Health Consultation

Exposure Investigation

Evaluation of Hydrogen Sulfide, Ammonia, Particulate Matter, and Meteorological Measurements Collected During ATSDR's Ambient Air Monitoring/Sampling Program on the Yakama Reservation

Harrah, Washington

September 2019

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AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. To prevent or mitigate exposures, a health consultation may lead to specific actions such as restricting use of or replacing water supplies, intensifying environmental sampling, restricting site access, or removing contaminated material.

In addition, health consultations may recommend additional public health actions, such as health surveillance activities to evaluate exposure or trends in adverse health outcomes, conducting biological indicators of exposure studies to assess exposure, or providing health education for health care providers and community members. This health consultation concludes the public health review process for the Harrah, WA site, but ATSDR could reopen the review process if it obtains additional information that in its opinion indicates a need to revise or append previously issued conclusions.

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Acronyms and Abbreviations

ADS	annual denuder system
AFO	animal feeding operation
AQG	air quality guidelines
AQI	air quality index
ASIL	acceptable source impact level
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
CRDS	cavity ring-down spectroscopy
CV	comparison value
E-BAM	electronic beta attenuation monitor
Ecology	(Washington State Department of) Ecology
EI	exposure investigation
EMEG	environmental media evaluation guideline
EPA	(U.S.) Environmental Protection Agency
H_2S	hydrogen sulfide
LOAEL	lowest observable adverse effect level
$\mu g/m^3$	micrograms per cubic meter
MRL	minimal risk level
NAAQS	(EPA) National Ambient Air Quality Standards
NH_3	ammonia
NOAEL	no observable adverse effect level
PM	particulate matter
PM_{10}	particulate matter 10 microns or smaller
$PM_{2.5}$	particulate matter 2.5 microns or smaller
ppb	parts per billion
ppbv	parts per billion by volume
RAM	rapid air monitor
RfC	reference concentration
SPM	single point monitor
WHO	World Health Organization
WTN	Washington Tracking Network

Summary

The Agency for Toxic Substances and Disease Registry (ATSDR) conducted an exposure investigation (EI) in Harrah, Washington to determine if residents in the community are exposed to harmful levels of air pollutants. Harrah, located on the Yakama Reservation in south-central Washington State, is home to many large dairy and beef animal feeding operations (AFOs). Residents have expressed concern about odors and exposures to air pollutants related to AFOs on the reservation. In 2011, The U.S. Environmental Protection Agency (EPA) contacted ATSDR on behalf of the Concerned Citizens of the Yakama Reservation and Friends of Toppenish Creek to conduct an Exposure Investigation (EI) to determine if residents are being exposed to harmful contaminants in air from AFOs on the reservation. ATSDR agreed to conduct the EI to determine the community's exposure to contaminants related to AFOs and review data on the general air quality in the region.

For this EI, ATSDR established several air sampling and monitoring locations (sites) near Harrah, a small town on the Yakama Reservation. To address community concerns and assess potential seasonal variation, ATSDR collected ambient air measurements of pollutants over two 8-week periods (events): from October 23, 2014, to December 18, 2014 (Fall 2014) and from June 22, 2015 to August 19, 2015 (Summer 2015). Various averaging times up to one day were used to assess short-term exposures while the average of both sampling events was used to assess long-term exposures. ATSDR notes that sampling periods (up to eight weeks) are much shorter than those generally used to estimate chronic exposure (greater than a year).

During both events, ATSDR collected measurements of particulate matter (PM), including particulate matter 2.5 microns or smaller ($PM_{2.5}$) and particulate matter 10 microns or smaller (PM_{10}), ammonia (NH_3), and hydrogen sulfide (H_2S) from residential, commercial, and other locations close to AFOs near Harrah. All these pollutants were detected at various concentrations over the course of the EI. The measured concentrations of ammonia and hydrogen sulfide were compared to chemical-specific, health-based comparison values (CVs) from ATSDR and EPA. EPA's air quality index (AQI) and National Ambient Air Quality Standards (NAAQS), and the World Health Organization's (WHO) Air Quality Guidelines (AQGs) were used to evaluate exposure to $PM_{2.5}$ and PM_{10}.

ATSDR prepared this health consultation as an in-depth public health evaluation of the pollutant concentrations measured during the EI. After a careful evaluation of the measured pollutant concentrations, ATSDR has come to the following conclusions:

Conclusion 1. ATSDR concludes that daily exposures to air with the maximum concentrations of $PM_{2.5}$ at each sampling location in the Harrah area, could harm people's health. Sensitive individuals with asthma or previous respiratory conditions are most at risk.

Basis for Conclusion 1. ATSDR does not have a comparison value for particulate matter. Short-term $PM_{2.5}$ samples were evaluated using the hazard categories from EPA's AQI – *good, moderate, unhealthy for sensitive people*, *unhealthy*, *very unhealthy,* and *hazardous*. The highest measured twenty-four (24)-hour average concentration falls into the *very unhealthy* AQI

category. This condition occurred at one site on one day during the fall sampling. Additionally, 3 of the 721 days (0.4% collected at two sites on three different days) during the fall sampling were categorized as unhealthy, and 27 of 721 (4%) were categorized as *unhealthy for sensitive groups* (23 of which occurred during the fall sampling event). According to the AQI, when $PM_{2.5}$ is in the *unhealthy for sensitive groups'* category, there is an increased likelihood of aggravation of respiratory symptoms and aggravation of heart or lung disease and premature mortality in sensitive individuals. These sensitive groups include older adults, children, and people with heart or lung disease. When $PM_{2.5}$ is in the *unhealthy* and *very unhealthy* categories, respiratory effects are also expected in the general population and there is a significant increase in aggravation of heart or lung disease and premature mortality in people with heart or lung disease.

Conclusion 2. ATSDR cannot currently conclude that breathing the <u>average</u> concentrations of $PM_{2.5}$ in the Harrah area could harm people's health. The short sampling duration of this EI (16 weeks), cannot be used to accurately evaluate health effects from long-term (chronic) exposures, which are defined as having an exposure duration of one year or longer. However, if the measured concentrations during this EI represent chronic conditions in the Harrah area, long-term exposure to the average $PM_{2.5}$ concentrations at each sampling location could harm people's health.

Basis for Conclusion 2. To assess long-term exposure, data from both fall and summer sampling events were combined and averaged by site. The combined study $PM_{2.5}$ 24-hour average was 12.88 µg/m^3, which shows there is a potential to be above the WHO AQG annual average (10 µg/m^3) and the primary NAAQS annual average (12 µg/m^3).[1] The measured concentrations in the fall sampling event (mean 16.20 µg/m^3) were higher than the summer sampling event (mean 10.34 µg/m^3). Site averages only exceed the NAAQS during the fall sampling event.

Long-term exposure above the annual NAAQS has been determined to worsen cardiopulmonary and respiratory diseases in people with pre-existing health conditions and can increase the risk of dying from these diseases. Further, there is evidence that long-term exposure to elevated $PM_{2.5}$ can also cause the development of cardiopulmonary diseases. The epidemiological and toxicological evidence suggests that long-term exposures to $PM_{2.5}$ negatively impacts reproductive and developmental outcomes (specifically low birth weight and infant mortality, related to respiratory causes during the post-neonatal period).

Conclusion 3. ATSDR concludes that breathing PM_{10} in the Harrah area is not expected to harm the general population. However, breathing the highest concentrations measured in the Harrah area may cause respiratory effects in some sensitive individuals.

Basis for Conclusion 3. PM_{10} was only measured at one site. Only 5% (3 of 61) of the 24-hour averages for PM_{10} were in the *moderate* AQI category. Health effects caused by PM_{10} are similar to but less clearly defined than exposure to $PM_{2.5}$. The remaining 58 days were in the *good* AQI category and appear to pose little to no risk. According to the AQI, on *moderate* days,

[1] ATSDR used the nominal value of the NAAQS to screen the average $PM_{2.5}$ data over the entire EI and did not apply the EPA statistical approach for NAAQS attainment.

respiratory symptoms may occur in some sensitive individuals (People with heart or lung disease, older adults, children, and people of lower socioeconomic status), as well as possible aggravation of heart or lung disease in people with cardiopulmonary disease and in older adults. On *moderate* days, unusually sensitive people should consider reducing prolonged or heavy exertion.

Conclusion 4. ATSDR concludes that breathing ammonia in the Harrah area is not expected to harm people's health.

Basis for Conclusion 4. Thirty-minute averages were calculated for comparison to the 30-minute exposure duration in the critical study, which was used as the basis for the acute CV. The highest 30-minute concentration at any EI site was 907.2 parts per billion (ppb), which is below ATSDR's acute CV.

