OPTIMIZING THE RESPIRATORY HEALTH OF SOLDIERS DURING PASTURE BURNING

by

ERICA CHRISTINE MCGINLEY

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Approved by:

Major Professor
Robert L. Larson, DVM, PhD, DACT, DACVPM (Epidemiology), ACAN

Abstract

Pasture burning is a practice native to the Flint Hills Region of Kansas. Without fire, the tallgrass ecosystem would cease to exist because woody species, such as the red cedar, would overtake the land (1). Ranchers in the area participate in prescribed burning to revitalize the native prairie grasses for cattle consumption (2). Burning produces higher quality grasses, more weight gain in cattle, and more profit for the rancher (1). Prescribed fire benefits the grass and simultaneously causes air pollution; the most common pollutants associated with burning are particulate matter (PM) and ozone. These by-products of burning have demonstrated acute and chronic respiratory effects in human studies (3). The typical time-frame for burning in Kansas is relatively short, running from March to May. Plumes of pollution can form as ranchers burn simultaneously on days when weather conditions are favorable (1). Fort Riley, KS is a United States Army installation nestled in the Flint Hills. Its population has nearly doubled since 2005, bringing the total number of individuals on the fort to approximately 53,000 (4). This military population is required to perform many duties outdoors, resulting in a unique exposure to spring burning in the Flint Hills. This report compiles air quality data including concentrations of ozone, PM 2.5, and PM 10 from Riley and Shawnee Counties as well as data for medically coded respiratory conditions from Fort Riley beneficiaries. All data utilized came from the months of February, March, April, and May from years 2008-2011. Monthly averages from all data sets were analyzed by a mixed effects model. This report addresses the need for further investigation into potential confounding factors such as local pollen counts and respiratory illness from cold and flu season. It establishes the importance of future air quality data collection from a singular source and the need for additional and more complex studies on Fort Riley.

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"Feeling gratitude and not expressing it is like wrapping a present and not giving it."
-William Arthur Ward

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Introduction

The limestone in Eastern Kansas harbors a rolling sea of Bluestem, Switch, and Indian grasses; it is an area known as the Flint Hills. The Flint Hills Region spans from Washington and Marshall Counties in the north to Cowley and Chautauqua Counties in the south; to the far east, the region contains Jackson and Shawnee Counties and to the far west it includes Harvey and Sedgwick Counties (5). Tallgrass grows down into Oklahoma, where the area is referred to as the Osage Hills. The grasses here have an extensive root system allowing them to thrive in the presence of fire. Fire eats away the dead matter above ground, while the root systems below wait for the opportunity to spring forth with new grass. Native Americans saw benefit with burning and early ranchers followed suit (6).

Pasture burning in the Flint Hills Region of Kansas plays a key role in agricultural vitality. Burning also restores nutrients to the soil and eliminates unwanted brush and shrubs; this is important for grass diversity and survival (7). Only 4% of the original North American prairie remains in existence today, making it one of the world's most endangered ecosystems. Modern-day ranchers in the area burn to stimulate grasses for cattle consumption to achieve weight gain. The grazing and subsequent burning preserve the tallgrass in its natural state (5). However, this prescribed or open burning does affect the air quality. The most abundant pollutants from burning in rural Kansas include ozone and particulate matter or PM (8). Through extensive research, both PM and ozone have demonstrated negative short-term and long-term effects on respiratory health (9).

Respiratory health is of key concern to the inhabitants of Fort Riley, KS, as the area is uniquely nestled within the Flint Hills. The United States Army installation contains 101,733 acres of land in Geary and Riley Counties with a population of approximately 53,000 (4). This population includes active duty military members and their families, civilian employees, retirees, and contractors (4). Many active duty military members are required to perform work outdoors during the burn season, which typically runs from March to May; this is a potentially hazardous time for these individuals. The military installation is also home to civilian family members who live, work, and play outdoors. Sometimes there is a visible haze in the sky during burn season, one that more than likely contains levels of ozone and particulate matter.

