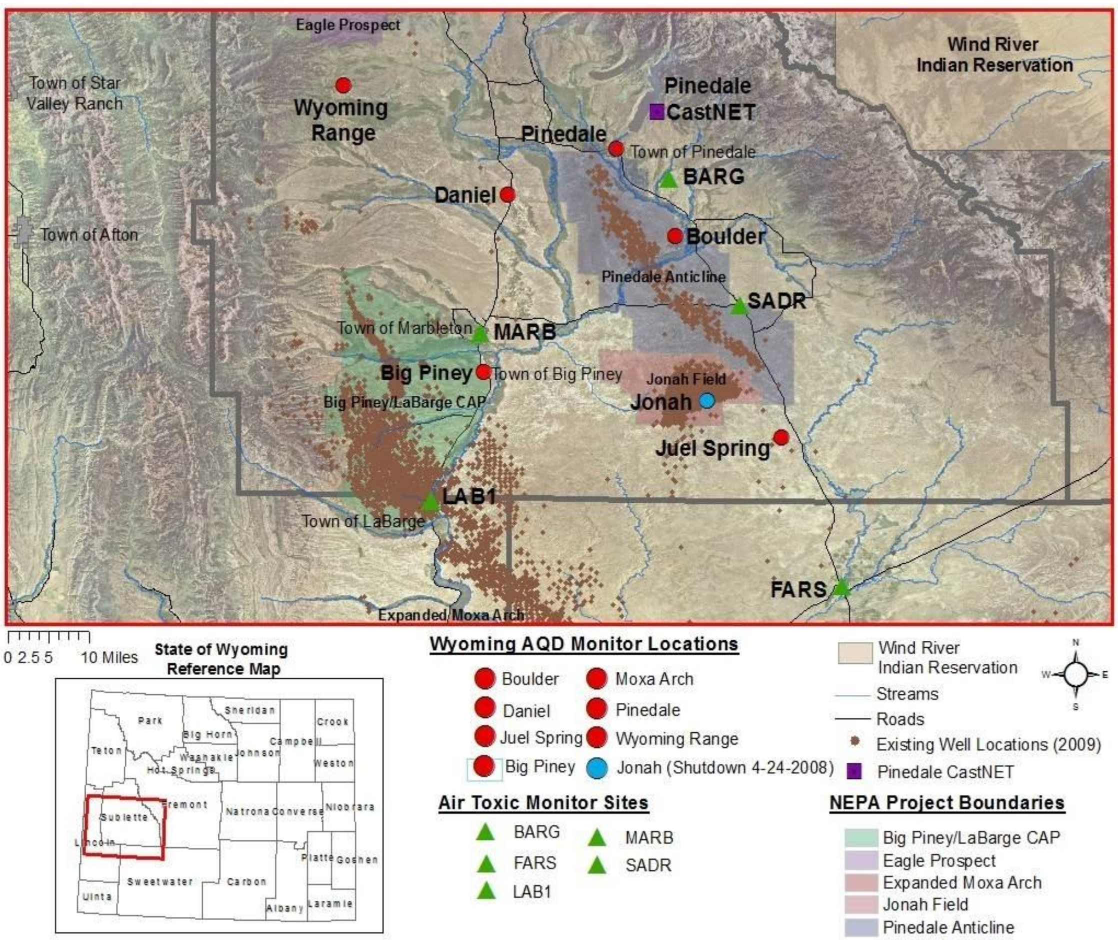

Table 1: Descriptive Analyses of All 13 Ground-Level Ozone Monitoring Stations, Sublette County, Wyoming, January 1, 2008–December 31, 2011

Monitor	Observation Days	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
Boulder	1429	49	10	49	22	123
Daniel	1363	47	8	47	19	84
Big Piney	190	51	6	52	38	72
Wyoming Range	273	50	7	49	34	83
Jonah	89	49	15	45	15	102
Pinedale CastNET	122	53	6	53	42	70
Juel Springs	726	49	8	49	28	94
Pinedale	879	46	8	46	14	89
FARS	424	46	9	46	25	65
SADR	422	47	8	48	18	70
MARB	440	44	8	45	16	75
Lab1	427	41	8	41	20	65
BARG	440	49	7	49	30	75

Ground-level ozone concentrations (8-hour max) tended to be highest during the winter months. See Appendix B for complete descriptive analyses of ground-level ozone by season and year for the Daniel and Boulder monitoring stations. The 8-hour max ground-level ozone concentrations followed a similar pattern year to year, the highest concentrations occurred early in the year (February to April) and the lowest concentrations occurred later in the year (October to December). A graph of the 8-hour max ground-level ozone concentrations for all monitoring stations from January 1, 2008 to December 31, 2011 is in Appendix C.

Ground-level ozone concentrations were moderately to highly correlated between the monitoring stations (correlation coefficient range: 0.61–0.94) (Appendices D and E). Slightly weaker correlations were found between the Wyoming Range monitoring station and the other monitoring stations (correlation coefficient range: 0.61 to 0.82). The Wyoming Range monitoring station is in the far northwest corner of the county, is over 1,000 feet higher than the rest of the monitoring stations, and is not near a population center or an oil and gas field in the county.