Although sampling periods (up to six weeks) were much shorter than those generally used to estimate chronic exposure (greater than a year), daily averages were used to calculate the mean over the entire sampling period and estimate the risk of adverse effects from long-term exposure to ammonia in air. None of the site averages in either sampling period or the combined sampling average exceeded the chronic CV. Therefore, ATSDR does not expect adverse health effects to occur from short or long-term exposures to ammonia.

Conclusion 5. ATSDR concludes that breathing hydrogen sulfide in the Harrah area is not expected to harm people's health.

Basis for Conclusion 5. Thirty-minute averages were calculated for comparison to the 30-minute exposure duration described in the toxicological study used to derive the acute CV. None of the 30-minute averages from any site exceeded the acute CV. Thus, ATSDR concludes short-term exposures to hydrogen sulfide concentrations in the Harrah area are not likely to cause adverse health effects.

Overall, hydrogen sulfide was detected in 45.6% of the samples. The average of the 24- hour values at three locations (ranging from 1.45 to 1.57 ppb) were above but similar to the chronic CV (1.4 ppb), which is considered protective of health effects from long-term exposure. These concentrations are well below levels observed to cause physical changes in the body, even in exercising asthmatics. Therefore, ATSDR does not expect long-term exposure to hydrogen sulfide concentrations in the Harrah area air to cause adverse health effects.

Conclusion 6. ATSDR concludes that the odors in the Harrah area are not expected to harm the general population, however, sensitive individuals may experience odor related symptoms such as headache and nausea and stress or annoyance when hydrogen sulfide and other gases exceeds their odor threshold.

Basis for Conclusion 6. ATSDR recognizes that community members are concerned about environmental odors in the area and whether they could lead to adverse health effects. ATSDR notes that people may experience odor-related health effects below irritant effect levels. In general, most substances that cause odors in the outdoor air are not at levels that can cause serious injury, long-term health effects, or death. However, odors may lead to odor related health effects, affect people's quality of life, and sense of well-being.

Some individuals can smell hydrogen sulfide at concentrations below its CVs. The odor threshold of the most sensitive people exposed to hydrogen sulfide in scientific studies (0.5 ppb) was exceeded during both sampling events at all sites. In all 44% of the samples were greater than or equal to the odor threshold of 0.5 ppb (60% of Fall 2014 and 30% in Summer 2015). When concentrations are above the odor threshold, but below health effect guidelines, individuals can smell odors in these areas, but are not likely to experience serious adverse health effects. Individuals vary in their response to unpleasant environmental odors. Sensitive individuals may endure odor related symptoms such as headache, nausea, and stress, which can affect people's sense of wellbeing and reduce their quality of life.

While ammonia is also often related to odors in areas with AFOs, it was not measured above its odor threshold during this EI. Both hydrogen sulfide and ammonia can also be incorporated into PM in the area; however, the concentration of the contaminants in the measured PM are unknown, and the contribution of PM to odors in the area cannot be determined.

Conclusion 7. ATSDR concludes that data from 2000-2014 show, the Harrah area had elevated rates of asthma hospitalizations and mortality from cardiovascular disease compared to the State of Washington as a whole. These health outcomes associated with $PM_{2.5}$ are also associated with various other factors that can occur over a person's lifetime, and ATSDR cannot determine if $PM_{2.5}$ was the cause of any specific health outcome.

Basis for Conclusion 7. As part of the public health evaluation process, ATSDR tried to identify potential health issues in Harrah that could be related to the measured $PM_{2.5}$ (which showed the potential to exceed regulatory values) or environmental odors. According to the EPA's Integrated Science Assessment for Particulate Matter [USEPA 2009], short and long-term exposure to $PM_{2.5}$ has been determined to have a causal relationship to cardiovascular effects and mortality, and a likely causal relationship with respiratory effects.

ATSDR analyzed health outcome data from the Washington State Department of Health's Washington Tracking Network (WTN) from 2000-2014. From the available data from the WTN, asthma hospitalizations for the zip code containing Harrah was consistently higher than that of Yakima County and the State of Washington as a whole. Mortality from cardiovascular disease was significantly higher in the census tract containing Harrah than that of the state during the same time period of 2000-2014. Although these data can give us an overall understanding of the health status in the community, they cannot provide any information on the cause of the health outcomes because there are a number of factors associated with the health outcomes (mortality, respiratory effects and cardiovascular effects) related to PM exposures, and this health outcome data cannot demonstrate cause and effect.

Next Steps

The EPA and the Yakama Nation should consider long-term efforts to reduce and monitor $PM_{2.5}$ in Harrah and other areas on the Reservation that may have elevated concentrations of $PM_{2.5}$.

The EPA, Washington Department of Ecology, the Yakima Regional Clean Air Agency, and the Yakama Nation may want to consider implementing measures to reduce odors related to animal feeding operations that impact community members and residents on the Yakama Reservation.

To facilitate these recommendations, ATSDR will

- provide a copy of this report to the Yakama Nation, EPA, EI Participants, and other community members as requested.
- meet individually with EI Participants to discuss the information provided in this report and to specifically discuss the data collected on their respective properties.
- meet with interested stakeholders to discuss the information provided in this report.

If requested, ATSDR will work with the EPA and the Yakama Nation to consider options to reduce exposures in the area.

Purpose and Statement of Issues

The Agency for Toxic Substances and Disease Registry (ATSDR) conducted an exposure investigation (EI) in Harrah, Washington (located on the Yakama Reservation) to determine if residents in the community are exposed to harmful levels of air pollutants. The Yakama Reservation encompasses approximately 1,130,000 acres and is located near the city of Yakima, in Yakima County (Figure 1). Yakima County is a major agricultural area in south central Washington that has numerous large dairy and cattle animal feeding operations (AFOs) including operations on the Yakama Nation Reservation near Harrah [Yakama Nation 2014].

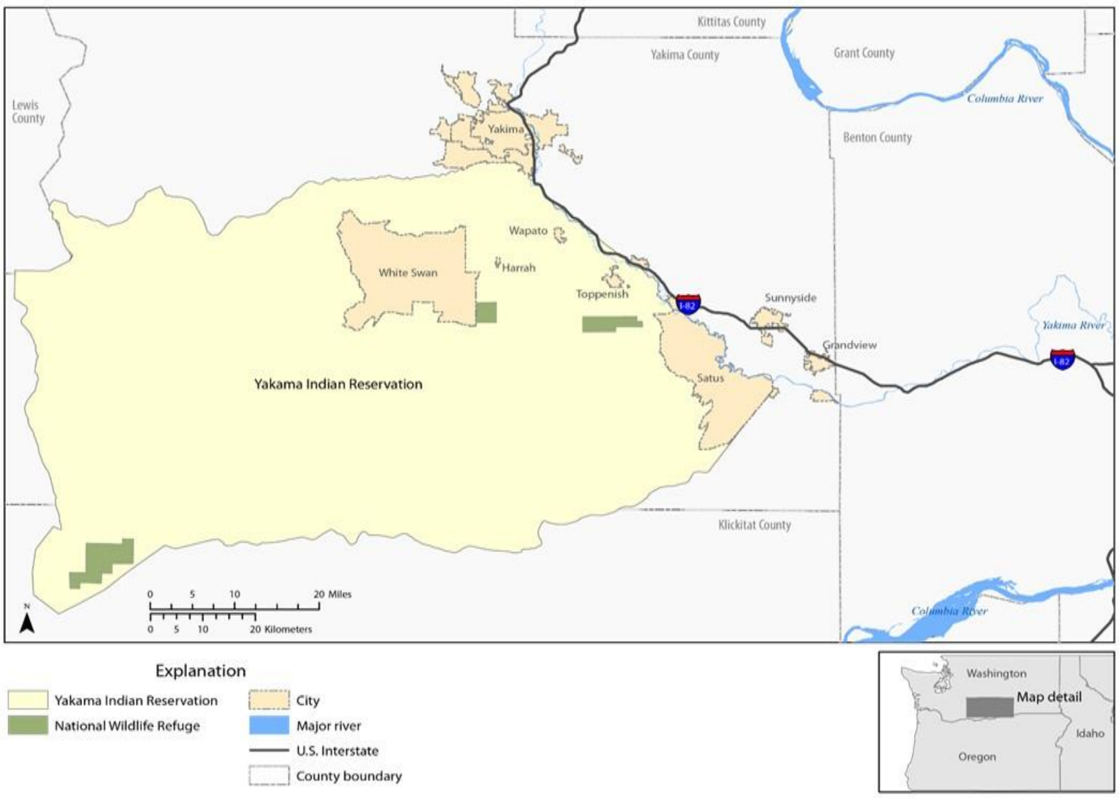

Figure 1. Map of Yakama Nation Reservation.