These pollutants, as well as other air quality standards, are addressed at the national, state, and local level in the Environmental Protection Agency's (EPA) *Clean Air Act* (10). It is under this act that the EPA has an Office of Air Quality Planning and Standards (OAQPS) responsible for setting the National Ambient Air Quality Standards (NAAQS). The *Clean Air Act* requires all states to have air monitoring stations in place (11). In 2003, the Flint Hills Region had its first encounter with publicity concerning monitored air quality during burn season. On the dates of April 12 and April 13, three air quality monitors reported ozone exceedances in Kansas City, Missouri (8). Interest in burning, air quality, and the potential effect on human health has grown for Kansas natives as well as those residing in neighboring states.

The Environmental Protection Agency has two types of national air quality standards under the *Clean Air Act*. The primary standards are in place to protect public health. The secondary standards establish protection for public welfare. A public health standard, for example, protects individuals with at-risk conditions such as asthma. A public welfare standard would include protection from impaired visibility or damage to crops. Ozone is currently limited under the NAAQS for primary and secondary standards to 0.075 ppm in an eight hour averaging time. This standard gets calculated as a three year average of each annual fourth highest daily maximum eight hour concentration. The EPA standard for PM 10 for primary and secondary standards is based on a twenty-four hour period. A level of 150 µg/m³ is not to be exceeded more than once on average annually over a period of three years (10). PM 2.5 currently has a primary standard at 12 µg/m³ as an annual mean, averaged over three years. Its secondary standard is set at 15 µg/m³ as an annual mean, averaged over three years. The primary and secondary standards combined for a twenty-four hour averaging time is 35 µg/m³. This figure is calculated as a three year average of the samples obtained in the ninety-eighth percentile (8).

The season for burning typically runs from early to late spring, but over decades, ranchers have debated about different benefits with various timing (8). Typically, steer yearling operations are associated with the highest levels of burning. The goal within these types of operations is to provide a high quality set of food for maximum weight gain in young cattle. Figure 1 is a graphic illustration of cattle gains with the timing of the spring burn (12).

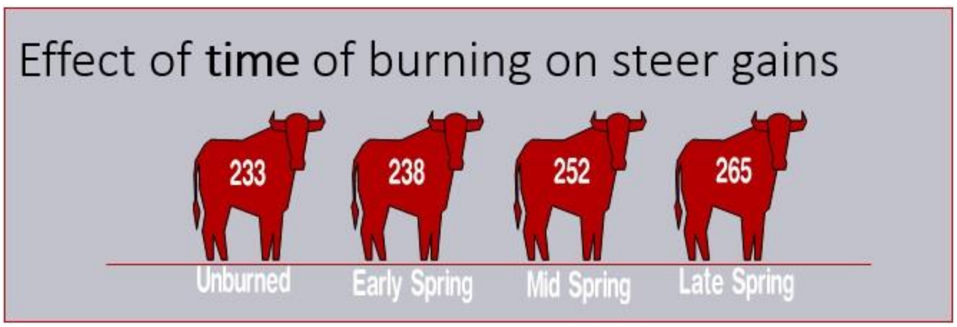


Figure 1, Cattle weight gain in pounds with timing of spring pasture burning (Kansas State University)

This knowledge makes it appealing to most ranchers to wait until later in the spring to burn. In general, ranchers feel they get the best cattle gains if burning occurs in April. Weather and wind conditions also determine when it is feasible to burn. These factors can combine to create a narrow window in the spring when prescribed burning occurs.

Elevated concentrations of PM and ozone have been recorded by the Kansas Ambient Air Monitoring Network during concentrated periods of burning (13). However, burning remains a valued practice in this region for natural habitat conservation and agricultural benefit. Public health officials seek to ensure that the byproducts of prescribed burning do not have a negative impact on the respiratory health of the local population.

Particulate matter is a mixture of solid and liquid particles suspended in the air. It contains both organic and inorganic substances. Its exact composition depends on the emission source, the weather, and wind pattern. The size of PM has a suspected relation to the severity of injury it causes in the human respiratory system. Particulate matter is classified into three different sizes. PM 10 has a diameter less than 10 µm in size, and it is referred to as course fraction. PM 2.5 has a diameter of less than 2.5 µm and it is referred to as fine fraction. Any PM with a diameter less than 0.1 µm is referred to as ultra-fine fraction. Particulate classified in the fine fraction category is of most concern to human health. Because of its size, this matter typically gets distributed into the alveolar ducts and sacs of the lungs. Once there, the fine fraction PM can elicit a local inflammatory response in the lung tissue or a systemic inflammatory response in the body (14).