Health Data

There were 14,529 case-days for all defined respiratory-related ICD-9 codes from January 1, 2008 to December 31, 2011. There were 1,787 repeat visits in the first 7 days, which were excluded from the final data set, leaving 12,742 case-days. Females accounted for 52.7% (6,717) of the case-days. The mean age was 31.2 years of age (median, 28.6 years of age; range 4 months to 98 years). Table 2 shows the number and percent of case-days by age category. In Sublette County females account for 48.2% (4,939) of the total population, persons <18 account for 25.6% (2,623), and the elderly (≥65 years of age) account for 8.8% (902) of the population.[15] Table 3 shows the number of total visits by ICD-9 diagnosis grouping in the bi-directional time-stratified case-crossover study.

Table 2: Age Categories of Case-Days

Age Category	**N (%)**
Child (<18 years of age)	4,863 (38%)
Adult (18–65 years of age)	6,758 (53%)
Senior (>65 years of age)	1,121 (9%)

Table 3: ICD-9 Groupings of Respiratory Diagnosis, 2008–2011

Respiratory Diagnosis Grouping	**ICD-9 Codes**	**N (%)**
All Respiratory Disease	460–465,466,477, 480–486,490–493,496, 786.09	12,742 (100%)
Asthma	493	796 (6.2%)
Chronic Obstructive Pulmonary Disease	490–492, 496	1,956 (15.4%)
Acute Bronchitis	466	179 (1.4%)
Pneumonia	480–486	301 (2.4%)
Upper Respiratory Infections	460–465, 477	9,335 (73.3%)
Other	786.09	175 (1.4%)

Bi-Directional Time-Stratified Case-Crossover

The adjusted odds ratio (aOR) for clinic visits for the defined respiratory codes with the cumulative unconstrained distributed lag 0–3 model is shown in Table 4.

Table 4: Model of Unconstrained Distributed Lag 0–3 Days, adjusting for average temperature, average temperature squared, average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.001	0.24	0.9903	1.012

Single ozone lag models for lag 0, lag 1, lag 2, and lag 3 were also evaluated (Table 5). While not significant at the 0.05 level, the results for lag 1 suggest an association between ground-level ozone concentrations and clinic visits in the magnitude of a 3% increase in adverse respiratory-related clinic visits for every 10 ppb increase in 8-hour max ground-level ozone.

Table 5: Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.009	0.64	0.973	1.046
Lag 1	**1.031**	**0.10**	**0.994**	**1.069**
Lag 2	0.994	0.75	0.958	1.031
Lag 3	0.980	0.27	0.945	1.016

There were no significant interactions by sex (p=0.58) or age group (p=0.23).

Sensitivity Analyses

The results of the following sensitivity analyses are presented in the tables below: removal of notification days (Tables 6 & 7), removal of the days immediately after a notification day (Tables 8 & 9), and the removal of days with ground-level ozone concentrations ≥75 ppb (Tables 10 & 11). The results of the sensitivity analyses are consistent with the previous models, with lag 1 from the single ozone lag model suggesting an association between ground-level ozone concentrations and clinic visits in the magnitude of a 3% increase in adverse respiratory-related clinic visits for every 10 ppb increase in 8-hour max ground-level ozone.

Table 6: aOR and 95% CI with Removal of Notification Days; Model of Unconstrained Distributed Lag 0–3 days adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.001	0.28	0.990	1.012

Table 7: aOR and 95% CI with Removal of Notification Days; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.000	0.99	0.963	1.038
Lag 1	**1.030**	**0.12**	**0.993**	**1.068**
Lag 2	0.998	0.90	0.962	1.035
Lag 3	0.981	0.29	0.946	1.017

The results obtained with removing the notification days (Tables 6 & 7) were consistent with the previous models, with lag 1 suggesting an association between ground-level ozone and clinic visits in the magnitude of a 3% increase in adverse respiratory-related visits for every 10 ppb increase in 8-hour max ground-level ozone.

Table 8: aOR and 95% CI with Removal of the Days Immediately after a Notification Day; Model of Unconstrained Distributed of Lag 0–3 days adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.001	0.26	0.990	1.012

Table 9: aOR and 95% CI with Removal of the Days Immediately after a Notification Day; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.007	0.73	0.970	1.044
Lag 1	**1.029**	**0.13**	**0.991**	**1.068**
Lag 2	0.993	0.72	0.958	1.030
Lag 3	0.981	0.30	0.946	1.017

The results obtained with removing the days immediately after a notification day (Tables 8 & 9) were consistent with the previous models, with lag 1 suggesting an association between ground-level ozone and clinic visits in the magnitude of a 3% increase in adverse respiratory-related visits for every 10 ppb increase in 8-hour max ground-level ozone.