The Concerned Citizens of the Yakama Indian Reservation and Friends of Toppenish Creek contacted the U.S. Environmental Protection Agency EPA voicing concerns regarding exposures to community members from the numerous cattle and dairy AFOs located on the reservation. Community members expressed concerns that air quality issues were impacting their quality of life and harming their health. Concerns expressed to EPA included the following:

- Many residents complained of not being able to be outdoors during times when odors (rotten egg and urine smells) are especially bad. Residents are concerned about odors at all times of the year but especially during September, November, March, and April; and

- Dust, ammonia, and sulfur compounds in the air are of special concern to community members since many residents with children live next to large dairy and cattle AFOs.

To address the community concerns, in 2011, EPA requested that ATSDR conduct an exposure investigation (EI) on the reservation, in the city of Harrah, to assess the presence of chemical contaminants in air that had a high potential to be released by AFOs [USEPA 2011a]. The contaminants identified as potentially related to AFOs included dust as particulate matter (PM), hydrogen sulfide (H_2S), and ammonia (NH_3).

Background

The Yakama Nation has approximately 6,300 tribal members. About 13,700 tribal and non-tribal people live on or close to the Yakama Reservation [Yakama Nation 2014]. The census tract containing the city of Harrah (53077940001) has a population of 6,588, with 5,079 being people of color (predominantly Native American and Hispanic), which puts this census tract in the highest 10% in the state. This census tract also has 3,008 children below the age of 5 [WDOH 2018]. The census tract containing the city of Harrah also has a significantly higher percentage of individuals living below the poverty line than Washington State as a whole. The census tract has 35.7% of children and a total of 22.3% living below the poverty line, while the state has 16.5% of children and 12.7% total respectively [WDOH 2018]. The zip code containing Harrah (98933) is approximately 23.1% Native American, while Yakima County as is about is 3.6% [WDOH 2018].

Washington State Department of Ecology (Ecology) currently oversees real-time PM air monitoring at four locations near Harrah [Ecology 2017].[2] $PM_{2.5}$ (particulate matter 2.5 microns or smaller) is monitored by the Yakima Regional Clean Air Agency (YRCAA) in the city of Yakima (roughly 12 miles northeast of Harrah), at Toppenish High School (roughly ten miles east of Harrah) and in the city of Sunnyside (roughly 25 miles southeast of Harrah). The Yakama Nation monitors $PM_{2.5}$ on the White Swan Yakama Reservation 8 miles west of Harrah. Data from the monitor at Sunnyside is not included in this consult because this information was not available at the time of the development of this report.

Although there are four $PM_{2.5}$ monitors surrounding Harrah, $PM_{2.5}$ concentrations vary greatly between monitors due to unique conditions at each location (e.g. geographical, meteorological, and those associated with human activities). Late fall and wintertime concentrations of $PM_{2.5}$ are strongly influenced by topographical and meteorological conditions or patterns, which prevent atmospheric dispersion. This can be attributed to very low surface level air movement and upper level inversion conditions. Such conditions frequently persist for several days, allowing pollutant concentrations to increase rapidly. Also, persistent winter high pressure systems have created inversions and large stable air masses which last for two to four weeks at a time, allowing even greater build-up of $PM_{2.5}$ [Ecology 2014, VanDeken et al. 2017].

[2] https://fortress.wa.gov/ecy/enviwa/

Researchers and agencies have performed studies on odors or dust related to AFOs in the greater area (beyond the reservation) in the past. These studies include the following:

- In 2008, researchers with John's Hopkins Bloomberg School of Public Health collected single 5-day averaged samples from 40 residence near AFOs east of the Harrah area [Williams et al. 2011]. Samples were collected from June to August and measured ammonia, total dust, and cow allergen in indoor and outdoor air. Outdoor ammonia concentrations (median 8.7 parts per billion (ppb)) were significantly higher closer to dairy facilities or manure-spraying operations (within a quarter mile) than concentrations measured more than three miles away (median 1.3 ppb). Total dust had a similar concentration gradient with higher levels (median 29 micrograms per cubic meter ($\mu g/m^3$)) close to operations compared to those at three miles away (median 18 $\mu g/m^3$) and statistically higher than those at locations more than five miles away (median 15 $\mu g/m^3$). Inside homes near operations, ammonia concentration (median 12 ppb) were statistically different than both intermediate and distal homes (median 4.9 and 5.7 ppb respectively. Indoor total dust was similar no matter what the distance from operations with median of all samples at 22 $\mu g/m^3$. Cow allergen (Bos d2) associated with total dust had a concentration gradient in outdoor and indoor air. The authors stated that "findings reinforce community concerns of exposure and substantiate the need for larger, well-designed environmental exposure and health effects studies to determine the influence of these facilities and their contaminants on health in adjacent communities." The authors noted that "*integrated sampling methods cannot evaluate important short-term within week and within day variability, which may be subject to exceptionally high concentrations. This is particularly important for ammonia where elevated short-term exposures can result in significant irritation and health effects*" [Williams et al. 2011];

- In 2013, Washington Department of Ecology hired Washington State University and Central Washington University to conduct an area-wide atmospheric chemistry study (Yakima Area Wintertime Nitrate Study, YAWNS) to determine why the nitrate is such a large fraction of wintertime $PM_{2.5}$ [Ecology 2014, VanDeken et al. 2017]. During the 22-day study in January 24-hour $PM_{2.5}$ levels fluctuated diurnally and peaked at one monitor at 54 $\mu g/m^3$ [VanDeken et al. 2017]. Findings point to ammonia in the atmosphere from 1) agricultural activities interacting with oxides of nitrogen from motor vehicles during specific weather conditions; 2) restriction of air mixing from the upper and lower Yakima valleys during cold, clear-sky, stagnant periods trapping pollution and preventing dispersion; and 3) possible leaks from food storage facilities that use industrial freezers may account for less than 10% of ammonia emissions. Further analysis of the data point to nitrogen oxide (NOx) emissions from vehicles and wood smoke as being the primary drivers of nitrate levels [VanDeken et al. 2017, VanderSchelden et al. 2017]; and

- In 2010, another study in the Yakima area examined ammonia exposures east of the Harrah area [Loftus et al. 2015]. The sampling area in this study was closer to the highway, roughly 10-12 miles east and southeast of Harrah, and had a higher number of AFOs. Their 24-hour ammonia concentrations taken at 18 locations every six days for 13 months ranged from 0.29-342 ppb (0.2-238.1 $\mu g/m^3$). Concentrations increased with proximity to AFOs. Authors followed measurements of asthma and pulmonary function (daily forced expiratory volume, FEV) in 51 children with asthma in the area. They reported a statistically significant reduction in FEV per 1-day and 2-day lagged interquartile increase (13-26 ppb) in ammonia concentration. No correlation was found between the measured concentrations and self-reported asthma symptoms or use of medication.

From the studies listed above there is evidence that increased concentrations of PM and ammonia are associated with proximity to agriculture and AFOs. Furthermore, both PM and ammonia concentrations are likely to be higher in the winter.

In May 2011, the EPA contacted ATSDR to determine if ATSDR would be able to conduct an exposure investigation on the Yakama Nation Reservation to help address community concerns of air quality issues of odors and dust [USEPA 2011a]. ATSDR conducted the EI to answer questions about odors and particulates on the Yakama Nation Reservation in the Harrah area.

Summary of Exposure Investigation

An exposure investigation is an approach ATSDR uses to fill data gaps in evaluating community exposure pathways. Its purpose is to better characterize exposures to hazardous substances in the environment and to evaluate possible public health consequences related to those exposures. An EI is not designed to be a long-term study.

For this EI, ATSDR identified $PM_{2.5}$, PM_{10}, hydrogen sulfide, and ammonia, as the target pollutants to evaluate in order to determine whether people living on the Yakama Reservation are exposed to contaminants related to AFOs that may pose a health hazard. ATSDR implemented several planning activities prior to developing a protocol to measure the target pollutants. In 2014 and 2015, ATSDR and EPA representatives made trips to the Yakama Reservation to develop consensus with local stakeholders on the pollutants and locations at which to collect measurements. During these trips, agency representatives met with Yakama Nation Air Quality Section staff, Yakima Regional Clean Air Agency (YRCAA), and community members and visited the investigation area.

The goal of the EI was for ATSDR to obtain representative community-based ambient air concentrations of the target pollutants, as well as meteorological measurements, from residential, commercial, and other locations close to AFOs. Target pollutants were selected based on concerns from the community about exposures from numerous large dairy AFOs located on the reservation. These pollutants have been linked to AFOs by other investigators and have health-based comparisons values (CVs). For a more complete discussion on CVs see Appendix A, Description of Comparison Values.

To determine whether these contaminants were present, ATSDR established nine air sampling and monitoring locations at residential, commercial, and other locations close to AFOs. The area of investigation was in and around Harrah, a small town on the Yakama Reservation (Figure 2). The EI was conducted in Harrah because

- there are schools located in close proximity to AFOs;
- one of the schools agreed to allow a monitoring station to be located on school property;
- several residents agreed to host monitoring stations;

- the geographic area is small enough that a network of monitoring locations could be established; and
- a limited number of possible contributing emission sources were present.