Ozone is one of the key pollutants in Kansas associated with pasture burning. It is a product of hydrocarbons interacting with oxides of nitrogen in the presence of sunlight (8). Research has indicated that ozone is not limited to causing illness in an at-risk population (9). Instead, it demonstrates capability of causing illness in large numbers of the general public. Ozone will exacerbate pre-existing conditions in individuals such as allergies, asthma, and emphysema (8). It will also decrease lung function in seemingly healthy people (9). Figure 2 gives a general summary of common health effects from ozone and particulate matter.

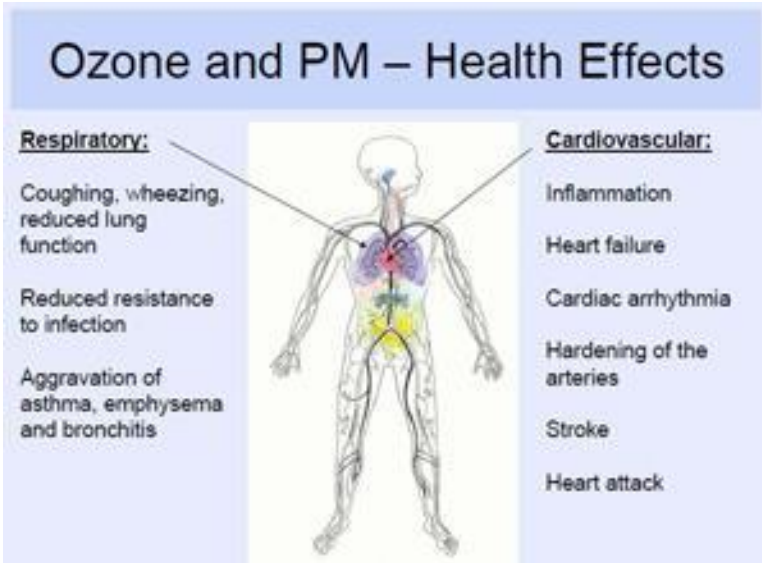


Figure 2, Ozone and PM effects on human health (Kansas Flint Hills Smoke Management 2015)

Methods

This report complied data from the months of a typical burn season in the Flint Hills which includes the months of February, March, April, and May. Air quality data was obtained on particulate matter and ozone concentrations in the Flint Hills Region for the aforementioned months from years 2008-2011. A set of medically coded respiratory conditions was also obtained for Fort Riley beneficiaries for years 2008-2011 in the months of February, March, April, and May. See Appendix A. These variables were analyzed to determine if any correlation existed between ozone and particulate matter concentrations and the number of recorded human respiratory counts.

Air quality data for this report was obtained from two independent monitoring sites, as displayed in Figure 3. Ozone data was retrieved from the Konza Biological Station through the

CASNET website, which is public domain. This station is AQS site ID 20-161-9991. It is physically located on the Konza Prairie Biological Station in Manhattan, KS, 66502; the exact coordinates of the monitor are as follows: latitude 39.102100 and longitude -96.609600.

Particulate matter data was obtained from the Kansas Department of Health and Environment (KDHE) from a monitor in Topeka. This air quality monitor is AQS site ID 20-177-0013. The address for the monitor is 2501 Randolph Avenue, Topeka, KS, Shawnee County; its exact coordinates are as follows: latitude 39.024265 and longitude -95.711275.

Figure 3, Location of air quality monitoring sites in Topeka, KS and Konza Biological Station near Manhattan, KS (Google Earth 2015)

The CASNET tower, located on the Konza Prairie, records ambient air measurements. It does so with a three-stage filter pack. Air is drawn in at a controlled flow rate through this open-face filter pack while it is mounted atop a 10 meter tower (shown in figure 6). This allows the filter pack to collect air pollutants in the form of gases and particles. The first stage of the filter pack encloses a Teflon filter, the second is a nylon filter, and the third stage contains two potassium carbonate-impregnated cellulose filters. The filter pack is changed weekly and shipped to the analytical chemistry laboratory for analysis.