Table 10: aOR and 95% CI with Removal of Days with Ground-Level Ozone Concentrations ≥75 ppb; Model of Unconstrained Distributed Lag 0–3 Days, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.000	0.11	0.989	1.011

Table 11: aOR and 95% CI with Removal of the Days with Ground-Level Ozone Concentrations ≥75 ppb; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max of ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	P Value	Lower CI	Upper CI
Lag 0	1.000	0.95	0.963	1.040
Lag 1	**1.033**	**0.09**	**0.995**	**1.073**
Lag 2	0.988	0.52	0.952	1.025
Lag 3	0.975	0.15	0.938	1.010

The results obtained with removing the days with ground-level ozone concentrations ≥75 ppb (Tables 10 & 11) were consistent with the previous models, with lag 1 suggesting an association between ground-level ozone and clinic visits in the magnitude of a 3% increase in adverse respiratory-related visits for every 10 ppb increase in 8-hour max ground-level ozone.

Sensitivity analyses were also completed for different temperature (minimum and maximum) and humidity models. These results were consistent with the previous models. Although not significant at the 0.05 level, the results for lag 1 suggest an association between ground-level ozone concentrations and clinic visits in the magnitude of a 3% increase in adverse respiratory-related clinic visits for every 10 ppb increase in 8-hour max ground-level ozone (Appendices F and G).

Sensitivity analyses were completed with the ground-level ozone data from the Boulder monitoring station for the cumulative unconstrained distributed lags 0–3 and for each single lag model of 0, 1, 2, and 3 days. Similar associations were observed with the Boulder monitoring station ground-level ozone data as was observed with ground-level ozone data from the Daniel monitoring station. Lag 1 from the single lag model showed an estimated 5.6% increase in clinic visits for adverse respiratory-related effects for every 10 ppb increase in 8-hour max ground-level ozone, which does reach statistical significance at the 0.05 level (aOR 1.056; 95% CI: 1.030–1.082). (Appendices H and I).

Discussion

The study results suggest an association between ground-level ozone and clinic visits for adverse respiratory-related effects for lag 1 (one day later). The results for lag 1 from the single lag model suggest an association between ground-level ozone concentrations and clinic visits in the magnitude of a 3% increase in adverse respiratory-related clinic visits for every 10 ppb increase in 8-hour max ground-level ozone. Although this measure did not reach statistical significance at the 0.05 level using ground-level ozone data from the Daniel monitoring station, this association was found consistently in all other models evaluated as part of the sensitivity analyses. In addition, this association was also observed in the analyses using the ground-level ozone concentrations from the Boulder monitoring station and statistical significance at the 0.05 level was demonstrated. It is also important to note that these models evaluate respiratory-related health impacts across the entire range of 8-hour max ground-level ozone observed (19 ppb to 84 ppb), not just for those days that exceed the regulatory standard. A meaningful association between ground-level ozone concentrations and clinic visits for adverse-respiratory related effects was not observed for other lag periods (cumulative unconstrained distributed lag 0–3 days, single lag 0, single lag 2, and single lag 3).

The results of this study are consistent with other ozone-associated adverse health effects studies. Many single city studies observed associations between hospital admissions or emergency room visits for adverse respiratory effects and ground-level ozone.[2,8] In a recent meta-analysis, findings showed hospital admissions at lag 1 were consistently higher than the hospital admissions at lag 0 for all comparisons.[10] Of all air pollutants present at ground-level, ozone has the smallest margin between natural background levels and those that are considered harmful to human health.[6]

The removal of the DEQ ozone notification days and the days immediately following a notification day had no effect on the results. If the association between clinic visits and ground-level ozone was purely a function of people seeking care because of the perceived health effects when ground-level ozone levels were expected to be high, removing these days would attenuate the magnitude of association. Further, no change in the magnitude of association was seen when the days with ≥75 ppb ground-level ozone were excluded from the analysis, which suggests that the results are not being driven by, or only due to, the days with 8-hour max ground-level ozone above the regulatory standard of 75 ppb.

Sublette County differs from many other areas of the world in that the elevated ground-level ozone concentrations occur primarily in the cold season (February and March) rather than the more typical summertime ground-level ozone season.[2,11] Given the small sample size, seasonal stratification resulted in unstable estimates of ground-level ozone effects, so such results were not presented. Seasonal differences in adverse respiratory-related health effects in Sublette County were not able to be determined in this study. A recent meta-analysis observed associations between ground-level ozone and adverse respiratory effects during the summer (largest effect), all year, and during the cold season. [10] The results of that meta-analysis suggest ground-level ozone adverse respiratory-related effects may not be just a summer problem.