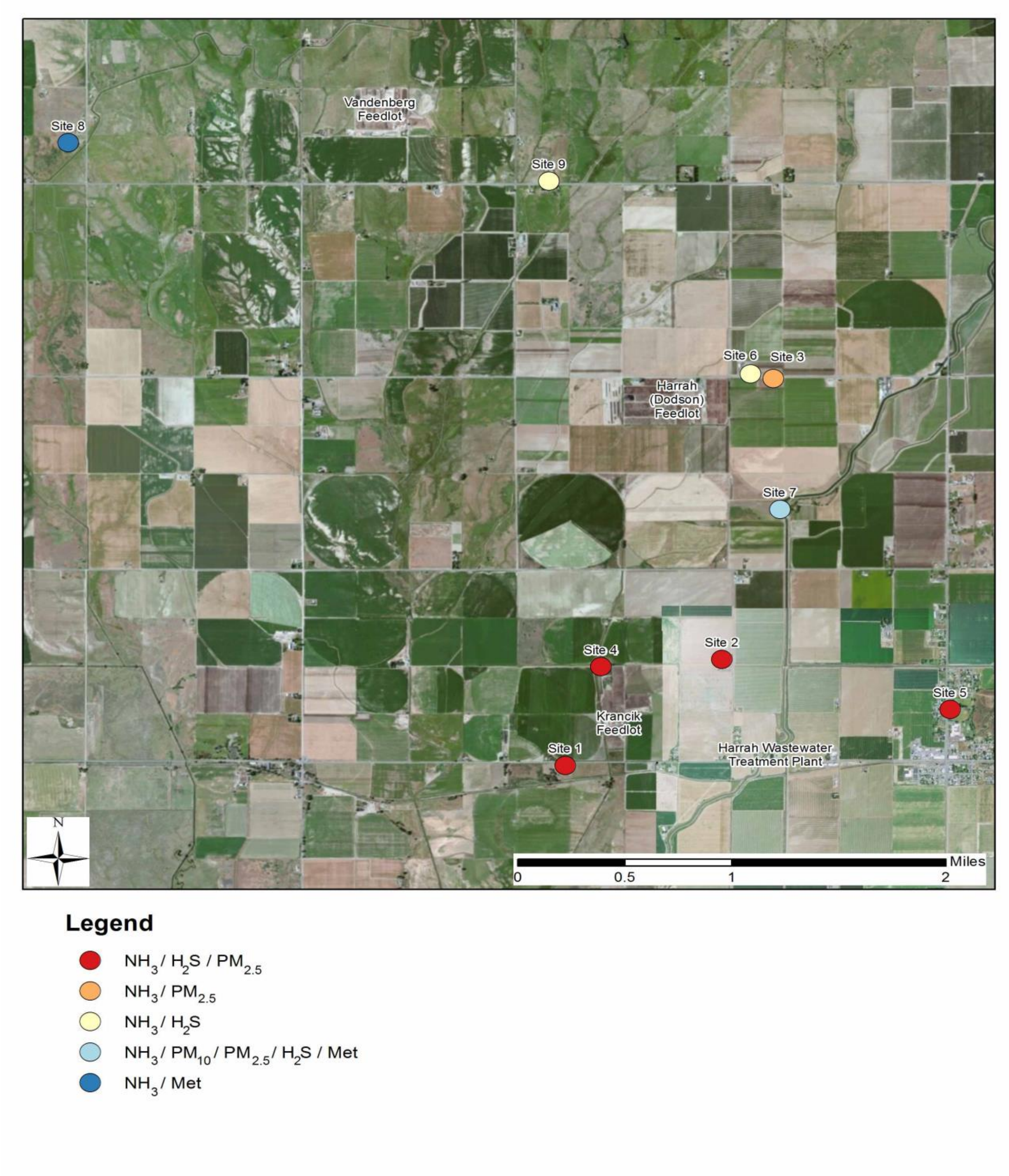

Figure 2. Map of Harrah and monitoring/sampling locations in the Yakama Nation Exposure Investigation, Harrah, WA. The legend below shows the data collected at each site: ammonia (NH_3), hydrogen sulfide (H_2S), particulate matter 2.5 microns or smaller ($PM_{2.5}$), particulate matter 10 microns or smaller (PM_{10}), and meteorological data (Met)

In summary, the sites were close to the following sources:

- Site 1 – Located within a quarter mile west of Krainick feedlot and less than a mile west of the Harrah Wastewater Treatment Plant;
- Site 2 – Located within a half mile northeast of Krainick feedlot and less than a mile north of Harrah Wastewater Treatment Plant;
- Site 3 – Located within a quarter mile east of Dolsen (Harrah) feedlot;
- Site 4 – Located adjacent to the Krainick feedlot and less than a mile northwest of the Harrah Wastewater Treatment Plant;
- Site 5 – Harrah Elementary School located about a mile east of the Harrah Wastewater Treatment Plant near other private residences;
- Site 6 – Located less than a quarter mile east of the Dolsen (Harrah) feedlot;
- Site 7 (met station) – Water Improvement Project canal gate located about a mile away from both Dolsen (to the northwest) and Krainick (to the southwest) feedlots and a mile north of the Harrah Wastewater Treatment Plant;
- Site 8 (met station) – Located about two miles west of Vandenberg feedlot; and
- Site 9 – Located about a mile southeast of the Vandenberg feedlot and less than two miles northwest of the Dolsen (Harrah) feedlot.

ATSDR selected two time periods (Fall 2014 and Summer 2015) to conduct monitoring/sampling to evaluate target pollutant concentrations during different seasons. The "Fall 2014" event was conducted from October 23, 2014, to December 18, 2014, and the "Summer 2015" event was conducted from June 22, 2015, to August 19, 2015. These time periods were selected so that monitoring would be conducted during times that were of specific concern to community members (November) and would allow for monitoring during summer heat extremes (July/August). Each monitoring event was conducted for eight weeks for a total of 16 weeks of sampling.

ATSDR collected measurements of particulate matter (PM) including particulate matter 2.5 microns or smaller ($PM_{2.5}$) and particulate matter 10 microns or smaller (PM_{10}), hydrogen sulfide (H_2S), and ammonia (NH_3). ATSDR collected meteorological parameters to assess the effect of local weather conditions and patterns on target pollutant concentrations in the investigation area. The purpose of the sampling/monitoring program was to determine if these pollutants in the ambient air on the Yakama Reservation were present at concentrations of potential health concern. For detailed information on the design and planning of the exposure investigation, see ATSDR's Yakama Exposure Investigation Protocol [ATSDR 2014]. For detailed information of methods used during the Exposure Investigation see ATSDR Field Report for the Yakama Reservation Exposure Investigation [ERG 2016] (available on request).

Locations for Monitoring and Sampling Equipment

To determine the concentrations of target pollutants in ambient air for this EI, ATSDR selected EI monitoring/sampling locations around large AFOs where community exposures were most likely expected to occur. ATSDR established a total of nine fixed monitoring/sampling locations near Harrah. The locations and types of measurements collected at each site during the EI events are shown in Table 1. The sites consisted of seven residential properties (six of them were used for Summer 2015), the canal gate of the Water Improvement Project and Harrah Elementary School—all of which were located within 2 miles from large cattle operations near Harrah and on the Yakama Reservation. Specifically, Sites 1 through 7 were sited around AFOs, while Sites 8 and 9 were sited near pasture-fed cattle. Sites 1, 2, 4, 5, and 7 were also near the wastewater treatment plant.