Figure 4, Air quality monitoring equipment inside trailer at Konza

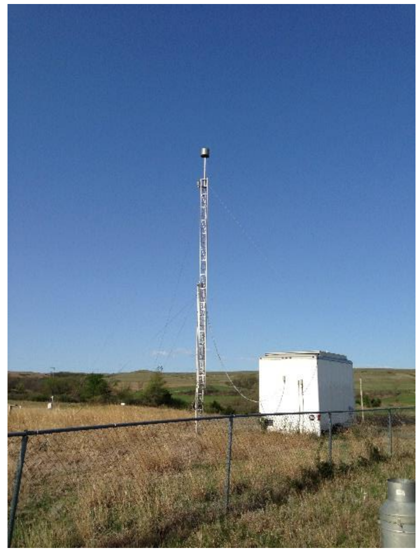


Figure 5, Reservoir for filter on top of air quality monitoring tower at Konza

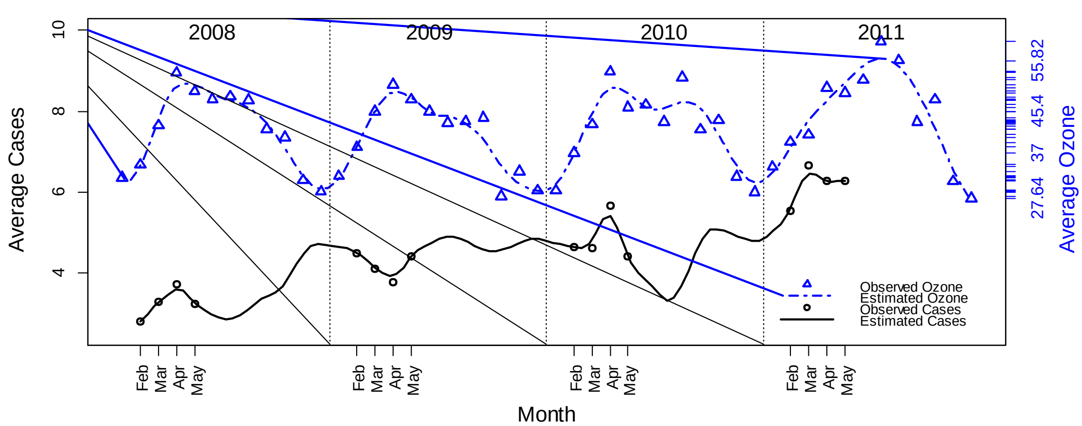
Figure 6, Air quality monitoring tower and equipment trailer at Konza

PM 2.5 and PM 10 data came from a KDHE air quality monitoring site in Shawnee County. The continuous PM 10 and filter-based PM 2.5 samplers have approximately 30 feet distance between them, and they utilize separate inlets. The air flow rate for both PM 2.5 and PM 10 collection was 16.67 liters per minute. PM 2.5 was collected with a 47 mm filter. PM 10 was collected using a continuous sampler; this method utilizes the Tapered Oscillating Microbalance Method. The filter size for collecting PM 10 was approximately 5/8 inch in

Human data was obtained from the Clinical Operations Department located in the Irwin Army Community Hospital (IACH). Individuals who were eligible for care within 40 miles of IACH (active duty and dependents) are included in this set. The data set contains respiratory counts from years 2008-2011 and the months of February, March, April, and May. Any respiratory count included in the data is from the list of ICD-9 medical codes listed in Appendix A.

Linear mixed effects models that can incorporate repeated measurements (or correlated data) were used to evaluate the effect of air quality on respiratory outcomes in the Fort Riley area.