The impact of ground-level ozone on adverse respiratory-related effects was not found to be different (no significant interactions) by sex or age category, but this might be because of the limited ability to detect statistical significance with our small sample size. Other studies have found children (persons <18 years of age) and seniors (persons ≥65 years of age) to be more sensitive to ground-level ozone and other air pollutants.[3,8,9,22,23] Children's lungs continue to develop through adolescence and a developing lung is highly susceptible to damage from environmental toxicants like ground-level ozone.[2,14] Children tend to spend more time outdoors, be highly active, and have high minute ventilation, which collectively increases their dose of ground-level ozone. [2,8,14] Seniors (persons ≥65 years of age) are hypothesized to be more susceptible to air pollution due to changes in the respiratory tract lining fluid antioxidant defense network.[2]

Limitations

This study has several potential limitations. This is one of few studies to measure health clinic visits rather than emergency room visits or hospital admissions to examine the association of ground-level ozone with adverse respiratory effects. In this rural setting, there are no local emergency rooms or hospitals. Clinic visits differ from hospital emergency room visits because primary care occurs at these clinics (including follow-up visits). Which visits were follow-up visits or were visits for a new adverse respiratory-related effect were not able to be determined in this study. All models utilized ground-level ozone measurement data from a central monitoring station, which might not have been representative of individual exposure. Individual exposure was not assessed in this study. However, utilizing a central monitor is a common technique and would most likely attenuate the observed associations, but not lead to spurious associations.[11,12] In addition, the same trend and associations were observed with the Boulder monitoring station. Interactions by subgroups other than age and sex were not able to be evaluated in this study due to sample size limitations. Finally, the sample size of this study may have limited the statistical power to detect associations.

Conclusion

The results from this study suggest an association between ground-level ozone concentrations and clinic visits for adverse respiratory-related effects in the magnitude of a 3% increase in clinic visits the day following every 10 ppb increase in 8-hour max ground-level ozone (lag 1).

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Appendix A: Glossary of Terms[17,18-20,24,25]

Adjusted odds ratio (aOR)-when stratification and multiple regression techniques are used to address confounding in a study

Case-crossover- a study design where all study subjects are cases who have experienced a well defined acute health event thought to be associated with short-term changes in a transient exposure are compared to reference times within a time strata; each subject serves as their own control; uses conditional logistic regression to compare exposure at the event time to weighted average of the exposure at the reference times for each subject, provides an estimate of the relative risk of exposure

Case day- designated for each person who visits a clinic for one of the defined respiratory disease diagnoses

Confounder-a factor that is associated with the exposure and independently affects the risk of developing the disease; distorts the association with the exposure and disease because it is unevenly distributed between the cases and controls

Daily (24-hour) averaged ozone-calculated by averaging 24-hourly ozone concentrations in parts per billion, valid when 18 hourly values are available

Daily maximum 8-hour average ozone concentration-24 possible 8-hour average ozone concentrations for each calendar day, daily maximum is the highest of the 24 possible 8-hour averages, valid when 18 running 8-hour averages are available or if the daily maximum is greater than the level of the standard

Hourly ozone concentrations-hourly ground-level ozone concentrations in parts per billion

Interaction-factors that modify the association between exposure and disease; answers the question of whether the relationship between exposure and disease appears to be different for varying levels of a factor (i.e. sex, age category) after baseline difference in the factor are controlled

Lag-delay in time between the exposure and the health effect

Odds ratio (OR)-a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure. OR are used most commonly in case control studies

Referent days-control days within a strata; preferable to use referents on the same day of the week to control for day-of-the week effects common in health outcomes and air pollution

Running 8-hour average ozone-uses hourly ground-level ozone concentrations in parts per billion backward averages over 8 hours; valid when at least 6 hourly values are available

Spline-a sufficiently smooth polynomial function that is piecewise-defined, and possesses a high degree of smoothness at the places where the polynomial pieces connect (which are known as *knots*)

Sensitivity Analysis-means of assessing the robustness of a model by checking whether similar results are obtained when different models or assumptions are used for the analysis

Time-stratified design- time is divided into disjoint strata, exposures in a 'hazard period' just prior to the acute event and exposures in multiple reference periods are only compared within strata of time; select times before and after the case event time

Unconstrained distributed lag-cumulative effect of individual lags over a few days

Ozone monitoring day-a day with at least 75% of the possible 8-hour averages in the day (18 of 24 averages); a day can also be valid if less than 75% complete if the daily maximum is greater than the level of the standard 75 ppb

Appendix B:

Table 9: Mean, Standard Deviation, Median, Minimum, and Maximum Ozone Concentrations for the Daniel Monitor, Sublette County, Wyoming, 2008–2011

Year	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
2008	47.2	9.5	48.0	23.0	75.0
2009	45.1	6.9	44.0	27.0	67.0
2010	49.0	6.1	49.0	33.0	73.0
2011	47.7	8.7	47.0	25.0	84.0

Table 10: Mean, Standard Deviation, Median, Minimum, and Maximum Ozone Concentrations for the Boulder Monitor, Sublette County, Wyoming, 2008–2011

Year	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
2008	50.9	13.0	51.0	24.0	122.0
2009	47.2	7.8	47.0	30.0	70.0
2010	48.9	8.1	49.0	28.0	72.0
2011	50.1	11.7	49.0	22.0	123.0

Table 11: Mean, Standard Deviation, Median, Minimum, and Maximum Ozone Concentrations by Monitor during Winter Months (January 1-April 1) 2008–2011, Sublette County