Table 1. Type of measurements taken at each monitoring/sampling location, Yakama Nation Exposure Investigation, Harrah, WA

Site ID	Site Description	Fall 2014 Measurement Type	Summer 2015 Measurement Type
Site 1	(Branch Road)	H_2S, NH_3 (RAM), $PM_{2.5}$	H_2S, NH_3 (CRDS* & RAM), $PM_{2.5}$
Site 2	(Batali Road)	H_2S, NH_3 (CRDS* & RAM), $PM_{2.5}$	H_2S, NH_3 (CRDS* & RAM), $PM_{2.5}$
Site 3	(Evans Road 1)	NH_3 (CRDS*), $PM_{2.5}$	H_2S collocated**, NH_3 (CRDS*), $PM_{2.5}$
Site 4	(Progressive Road)	H_2S, NH_3 (ADS, CRDS*, RAM), $PM_{2.5}$	H_2S, NH_3 (ADS, CRDS*, RAM), $PM_{2.5}$
Site 5	Harrah Elementary School	H_2S, NH_3 (CRDS* & RAM), $PM_{2.5}$	H_2S, NH_3 (CRDS* & RAM), $PM_{2.5}$
Site 6	(Evans Road 2)	H_2S collocated**, NH_3 (RAM)	Not used during Summer 2015
Site 7	Canal Gate at the Water Improvement Project†	H_2S, NH_3 (RAM), $PM_{2.5}$, PM_{10}, Met	H_2S, NH_3 (RAM), $PM_{2.5}$, PM_{10}, Met
Site 8	(Wildwood Road)	NH_3 (CRDS* and RAM), Met	H_2S, NH_3 (RAM), $PM_{2.5}$, Met
Site 9	Private Residence (Wapato Road)	H_2S, NH_3 (CRDS* and RAM)	H_2S, NH_3 (CRDS* & RAM), $PM_{2.5}$

Source: [ERG 2016, ATSDR 2014]
Notes: ADS – Annular Denuder System, CRDS – Cavity Ring-down Spectroscopy, H2S – hydrogen sulfide, Met – meteorological station, NH_3 – Ammonia, PM – Particulate matter less than 10 (PM_{10}) or 2.5 microns ($PM_{2.5}$), RAM – Rapid Air Monitor
*Portable CRDS used as a roving instrument and stationed across sites for 3-5 day (Fall 2014) or ≥7 day intervals (Summer 2015)
***Collocated* samples collected simultaneously using two independent collection systems at the same location at the same time
†Water Improvement Project is a canal gate and retired hydroelectric station on the Yakama Reservation.

Methods and Data Analysis

The discussion below summarizes the monitoring and sampling methodologies ATSDR used during the EI. A detailed discussion of the procedures can be found in both the Exposure Investigation's protocol and field report [ATSDR 2014; ERG 2016].

Meteorological Parameters. Meteorological measurements were obtained at Sites 7 and 8 using stand-alone meteorological monitoring systems attached to secured tripod assemblies. These systems monitored wind speed, direction, humidity, and temperature during the Fall 2014 and

Summer 2015 sampling periods. See Appendix B for Meteorological Results and Polar Plots of Concentration, Wind Speed, and Wind Direction at Each Monitoring or Sampling Location

Particulate Matter. $PM_{2.5}$ data were collected at six sites during Fall 2014 (from October 23rd to December 18th) and eight sites during Summer 2015 (from June 22nd to August 19th). PM_{10} data was only measured at Site 7. Measurements of continuous $PM_{2.5}$ and PM_{10} particulates were made using Met One Instruments, Inc. E-BAM real-time electronic beta attenuation monitors. The E-BAMs are portable self-contained units that meet or exceed all EPA requirements for automated particulate measurement. The measurement range for these units is 0–10 milligrams per cubic meter (mg/m^3). These units provide one-minute data that were used to calculate hourly averages. Hourly averages were used to make 24-hour averages, which were combined to get an average for one or both sampling events (See Appendix C, Tables C1 and C2).

Ammonia. Three separate types of passive monitoring and sampling of ammonia were conducted during the Fall 2014 and Summer 2015 sampling events: Ammonia Rapid Air Monitors (RAM), Cavity Ringdown Spectroscopy (CRDS) sampling, and Annular Denuder System (ADS) sampling. ATSDR used 1- and 30-minute CRDS; daily ADS; and weekly passive Rapid Air Monitors (RAM) averages to assess short-term exposure. Averages of the individual sampling events from each method as well as averages from both the combined events were analyzed to assess long-term exposure.

<u>Cavity Ring Down Spectroscopy (CRDS)</u> Samples were collected from 6 sites in both the Fall and Summer sampling (method detection range of 1-10,000 ppb). The Fall 2014 samples were collected from November 8th to December 18th and Summer samples were collected from June 23rd to August 18th. These data were collected continuously as 132,723 one-minute averaged samples and used to calculate 30-minute and 24-hour averages (See Appendix C, Tables C3-C5). The highest 30-minure average was used to assess short-term exposures, and the average of 24-hour values was used to assess long-term exposure.

<u>ADS</u> Daily samples were only collected at site 4 (Method detection limit [MDL] 0.33 ppb). In Fall 2014, 36 samples were collected from November 2nd to December 17th (one sample collected every day). Field samples were shipped to a certified laboratory, accredited by the National Environmental Laboratory Accreditation Program (NELAP), or similar federal or state entity, for analysis. Of the 36 samples, 3 were trip blanks taken for quality assurance purposes [3]. The ammonia ADS samples from Summer 2015 were collected from June 23rd to August 13th (40 samples total; see Appendix C, Table C6). The highest daily value was used to assess short-term exposures, and the average daily value was used to assess long-term exposures.

<u>Passive RAM</u> Samples were collected from 8 sites in both the Fall and summer sampling. Samples were collected as one-week and two-week measurements in Fall 2014 (from October 23rd to December 14th) and 24-hour and 1-week measurements in Summer 2015 (from June 23rd to August 18th). Field samples were shipped to a certified laboratory, accredited by the National Environmental Laboratory Accreditation Program (NELAP), or similar federal or state entity, for

[3] Trip blanks were used to ensure contamination was not introduced during equipment preparation or sample analyses. Trip blanks are not used to calculate measurement averages. Trip blank values are documented in the in the Exposure Investigation Field Report [ERG 2016].

analysis. Since these samples were collected over varying lengths of time less than 14 days, the sampling data were used to calculate weekly averages. The highest weekly average was used to assess short-term exposures and the average of weekly values was used for long-term exposures (see Appendix C, Tables C7 and C8). The MDL was 3.6 ppb for up to one-week samples and 2.1 ppb for two-week samples

Hydrogen sulfide. Samples were collected from 7 sites in Fall 2014 (from October 23rd to December 14th) and 8 sites in Summer 2015 (from June 23rd to August 18th). Hydrogen sulfide was measured using Honeywell single point monitors (SPM). SPM measurements were taken continuously at 1-minute intervals and used to calculate 30-minute averages. The highest 30-minute averages were used to assess short-term exposure. The average of 24-hour samples was used to assess long-term exposure to hydrogen sulfide. The range of linear detection for instruments used to monitor outdoor H_2S concentrations was 2- 90 parts per billion by volume (ppbv). However, the instruments were calibrated from 0-90 ppbv. Results are found in Appendix C, Tables C9-C11.

Results

The measured concentrations of ammonia and hydrogen sulfide were compared to chemical-specific, health-based CVs from ATSDR and EPA. EPA's air quality index (AQI) and National Ambient Air Quality Standards (NAAQS), and the World Health Organization's (WHO) Air Quality Guidelines (AQGs) were used to evaluate exposure to $PM_{2.5}$ and PM_{10}.

The following boxplots show the concentrations of each contaminant measured across all sites during this EI. See Appendix D for guidance on interpreting boxplots. See Appendix C for the concentrations measured at each site. Figure 3 below shows the boxplots of the 24-hour samples of PM_{10} and $PM_{2.5}$. This figure is laid over the corresponding AQI category. From Figure 3, we can see that across all sites, PM10 exceeded the AQG but not the NAAQS and reached the *moderate* AQI category. $PM_{2.5}$ exceeded both the AQG and the NAAQS and reached the *unhealthy* AQI category.