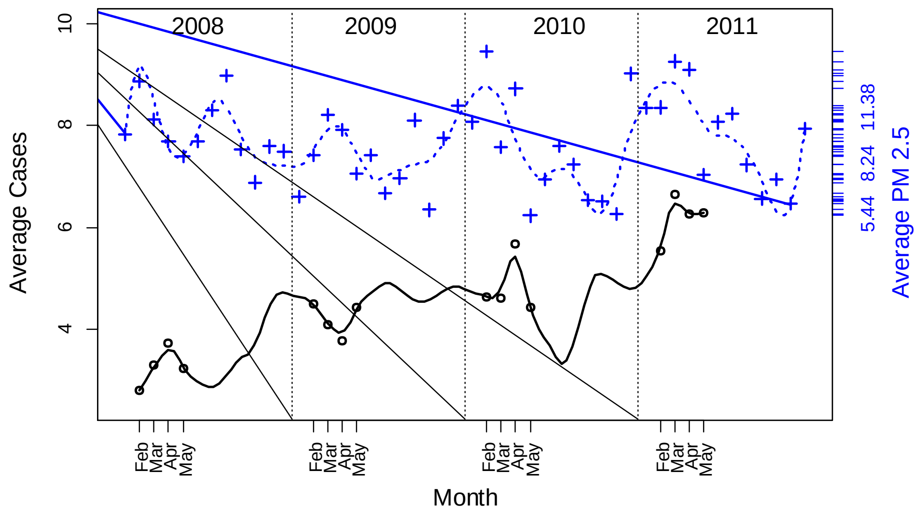
The data in this report came from the same months over a series of years, meaning repeated measurements were taken over time that exhibit correlation. The covariates of interest are concentrations of ozone, PM 2.5, and PM 10. The year of the measurement taken is also included in this model as three indicator variables (2008, 2009, 2010; 2011 as the reference year). The outcome, or dependent variable in this analysis is the number of respiratory cases. This analysis was performed using SAS 9.4 with the procedure PROC MIXED, coupled with a robust sandwich estimator to adjust the potential misspecification of the correlation structure in the data.



Graph 1, Average ozone concentrations (ppb) plotted with average respiratory cases

Results

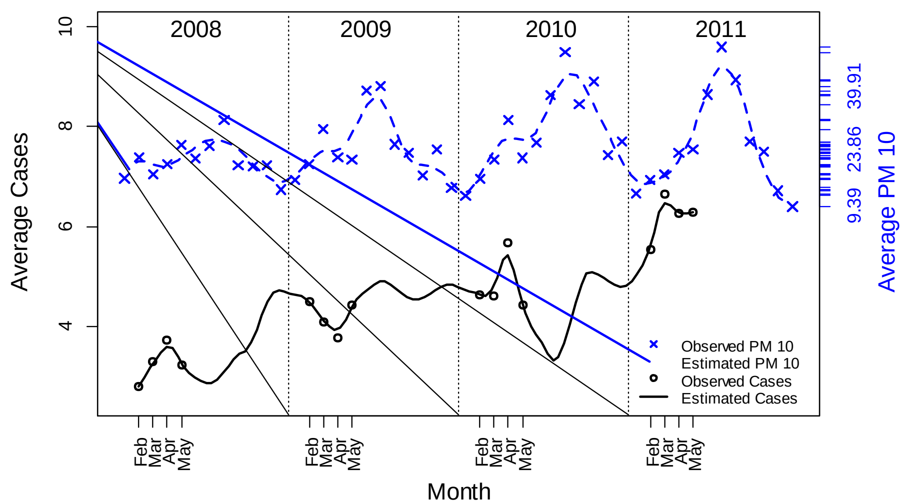
Monthly averages of the daily 8-hour maximum ozone concentrations from the Konza site are plotted in Graph 1 along with the monthly averages of respiratory cases. These graphs were created with R software package, using a smooth function to roughly estimate the missing data points for the other months of each year, not included in this report's data set. This



Graph 2, Average monthly PM 2.5 (μg/m³) concentrations plotted with average monthly respiratory cases

estimation provides comparability of pollutants and respiratory cases for other times of the year.

Monthly averages of PM 2.5 concentrations from the KDHE site in Topeka, KS are plotted in Graph 2 along with monthly averages of respiratory cases from the months of February, March, April, and May for years 2008-2011. The graph was generated with R software, and missing data points from the other months of each set of years have been



Graph 3, Average monthly PM 10 concentrations (µg/m³) plotted with average monthly respiratory cases

estimated.

Monthly averages of PM 10 concentrations from the KDHE site in Topeka, KS are plotted in Graph 3 along with monthly averages of respiratory cases of Fort Riley beneficiaries from the months of February, March, April, and May from years 2008-2011. The graph was generated using R software, and the missing data points from other months of each year set have been estimated.

The results in Table 1 were provided by using a liner mixed effects model in SAS. Monthly data was utilized in this analysis. The subject in this model is month (with repeated measurements from February-May for years 2008-2011), the covariates/predictors are ozone, PM 2.5, and PM 10, and the outcome is the number of cases of respiratory illness.