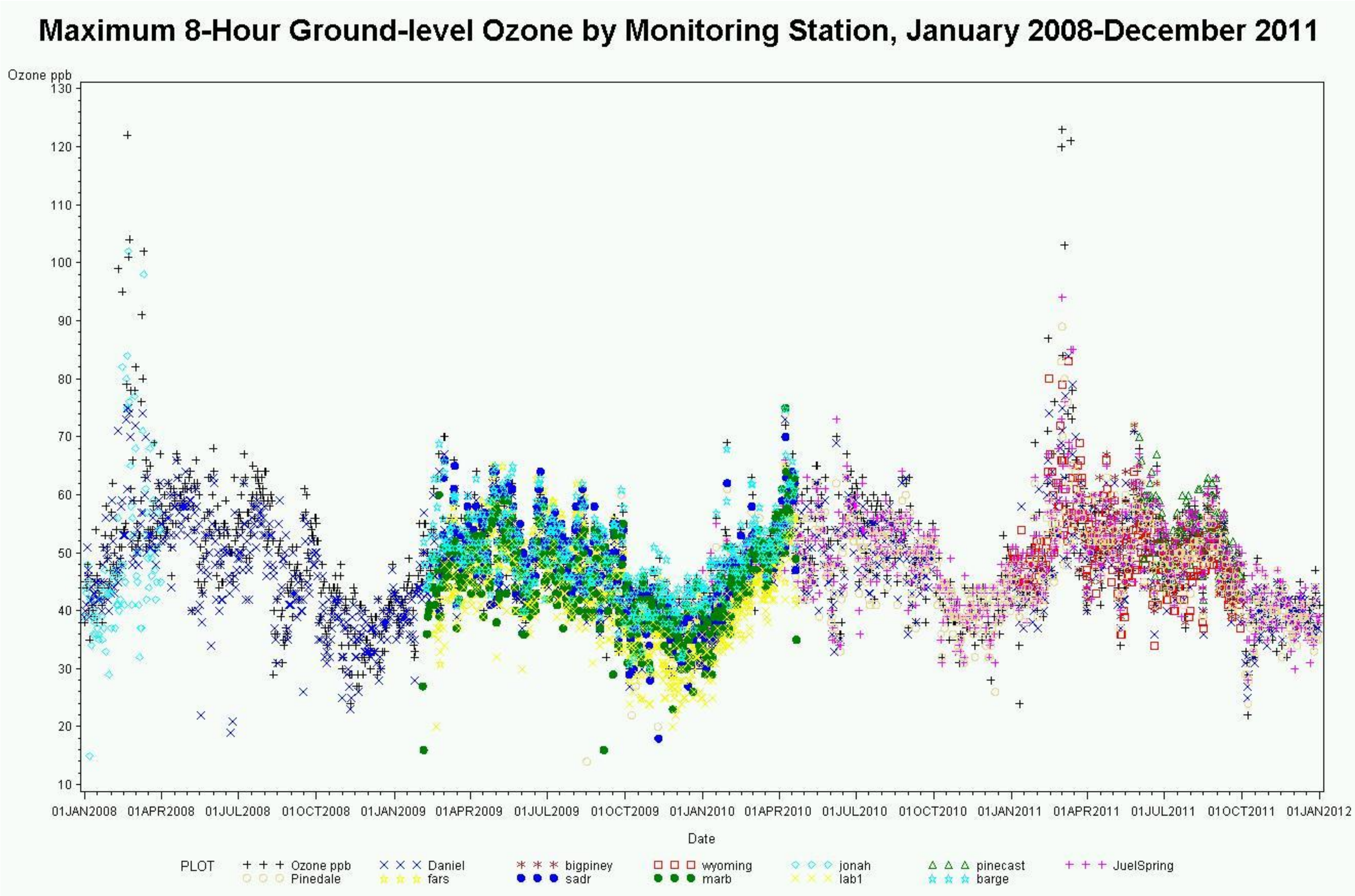
Year and Station	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
Boulder Winter 2008	58.8	16.9	53.0	38	122.0
Daniel Winter 2008	52.0	9.1	51.0	39.0	75.0
Boulder Winter 2009	49.1	8.0	49.0	32.0	70.0
Daniel Winter 2009	46.3	6.9	46.5	28.0	67.0
Boulder Winter 2010	47.9	6.0	48.0	32.0	69.0
Daniel Winter 2010	45.6	4.1	46.0	35.0	54.0
Boulder Winter 2011	57.1	17.6	50.0	34.0	123.0
Daniel Winter 2011	52.4	10.6	49.0	37.0	84.0

Appendix B: (Continued)

Table 12: Mean, Standard Deviation, Median, Minimum, and Maximum Ozone Concentrations by Monitor during Summer Months (April 1-October 31) 2008–2011, Sublette County

Year and Station	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
Boulder Summer 2008	52.0	8.6	53.0	31.0	68.0
Daniel Summer 2008	48.6	7.7	50.0	31.0	66.0
Boulder Summer 2009	49.0	7.0	49.0	30.0	65.0
Daniel Summer 2009	46.3	6.8	46.5	27.0	62.0
Boulder Summer 2010	51.9	7.7	53.0	31.0	72.0
Daniel Summer 2010	50.7	6.1	51.0	33.0	73.0
Boulder Summer 2011	49.4	7.3	50.0	22.0	71.0
Daniel Summer 2011	48.3	7.2	49.0	25.0	71.0