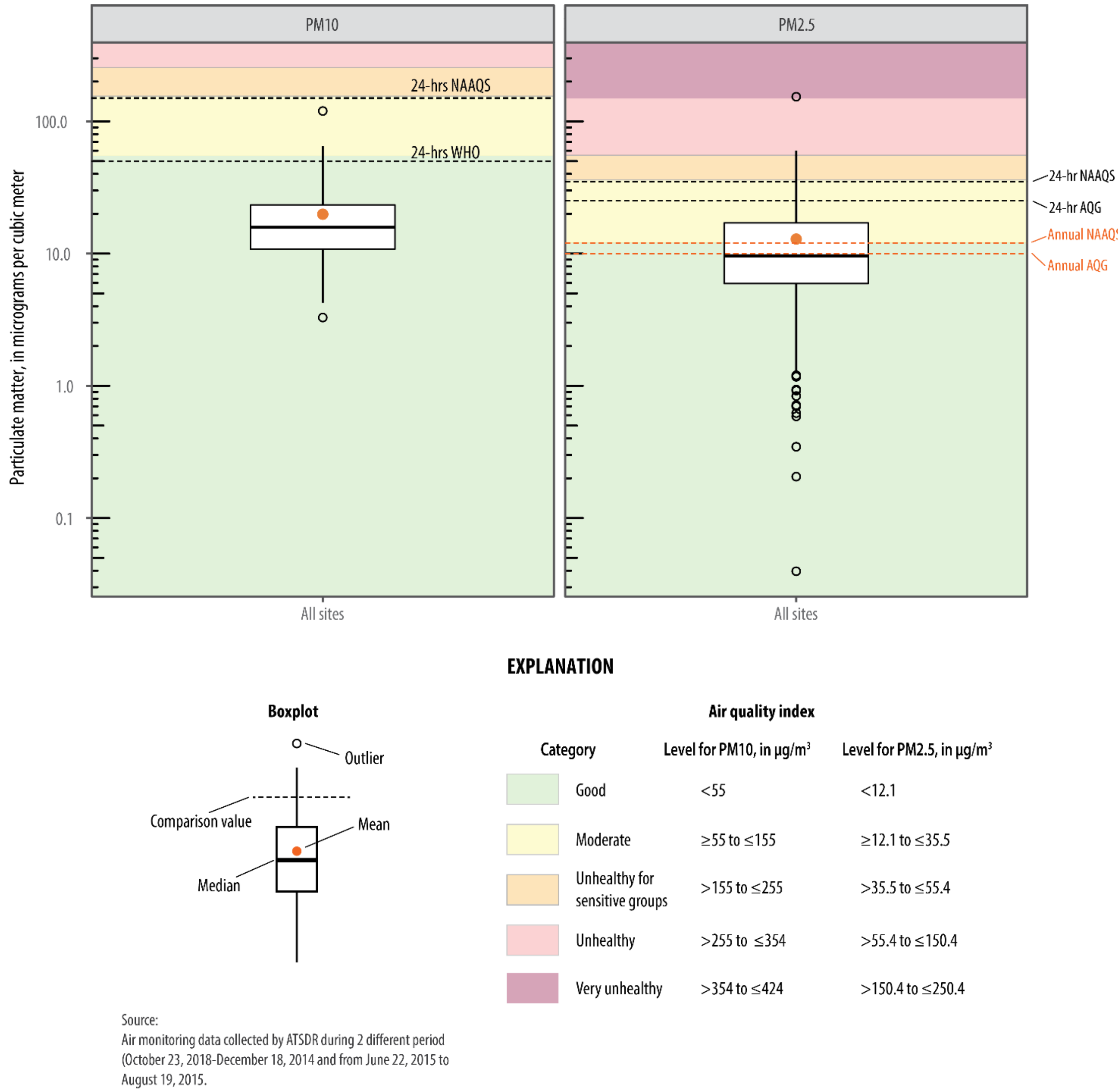

Figure 3. Boxplots of the measured 24-hour concentrations of PM_{10} and $PM_{2.5}$ in Harrah WA. The dotted lines represent the CVs used in screening the contaminants. (See Appendix D for guidance on interpreting boxplots.)

Figure 4 below shows the boxplots of the ammonia and hydrogen sulfide samples of varying durations. Ammonia samples ranged from 30 minutes to 2 weeks and hydrogen sulfide samples from 1-minute to 24-hours. From Figure 4, we can see that across all sites, ammonia samples never exceeded the lowest CV. Hydrogen sulfide samples exceeded all CVs at some point, and on average were above the odor threshold.

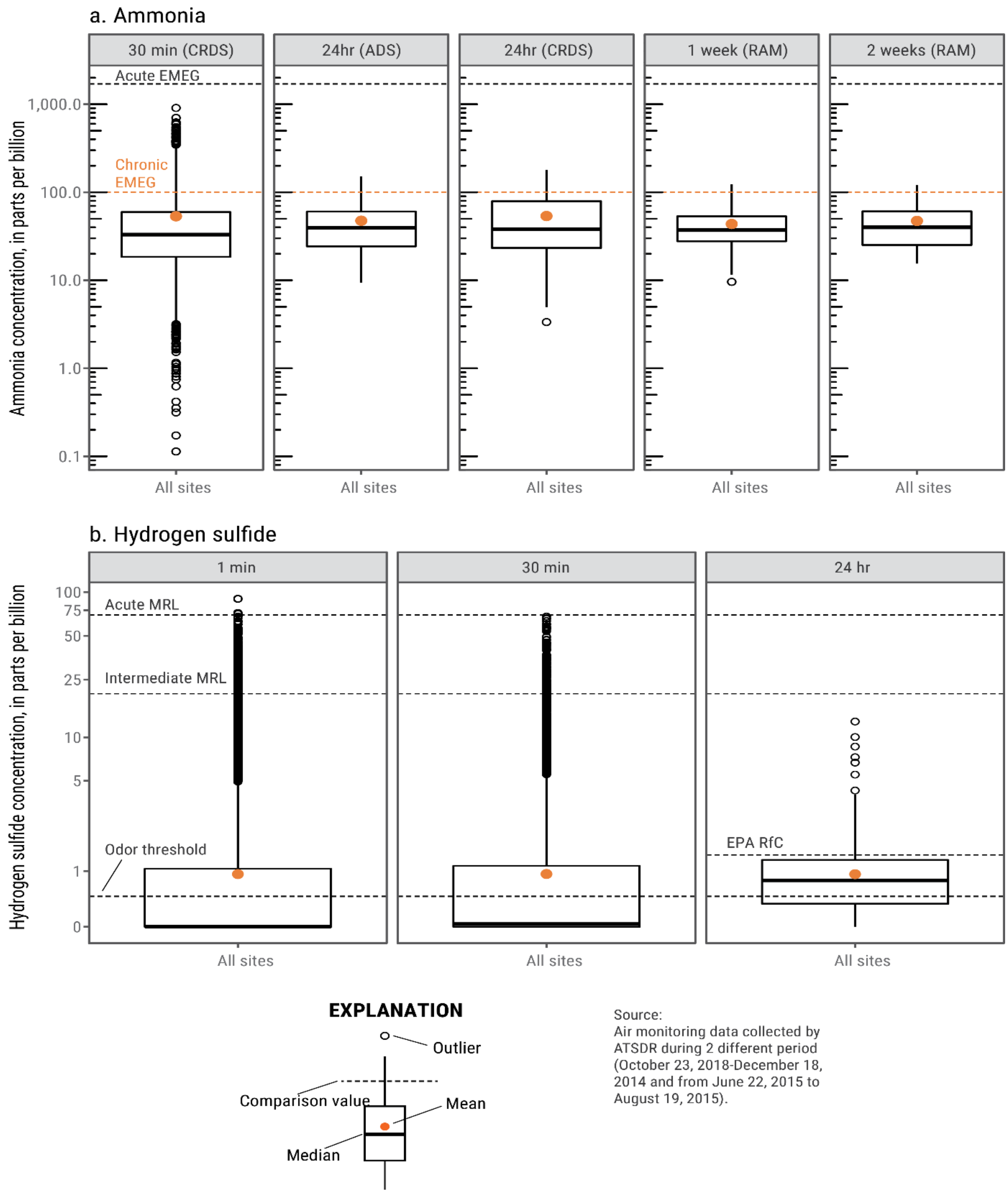

Figure 4. Boxplots of the measured concentrations of a) Ammonia and b) Hydrogen Sulfide in Harrah WA. The dotted lines represent the CVs used in screening the contaminants. (See Appendix D for guidance on interpreting boxplots.)

Screening and Health Evaluation

ATSDR compared averaged concentrations from each sampling event and both totaled to various health-based and environmental guidelines to determine the potential for adverse health effects from exposure to ambient air in the Harrah area. These comparison values (CVs) (discussed in Appendix A) are intended to protect the general public from adverse health effects for specific durations of exposure. They are used to screen out contaminants that are measured at concentrations that are generally safe (below the CV). A concentration above the CV does not necessarily mean that an adverse effect will occur, but it is an indication that the specific contaminant should be further investigated and compared to the health effects and doses documented in scientific literature. All contaminants measured exceeded at least one of their CVs at some site during the exposure investigation. See Appendix C for tables summarizing the measured concentrations at each site with respect to health–based CVs. The following descriptions present a summary of each contaminant measured, the results of the pollutant screening, and comparison to health effects documented in the scientific literature.

Particulate Matter

"Particulate matter (PM) is the generic term for a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes. The chemical and physical properties of PM vary greatly with time, region, meteorology, and source category..." (from EPA's Integrated Science Assessment for Particulate Matter, [USEPA 2009]).

The size of particles is directly linked to their potential for causing health problems [USEPA 2006]. Particles less than 10 microns in diameter (PM_{10},) can pass through the throat and nose to enter the lungs. Fine particles less than 2.5 microns in diameter ($PM_{2.5}$) can lead to deeper penetration of the lungs and higher toxicity. ATSDR has no way of knowing the distribution of particle sizes below the 2.5- or 10-micron cutoff point unless special particle size distribution instruments are used. Both $PM_{2.5}$ and PM_{10} have been associated with short-term health effects. However, EPA revoked the annual PM_{10} standard in 2006 because available evidence generally does not suggest a link between long-term exposure to current levels of coarse particles and health problems [USEPA 2006].