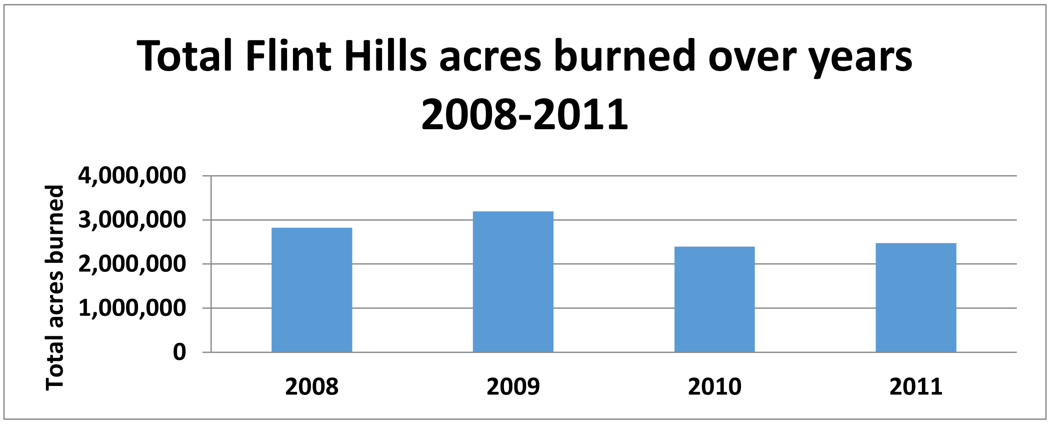
The Mixed Effects Model for Respiratory Cases of Fort Riley

Effect	Year	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept		4.0193	0.1811	3	22.19	0.0002
Year	**2008**	-2.8881	0.1251	6	-23.09	<.0001
Year	**2009**	-1.9406	0.3098	6	-6.26	0.0008
Year	**2010**	-1.3228	0.1640	6	-8.07	0.0002
Year	**2011**	0	.	.	.	.
Ozone		0.03191	0.007937	6	4.02	0.0070
PM 2.5		0.04616	0.02121	6	2.18	0.0724
PM 10.0		0.009947	0.02465	6	0.40	0.7005

Table 1

A p-value of 0.0070 indicates there is a significant positive association between ozone concentrations and the number of respiratory related illnesses (coefficient estimate = 0.032). A p-value of 0.0724 indicates that there is no relationship between PM 2.5 and respiratory related illness (coefficient estimate = 0.046). The data in this report did not support a statistically significant correlation existing between PM 10 and respiratory related illness in the population in and around Fort Riley (coefficient estimate = 0.010, p-value = 0.70).

The indicators for the spring season of each year from 2008-2011 show a statistically significant increase in the number of cases of respiratory illness compared to the reference year 2011.



Graph 4 was obtained from KDHE. It displays the amount of burning in the Flint Hills each season from years 2008-2011. It is important to quantify burning during the seasons and years studied in this report to determine if the number of respiratory cases coincide with the amount burned.

Graph 4, Acres burned in the Flint Hills from 2008-2011 (KDHE)

Discussion

The results in Table 1 indicate that over the four years included in the report, the number of respiratory related cases increased each year. The chart from KDHE in Graph 4 does not demonstrate an increase in the number of acres burned from 2008-2011. Less acreage was burned in years 2010 and 2011 than in years 2008 and 2009. There were also approximately 600,000 less acres burned in 2010 than 2009. Future studies should investigate other potential sources of ozone and study the patterns of emissions to see if a correlation exists between respiratory counts and additional sources of ozone.

There are many other variables and potential confounders that were not addressed in this report. A pollen allergy forecast or an equivalent measurement should be included in a future study. Burn season, which typically runs from March to May, coincides with an increase in tree pollen circulating in the air. These irritants could both potentially be culprits of respiratory illness in the spring season.

Red Cedar, a type of evergreen tree found on the prairie, is known as a pioneer invader and an allergen (15). It typically pollenates and subsequently causes allergy-related symptoms from February to April. This time-frame essentially mirrors the time-frame of a burn season. It may be of particular interest in a future study that examines the impact of allergies on respiratory-related visits to a clinic or hospital.