Appendix C: Daily Maximum 8-Hour Ozone by Monitoring Station, January 01, 2008 to December 31, 2011



Appendix D: Pearson's Correlations between Ground-Level Ozone Monitoring Stations

*blanks mean no overlapping observations between stations

Station	Boulder	Daniel	Big Piney	Wyoming	Jonah	Pinecast	Juel	Pinedale	Fars	SADR	Marb	Lab1	Barge
Boulder	1.0000 Obs 1429	0.83538 Obs 1331	0.84379 Obs 185	0.61057 Obs 268	0.85805 Obs 87	0.86873 Obs 117	0.87577 Obs 707	0.87634 Obs 856	0.80604 Obs 410	0.91013 Obs 408	0.80668 Obs 426	0.82730 Obs 413	0.93463 Obs 426
Daniel	0.83538 Obs 1331	1.0000 Obs 1363	0.89636 Obs 189	0.82449 Obs 269	0.74675 Obs 89	0.91242 Obs 122	0.85724 Obs 630	0.91153 Obs 784	0.82522 Obs 424	0.89999 Obs 422	0.82979 Obs 440	0.84485 Obs 427	0.92721 Obs 440
Big Piney	0.84379 Obs 185	0.89636 Obs 189	1.0000 Obs 190	0.72166 Obs 190	*	0.79055 Obs 119	0.79658 Obs 186	0.87028 Obs 190	*	*	*	*	*
Wyoming	0.61057 Obs 268	0.82449 Obs 269	0.72166 Obs 190	1.0000 Obs 273	*	0.81221 Obs 122	0.67997 Obs 269	0.74344 Obs 273	*	*	*	*	*
Jonah	0.85805 Obs 87	0.74675 Obs 89	*	*	1.0000 Obs 89	*	*	*	*	*	*	*	*
Pinecast	0.86873 Obs 117	0.91242 Obs 122	0.79055 Obs 119	0.81221 Obs 122	*	1.0000 Obs 122	0.81169 Obs 118	0.94237 Obs 122	*	*	*	*	*
Juel	0.87577 Obs 707	0.85724 Obs 630	0.79658 Obs 186	0.67997 Obs 269	*	0.81169 Obs 118	1.0000 Obs 726	0.89017 Obs 725	0.83428 Obs 111	0.89412 Obs 111	0.81817 Obs 112	0.84938 Obs 112	0.90963 Obs 111
Pinedale	0.87634 Obs 856	0.91153 Obs 784	0.87028 Obs 190	0.74344 Obs 273	*	0.94237 Obs 122	0.89017 Obs 725	1.0000 Obs 879	0.77446 Obs 261	0.87171 Obs 260	0.79257 Obs 262	0.81032 Obs 262	0.90348 Obs 261
Fars	0.80604 Obs 410	0.82522 Obs 424	*	*	*	*	0.83428 Obs 111	0.77446 Obs 261	1.0000 Obs 424	0.90054 Obs 417	0.79045 Obs 424	0.90620 Obs 421	0.78715 Obs 424
SADR	0.91013 Obs 408	0.89999 Obs 422	*	*	*	*	0.89412 Obs 111	0.87171 Obs 260	0.90054 Obs 417	1.0000 Obs 422	0.86117 Obs 422	0.89835 Obs 422	0.91294 Obs 422
Marb	0.80668 Obs 426	0.82979 Obs 440	*	*	*	*	0.81817 Obs 112	0.79257 Obs 262	0.79045 Obs 424	0.86117 Obs 422	1.0000 Obs 440	0.87397 Obs 427	0.81401 Obs 438
Lab1	0.82730 Obs 413	0.84485 Obs 427	*	*	*	*	0.84938 Obs 112	0.81032 Obs 262	0.90620 Obs 421	0.89835 Obs 422	0.87397 Obs 427	1.0000 Obs 427	0.81507 Obs 426
Barge	0.93463 Obs 426	0.92721 Obs 440	*	*	*	*	0.90963 Obs 111	0.90348 Obs 261	0.78715 Obs 424	0.91294 Obs 422	0.81401 Obs 438	0.81507 Obs 426	1.0000 Obs 440

Appendix E: Spearman's Correlations between Ground-Level Ozone Monitoring Stations