PM_{10} is primarily produced by mechanical processes such as construction activities, road dust resuspension and wind. $PM_{2.5}$ originates primarily from combustion sources—like wood smoke, motor vehicle exhaust, and emissions from power plants—and certain industrial processes [USEPA 2009]. Although both can mobilize with wind, PM_{10} is more rapidly deposited and travels shorter distances than $PM_{2.5}$ [Hiranuma et al. 2011]. The risk for various health effects has been shown to increase with exposure to PM. The lowest concentrations at which adverse health effects have been demonstrated is not greatly above $PM_{2.5}$ background concentrations, which have been estimated to be 3–5 $\mu g/m^3$ in both the United States and western Europe [WHO 2005].

Particulate matter has been associated with a range of respiratory and cardiovascular health problems. Health effects linked to exposure to ambient particulate matter include the following: premature mortality (or death), aggravation of respiratory and cardiovascular disease, aggravated asthma, acute respiratory symptoms, chronic bronchitis, decreased lung function, and increased risk of heart attack [USEPA 2009]. Since personal susceptibility to PM exposure is highly variable from person to person and there is no known threshold of effect from exposure to PM, it is unlikely that any standard or guideline value could lead to complete protection for everyone. PM constituents vary widely in content and thus vary in their ability to cause adverse human health effects.

Short-term exposures to elevated levels of $PM_{2.5}$ have been determined to cause a range of cardiovascular and respiratory effects. Epidemiology studies described in the EPA Integrated Science Assessment for Particulate Matter [USEPA 2009] show a 0.5 to 3.4% increase in cardiovascular emergency department visits and hospital admissions and a 1 to 4% increase in respiratory outcomes (such as chronic obstructive pulmonary disease (COPD), respiratory infections, and asthma) for every 10 $\mu g/m^3$ increase in $PM_{2.5}$.

In 2012, the EPA completed a review and assessment of numerous recent studies on $PM_{2.5}$ and long-term effects [USEPA 2012]. Generally, there is evidence for an association between long-term exposure to $PM_{2.5}$ and mortality (i.e., all-cause and cardiovascular) within the range of long-term mean $PM_{2.5}$ concentrations of 10–32 $\mu g/m^3$ [USEPA 2012]. Studies provide evidence for increased respiratory symptoms and incident asthma, as well as respiratory hospitalizations, at long-term mean $PM_{2.5}$ concentrations ranging from 9.7–27 $\mu g/m^3$ [USEPA 2012]. EPA also finds that:

- "Evidence is accumulating from epidemiologic studies for effects on low birth weight and infant mortality, especially due to respiratory causes during the post-neonatal period. The mean $PM_{2.5}$ concentrations during the study periods ranged from 5.3–27.4 $\mu g/m^3$" [USEPA 2009]; and
- "Recent evidence remains inconsistent for the association between exposure to $PM_{2.5}$ and preterm birth, with some studies providing evidence for an association" [Chang et al. 2012; Wu et al. 2009], while others did not [Rudra et al. 2011; Darrow et al. 2009]." [USEPA 2012].

The EPA's National Ambient Air Quality Standards (NAAQS) and the World Health Organization (WHO) Air Quality Guidelines (AQGs) for PM are presented in Table 3. The AQG is a health-based guideline. While the NAAQS were established based on some health outcomes, they are also regulatory standards based on technological feasibility and economic considerations in addition to public health priorities.

Table 2. Standards and guidelines used to evaluate levels of particulate matter in air, Yakama Nation Exposure Investigation, Harrah, WA

Size of Particulate	EPA	WHO	ATSDR[d]
PM_{10}	150 $\mu g/m^3$ (24-hour average)[a]	50 $\mu g/m^3$ (24-hour average) 20 $\mu g/m^3$ (annual average)	NA
$PM_{2.5}$	35 $\mu g/m^3$ (24-hour average)[b] 12 $\mu g/m^3$ (annual average)[c]	25 $\mu g/m^3$ (24-hour average) 10 $\mu g/m^3$ (annual average)	NA

Notes: ATSDR – Agency for Toxic Substances and Disease Registry, EPA – Environmental Protection Agency, $\mu g/m^3$ – micrograms per cubic meter; NA – not available, PM – particulate matter less than 10 microns (PM_{10}) or 2.5 microns ($PM_{2.5}$), WHO – World Health Organization

[a] EPA's NAAQS requires that the 24-hour average PM_{10} concentrations are not to exceed 150 $\mu g/m^3$ more than once per year (on average) over a 3-year period.

[b] EPA's NAAQS requires that the 98th percentile of 24-hour average $PM_{2.5}$ concentrations, averaged over three consecutive calendar years, must not exceed 35 $\mu g/m^3$.

[c] EPA's NAAQS require that annual average concentrations of $PM_{2.5}$, averaged over three consecutive calendar years, do not exceed 12 $\mu g/m^3$

[d] ATSDR does not have a comparison value for particulate matter

An EPA study evaluated air quality trends from 2005–2007 at more than 2,000 ambient air monitoring stations in metropolitan areas around the U.S. and found that more than half of these stations had $PM_{2.5}$ and PM_{10} annual average concentrations greater than the WHO AQGs. This same study found that $PM_{2.5}$ and PM_{10} 24-hour averages exceeded the WHO AQGs in more than 5% of the samples [USEPA 2009]. ATSDR notes that trend site data are mentioned to put background concentrations into perspective for the reader—not to imply the acceptability of the levels from a public health perspective.

Screening Particulate Matter Results

EPA's Air Quality Index (AQI) online tool, "AIRNow AQI Calculator" was used in the screening process to estimate the potential for health effects from short-term exposure to 24-hour averages of PM_{10} and $PM_{2.5}$ measured in Yakima (see http://airnow.gov/index.cfm?action=resources.conc_aqi_calc) [USEPA 2015]. This tool offers guidance to the potential health effects associated with short-term exposure to specific concentrations of PM. The AQI categorizes 24-hour PM concentrations into six categories: good, moderate, unhealthy for sensitive populations, unhealthy, very unhealthy, and hazardous.

ATSDR used the moderate category as a screening tool to determine if PM concentrations measured in Yakima had the potential to cause adverse health effects. Exposure to $PM_{2.5}$ or PM_{10} at the moderate AQI category may require some sensitive individuals to reduce prolonged or heavy exertion; the health of other individuals should not be affected. The range of the moderate category for $PM_{2.5}$ is 12 to 35.5 $\mu g/m^3$.

The health effect statements of the AQI suggest that sensitive individuals with respiratory or heart disease, the elderly and children are the groups most at risk for health effects due to $PM_{2.5}$, and people with respiratory disease are the group most at risk for effects from PM_{10}. See Appendix A, Table A1, for the concentration range of each AQI category, the associated public health statements, and relevant CVs and measured concentrations.

ATSDR compares the annual average (or shorter durations in the absence of annual averages) to the WHO annual AQGs to screen PM_{10} and $PM_{2.5}$ and determine the potential for adverse health effects from long-term exposures.

Short-term Exposure to PM_{10}

PM_{10} measurements were collected at Site 7 for eight weeks during Fall 2014 and four days during Summer 2015. The maximum 24-hour concentration of PM_{10} fell into the *moderate* category using the AQI calculator (Table 4). According to the AQI calculator, at the maximum 24-hour concentration measured, sensitive individuals may want to consider reducing prolonged or heavy exertion. In all, the average PM_{10} 24-hour concentration fell into the *moderate* category three out of the 61 (4.9%) days of sampling.

Table 3. Percent and number of days that PM_{10} (24-hour average) falls into each category of EPA Air Quality Index, Yakama Nation Exposure Investigation, Harrah, WA

Sampling Event	Good <55 μg/m³ Percent (number of days)	Moderate ≥55 to ≤155 μg/m³ Percent (number of days)	Unhealthy for Sensitive Groups >155 to ≤255 μg/m³ Percent (number of days)	Unhealthy >255 to ≤354 μg/m³ Percent (number of days)
Fall 2014 (57)	94.7 (54)	5.3 (3)	0.00 (0)	0.00 (0)
Summer 2015 (4)	100.00 (4)	0.00 (0)	0.00 (0)	0.00 (0)
Total (61)	95.1 (58)	4.9 (3)	0.00 (0)	0.00 (0)

Source: [ERG 2016] (data); AQI Calculator website:
Notes: AQI – air quality index from EPA AirNow Calculator); EPA – U.S. Environmental Protection Agency; μg/m³ – micrograms per cubic meter; PM_{10} – particulate matter smaller than 10 microns

Thus, ATSDR does not expect that short-term exposures to PM_{10} would result in harmful health effects in the general population; however, some sensitive individuals (children and the elderly with advanced heart or lung disease) may experience respiratory effects and/or aggravation of heart or lung disease.