This study included air quality monitoring data from two geographically separate locations. Ideally, all air quality data would have come from a single source. The Konza site was selected for ozone data collection because it was geographically the closest known monitoring site in proximity to the fort. This site ceased monitoring ozone concentrations in 2013. The site in Topeka was selected because it was the closest known site to the fort that measured particulate matter.

This report did not account for demographic variables such as age and gender. It also did not include smoking status or level of exposure to the outdoors. The Fort Riley population consists predominantly of young, healthy, fit males. As demonstrated in research, the young and the old are more susceptible to respiratory infections and conditions that compromise the airway. In a future study it would be valuable to have additional information about the participants to make more detailed inferences about the impacts of these pollutants.

As a result of the lack of this kind of demographic information, the findings generated in this report should not be extrapolated and applied to any other population. As mentioned in the previous paragraph, Fort riley has a demographically unique population, and it was not taken into consideration with this report.

This report generated results based on the months of February, March, April, and May. In a future study, it would be valuable to look at the pollutant levels and respiratory counts for rest of the months within each year; this would serve as a good comparison for the burn season.

A future study comparing Fort Riley to a similar post that does not practice prescribed burning would give valuable insight to the subject matter. Selecting a site that has a similar mission, training operation, population, and terrain would be essential. Fort Carson, located in Colorado, may be a good candidate to serve as a comparison to Fort Riley in a future study.

Conclusion

It is important to note that despite high hourly readings for PM 10 in Kansas, the state has not violated the federal regulations for the daily or annual standards for total PM 10. In addition to this fact, no monitor stations in the state have exceeded standards for ozone within current EPA guidelines. Monitors in Kansas City, MO have exceeded these ozone standards (8). Despite the lack of federal regulation violation in Kansas, soldiers performing tasks at Fort Riley are often executing duties that include outdoor or field exercises. This poses a unique environmental exposure to the population. Extended exposure to pollutants during burn season could pose a potential threat to the military service members at Fort riley.

The effects of poor air quality on respiratory health are well-documented. Solutions for prevention are highly geared toward air quality monitoring and regulation. The EPA continually evaluates and restructures its guidelines based on evidence. There are currently tools available to aid ranchers in timing their prescribed burning activities. For example, weather conditions such as wind speed, direction, and cloud cover can all influence smoke dispersion and should be taken into consideration before burning (13).

There are financial implications for changes made on either side of this complex public health issue. Tighter regulations for ranchers and land managers could directly impact earnings from the cattle industry. This could, in turn, impact the local economy. However, if the by-products of burning cause exceedances in EPA standards for air quality, the state of Kansas could be penalized. It is a long and costly process to restructure production and impose new rules in order to come back into attainment under NAAQS. The short- and long-term health effects and potential burden to the health care system should be considered as well.

The Kansas Department of Health and Environment (KDHE) currently has an evolving smoke management plan which incorporates input from stakeholders, the EPA, land managers, and environmental groups. By bringing these groups together and encouraging land managers to report on specific aspects of their burning, the department hopes to obtain more accurate data to create a safer and more organized burn season (13). Through better communication with land managers, the KDHE seeks to educate on fire management practices (FMPs) for air quality benefit. These recommendations have been made available on the Fire and Smoke Planning Resource website (www.ksfire.org) or from any county extension agent (8).

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Appendix A - ICD 9 Medical Codes

Medical Code	Respiratory Condition
460-466, 477, 480-487	Respiratory infection (including upper)
466	For children (as it may be difficult to distinguish from asthma): acute bronchitis and bronchiolitis
480-486	Pneumonia
480	Viral pneumonia
481	Pneumococcal pneumonia
482	Other bacterial pneumonia
483	Pneumonia due to other unspecified organism
485	Bronchopneumonia organism unspecified
486	Pneumonia organism unspecified
490-492, 494-496	Chronic Obstructive Pulmonary Disease (COPD)
491	Bronchitis
492	Emphysema
493	Asthma
508	Respiratory conditions due to other and unspecified external agents
786	Other respiratory symptoms
786.05	Shortness of breath
786.07	Wheeze
786.1	Stridor (whistling)
786.2	Cough
786.5	Chest Pain