*blanks mean no overlapping days between stations

Station	Boulder	Daniel	Big Piney	Wyoming	Jonah	Pinecast	Juel	Pinedale	Fars	SADR	Marb	Lab1	Barge
Boulder	1.0000 Obs 1429	0.90478 Obs 1331	0.82543 Obs 185	0.70827 Obs 268	0.77105 Obs 87	0.88032 Obs 117	0.90250 Obs 707	0.92574 Obs 856	0.82797 Obs 410	0.92251 Obs 408	0.85414 Obs 426	0.85602 Obs 413	0.94181 Obs 426
Daniel	0.90478 Obs 1331	1.0000 Obs 1363	0.88292 Obs 189	0.80154 Obs 269	0.75938 Obs 89	0.92280 Obs 122	0.89631 Obs 630	0.95461 Obs 784	0.83191 Obs 424	0.91592 Obs 422	0.87564 Obs 440	0.87172 Obs 427	0.93448 Obs 440
Big Piney	0.82543 Obs 185	0.88292 Obs 189	1.0000 Obs 190	0.71433 Obs 190	*	0.77297 Obs 119	0.84466 Obs 186	0.84600 Obs 190	*	*	*	*	*
Wyoming	0.70827 Obs 268	0.80154 Obs 269	0.71433 Obs 190	1.0000 Obs 273	*	0.80401 Obs 122	0.70497 Obs 269	0.79008 Obs 273	*	*	*	*	*
Jonah	0.77105 Obs 87	0.75938 Obs 89	*	*	1.0000 Obs 89	*	*	*	*	*	*	*	*
Pinecast	0.88032 Obs 117	0.92280 Obs 122	0.77297 Obs 119	0.80401 Obs 122	*	1.0000 Obs 122	0.81355 Obs 118	0.93655 Obs 122	*	*	*	*	*
Juel	0.90250 Obs 707	0.89631 Obs 630	0.84466 Obs 186	0.70497 Obs 269	*	0.81355 Obs 118	1.0000 Obs 726	0.90768 Obs 725	0.77989 Obs 111	0.89380 Obs 111	0.78100 Obs 112	0.83024 Obs 112	0.91081 Obs 111
Pinedale	0.92574 Obs 856	0.95461 Obs 784	0.84600 Obs 190	0.79008 Obs 273	*	0.93655 Obs 122	0.90768 Obs 725	1.0000 Obs 879	0.82838 Obs 261	0.92232 Obs 260	0.84681 Obs 262	0.85514 Obs 262	0.94073 Obs 261
Fars	0.82797 Obs 410	0.83191 Obs 424	*	*	*	*	0.77989 Obs 111	0.82838 Obs 261	1.0000 Obs 424	0.91522 Obs 417	0.81263 Obs 424	0.91231 Obs 421	0.80309 Obs 424
SADR	0.92251 Obs 408	0.91592 Obs 422	*	*	*	*	0.89380 Obs 111	0.92232 Obs 260	0.91522 Obs 417	1.0000 Obs 422	0.89234 Obs 422	0.92120 Obs 422	0.93318 Obs 422
Marb	0.85414 Obs 426	0.87564 Obs 440	*	*	*	*	0.78100 Obs 112	0.84681 Obs 262	0.81263 Obs 424	0.89234 Obs 422	1.0000 Obs 440	0.89913 Obs 427	0.86070 Obs 438
Lab1	0.85602 Obs 413	0.87172 Obs 427	*	*	*	*	0.83024 Obs 112	0.85514 Obs 262	0.91321 Obs 421	0.92120 Obs 422	0.89913 Obs 427	1.0000 Obs 427	0.84469 Obs 426
Barge	0.94181 Obs 426	0.93448 Obs 440	*	*	*	*	0.91081 Obs 111	0.94073 Obs 261	0.80309 Obs 424	0.93318 Obs 422	0.86070 Obs 438	0.84469 Obs426	1.0000 Obs 440

Appendix F: Sensitivity Analyses for Different Minimum Temperature and Humidity Models for Single Ozone Lag 0, Lag 1, Lag 2, and Lag 3 and the Cumulative Unconstrained Distributed Lag 0–3 Lag Model

	Lag with aOR and 95% CI				
Temperature and Humidity Model	**Single Lag 0**	**Single Lag 1**	**Single Lag 2**	**Single Lag 3**	**Cumulative Unconstrained Distributed Lag 0–3**
tmin+tmin2+h+h2+h3	1.010 (0.974–1.047)	**1.031 (0.994–1.070)**	0.995 (0.959–1.032)	0.980 (0.945–1.016)	1.001 (0.990–1.012)
tmin+tmin2+h	1.009 (0.973–1.046)	**1.030 (0.993–1.068)**	0.993 (0.957–1.030)	0.980 (0.945–1.016)	1.001 (0.990–1.012)
tmin+tmin2+tmin3+h	1.007 (0.970–1.044)	**1.029 (0.991–1.068)**	0.991 (0.956–1.028)	0.978 (0.943–1.015)	1.001 (0.990–1.012)
tmin+h+h2+h3	1.012 (0.975–1.049)	**1.034 (0.997–1.073)**	0.996 (0.961–1.034)	0.981 (0.947–1.018)	1.002 (0.991–1.013)
tmin+tmin2+tmin3+h+h2	1.007 (0.971–1.045)	**1.028 (0.990–1.067)**	0.991 (0.955–1.028)	0.978 (0.943–1.014)	1.002 (0.991–1.012)
tmin	1.013 (0.978–1.050)	**1.034 (0.998–1.072)**	0.997 (0.961–1.033)	0.983 (0.948–1.019)	1.001 (0.991–1.013)
tmin+h	1.010 (0.974–1.047)	**1.033 (0.996–1.071)**	0.994 (0.959–1.031)	0.981 (0.946–1.017)	1.001 (0.990–1.012)
tmin+tmin2	1.011 (0.976–1.048)	**1.031 (0.994–1.069)**	0.995 (0.960–1.032)	0.981 (0.947–1.017)	1.001 (0.991–1.012)
tmin+tmin2+tmin3	1.010 (0.974–1.047)	**1.030 (0.993–1.069)**	0.994 (0.958–1.031)	0.980 (0.946–1.016)	1.001 (0.990–1.012)

Appendix G: Sensitivity Analyses for Different Maximum Temperature and Humidity Models for Single Ozone Lag 0, Lag 1, Lag 2, and Lag 3 and the Cumulative Unconstrained Distributed Lag 0–3 Lag Model

	Lag with aOR and 95% CI				
Temperature and Humidity Model	**Single Lag 0**	**Single Lag 1**	**Single Lag 2**	**Single Lag 3**	**Cumulative Unconstrained Distributed Lag 0–3**
tmax+tmax2+h+h2+h3	1.011 (0.970–1.048)	**1.032 (0.995–1.070)**	0.996 (0.960–1.033)	0.998 (0.945–1.016)	1.001 (0.991–1.012)
tmax+tmax2+h	1.010 (0.974–1.047)	**1.032 (0.995–1.070)**	0.995 (0.959–1.032)	0.980 (0.945–1.017)	1.001 (0.990–1.012)
tmax+tmax2+tmax3+h	1.006 (0.970–1.044)	**1.029 (0.991–1.068)**	0.993 (0.958–1.030)	0.979 (0.944–1.016)	1.000 (0.990–1.012)
tmax+h+h2+h3	1.012 (0.976–1.050)	**1.034 (0.997–1.072)**	0.997 (0.960–1.034)	0.982 (0.947–1.018)	1.001 (0.990–1.013)
tmax+tmax2+h+h2	1.010 (0.974–1.047)	**1.030 (0.993–1.068)**	0.993 (0.958–1.030)	0.979 (0.944–1.016)	1.000 (0.990–1.012)
tmax+h	1.011 (0.975–1.048)	**1.033 (0.996–1.071)**	0.995 (0.960–1.032)	0.982 (0.947–1.018)	1.001 (0.991–1.012)
tmax+h+h2	1.012 (0.976–1.049)	**1.032 (0.995–1.071)**	0.994 (0.959–1.031)	0.981 (0.946–1.017)	1.001 (0.991–1.012)
Natural Cubic Splines for tmax and h	1.009 (0.972–1.047)	**1.029 (0.991–1.068)**	0.999 (0.963–1.037)	0.983 (0.948–1.020)	1.001 (0.990–1.012)

Appendix H: Sensitivity Analyses the Boulder Monitoring Station the Cumulative Unconstrained Distributed Lag 0–3 Lag Model and Single Ozone Lag Model for Lag 0, Lag 1, Lag 2, and Lag 3

Table 12: Model; unconstrained distributed lag 0–3 days, adjusting for average temperature, average temperature squared, average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb for the Boulder Monitor

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.002	0.10	0.9960	1.010

Table 13: Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.009	0.46	0.985	1.034
Lag 1	**1.056**	**<0.0001**	**1.030**	**1.082**
Lag 2	1.001	0.94	0.977	1.026
Lag 3	0.984	0.19	0.961	1.008

Appendix I: Sensitivity Analyses for the Boulder Monitoring Station with Removal of Notification Days, Removal of the Days Immediately Following an Notification Day, and Removal of Days with ≥75 ppb Ground-Level Ozone Concentrations

Table 14: aOR and 95% CI with Removal of Notification Days; Model of Unconstrained Distributed Lag 0–3 days, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.003	0.10	0.995	1.010

Table 15: aOR and 95% CI with Removal of Notification Days; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.006	0.65	0.981	1.031
Lag 1	**1.053**	**<0.0001**	**1.027**	**1.079**
Lag 2	0.998	0.89	0.974	1.023
Lag 3	0.983	0.15	0.959	1.010

Table 16: aOR and 95% CI with Removal of the Days Immediately after a Notification Day; Model of Unconstrained Distributed of lag 0–3 days, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.003	0.11	0.996	1.010

Appendix I: (Continued)

Table 17: aOR and 95% CI with Removal of the Days Immediately after a Notification Day; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.008	0.53	0.983	1.033
Lag 1	**1.054**	**<0.0001**	**1.028**	**1.080**
Lag 2	0.996	0.74	0.970	1.021
Lag 3	0.984	0.19	0.961	1.008

Table 18: aOR and 95% CI with Removal of Days with Ground-Level Ozone Concentrations ≥75 ppb; Model of Unconstrained Distributed Lag 0–3 Days, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.001	0.74	0.993	1.009

Table 19: aOR and 95% CI with Removal of the Days with Ground-Level Ozone Concentrations ≥75 ppb; Single Lag Models of Lag 0, Lag 1, Lag 2 and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	0.986	0.43	0.952	1.021
Lag 1	**1.071**	**<0.0001**	**1.039**	**1.105**
Lag 2	0.990	0.50	0.963	1.018
Lag 3	0.978	0.10	0.953	1.004