Short-term Exposure to $PM_{2.5}$

In general, concentrations of $PM_{2.5}$ were lower in Summer 2015 than in Fall 2014. Over an eight-week period, $PM_{2.5}$ hourly data were collected at six sites in Fall 2014 and eight sites in Summer 2015. Each site had at least one 24-hour average in the *moderate* category. In all, one of 721 (0.14%) 24-hour samples fell into the *very unhealthy* category, and 3 of 721 (0.42%) fell into the *unhealthy* category using the AQI calculator (Table 5). Each of these was measured in the fall event (measured at three sites on different days). An additional 27 days (3.7%) were categorized as *unhealthy for sensitive groups* by the AQI.

Table 4. The percent and number of days that $PM_{2.5}$ (24-hour average) falls into each category of the EPA Air Quality Index, Yakama Nation Exposure Investigation, Harrah, WA

Sampling Event	Good <12.1 μg/m³ Percent (Number of Days)	Moderate ≥12.1 to ≤35.5 μg/m³ Percent (Number of Days)	Unhealthy for Sensitive Groups >35.5 to ≤55.4 μg/m³ Percent (Number of Days)	Unhealthy >55.4 to ≤150.4 μg/m³ Percent (Number of Days)	Very Unhealthy >150.5 to ≤250.4 μg/m³ Percent (Number of Days)
Fall 2014 (312)	45.5 (142)	45.8 (143)	7.4 (23)	1.0 (3)	0.3(1)
Summer 2015 (409)	72.4 (296)	26.7 (109)	1.0 (4)	0.00 (0)	0.00(0)
Total (721)	60.7 (438)	35.0 (252)	3.7 (27)	0.42 (3)	0.1(1)

Source: [ERG 2016] (data); AQI Calculator website:
Notes: AQI – air quality index from EPA AirNow Calculator); EPA – U.S. Environmental Protection Agency; μg/m³ – micrograms per cubic meter; $PM_{2.5}$ – particulate matter smaller than 2.5 microns.

Concentrations of $PM_{2.5}$ in the *unhealthy for sensitive groups* category leads to increasing likelihood of respiratory symptoms in older adults, children, and people of lower socioeconomic status; aggravation of heart or lung disease; and premature mortality in people with heart or lung disease. People who fall into this category should reduce prolonged or heavy exertion [USEPA 2016].

In addition to the above effects, when concentrations reach the *unhealthy* category, there is an increase in the aggravation of heart or lung disease, and premature mortality in people with heart or lung disease, and an increase in respiratory effects in the general (healthy) population. On days categorized as unhealthy, sensitive individuals should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion.

On the days in the very unhealthy category, there will be a significant increase in the above health effects, and sensitive individuals should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.

Thus, ATSDR concludes that breathing air with the maximum daily concentrations of $PM_{2.5}$ in the Harrah area could harm people's health. status

Long-term Exposure to $PM_{2.5}$

ATSDR evaluates average $PM_{2.5}$ levels, not average PM_{10} levels, to determine the likelihood of non-cancer health effects from long-term exposures to particulate matter. There are no EPA standards for PM_{10} that apply to long-term exposures. Although ATSDR does not evaluate long-term exposure to PM_{10}, the combined average PM_{10} concentration was 19.84 $\mu g/m^3$, which is nearly equal to the annual WHO AQG. Furthermore, the annual average is likely lower, since PM_{10} concentrations were observed to be highest in the fall sampling period.

To assess long-term exposure, $PM_{2.5}$ data from both events were combined and averaged by site. In the Harrah area air, the mean concentrations of $PM_{2.5}$ at monitoring sites ranged from 14.20-21.69 $\mu g/m^3$ in Fall 2014 to 8.19-11.32 $\mu g/m^3$ in Summer 2015. The combined study $PM_{2.5}$ 24-hour average was 12.88 $\mu g/m^3$. During the fall sampling, $PM_{2.5}$ means at each site were above the annual NAAQS of 12 $\mu g/m^3$. During the summer sampling, none of the site means exceeded the annual NAAQS.

These separate two-month periods, either alone, or combined may not accurately represent the annual $PM_{2.5}$ concentrations in the Yakima area. The monitoring periods for the EI were chosen to coincide with the expected worst-case ambient concentrations of typical pollutants from large animal feeding operations. Thus, mean values calculated from our four months of data may be overstating the actual annual mean. ATSDR also notes that sampling periods (up to eight weeks) are much shorter than those generally used to estimate chronic exposure (greater than a year), and the risks of health effects from long-term exposures are not clear.

Based on the different findings in the two sampling events ATSDR finds that $PM_{2.5}$ concentrations can fluctuate day-to-day, seasonally, and by site. These fluctuations could not be consistently linked to any site, source, or wind direction. The average concentrations measured in the Harrah area are above the AQI cutoff for moderate air quality and at the lower end of those likely to cause adverse effects. People with respiratory or heart disease, the elderly and children, are most at risk for health effects from long-term exposure to $PM_{2.5}$ in the Harrah area.

Cancer risk

Because of the varying composition of PM, a chemical-specific cancer risk cannot be calculated for PM as a whole.

Comparison to $PM_{2.5}$ Data from Nearby Air Monitors

In order to compare the measured concentrations of $PM_{2.5}$ in Harrah, ATSDR also reviewed background data from the three air monitors in the area [WSDE 2018]. Those monitors were:

1. 4th St. monitor located in the city of Yakama roughly 12 miles NE of Harrah;
2. Toppenish High School monitor located roughly 10 miles east of Harrah; and
3. White Swan Reservation monitor located roughly 8 miles west of Harrah.

ATSDR reviews background data to put the concentrations measured in this EI in perspective, not to determine if they are likely to cause adverse health effects. Only data from the air monitor at White Swan Reservation was available for the same dates as the EI. The data from the 4th St. and Toppenish monitors coinciding with the dates of the EI were not available until 2015 and 2016 respectively. In Harrah, higher $PM_{2.5}$ values were measured during the fall, which was not consistent across the background sites (Only the 4th St. monitor had a higher mean in the fall than the summer). Overall, the mean $PM_{2.5}$ concentration in Harrah during the fall sampling event was higher than any of the fall or summer means at the background sites. When comparing the combined sampling averages from both fall and summer sampling to annual background averages, Harrah was above the background values at the 4th St and White Swan monitors but below that at Toppenish.

Table 5. Comparison of 24-hour and Annual Background $PM_{2.5}$ Data to Measured Concentrations in Harrah ($\mu g/m^3$).

Measurement	Harrah[a]	4th St [b]	Toppenish [c]	White Swan
Fall				
Mean 24-hr	16.20	12.7	12.9	9.9
Max 24-hr	153.56	41	47.9	37.4
Summer				
Mean 24-hr	10.34	4.9	13.7	9.3
Max 24-hr	47.22	14.5	61.9	35.8
Annual[d]				
Mean 24-hr	12.88	8.6	13.6	6.8
Max 24-hr	153.36	63.9	184	62

Source: [WSDE 2018]

[a] The annual values reported for Harrah are the combined 24-hr average from the fall and summer sampling events.

[b] $PM_{2.5}$ data was not available for the duration of the EI, data from the same dates in Fall 2015 and summer 2016 are presented

[c] $PM_{2.5}$ data was not available for the duration of the EI, data from the same dates in Fall 2016 and summer 2017 are presented

[d] Annual data from Harrah are from the dates of the EI, where annual values from other sites cover an entire year (365 days) from the start date of the Fall sampling event in the corresponding year of available data.

Ammonia

Ammonia is a colorless gas with a very sharp odor. The odor of ammonia is familiar to most people because ammonia is used in smelling salts and household cleaning products. Ammonia concentrations around AFOs are often elevated as ammonia is produced from the breakdown of manure which is then used as a fertilizer [ATSDR 2004].

Ammonia has an odor threshold of around 2,600 ppb, but its threshold of irritation is roughly 50,000 ppb [Smeets et al. 2007]. Thus, a person can smell ammonia before they are exposed to a concentration that may be harmful. Levels of ammonia in air that cause serious effects in people are much higher than levels people are normally exposed to at home or work. However, exposure to low levels of ammonia may irritate people with asthma and other sensitive individuals [ATSDR 2004].

ATSDR has acute and chronic minimal risk levels (MRL) for ammonia (1,700 ppb and 100 ppb, respectively), and EPA has a reference concentration (RfC) of 720 ppb. Washington Department of Ecology's Air Quality Program has a 24-hr acceptable source impact level (ASIL) value of 100 ppb adopted from the ATSDR chronic MRL. Ammonia has not been classified as a carcinogen by the International Agency for Research on Cancer (IARC) or EPA. In addition, none of the studies in the ATSDR toxicological assessment have documented any link to cancer and ammonia exposures. Thus, the following discussion will only include the potential for non-cancer health effects due to exposure to ammonia in air.

Short-term Exposures to Ammonia

To determine if ammonia levels in air posed an acute health risk, the ATSDR EI evaluated minute and hourly CRDS, daily ADS, and daily and weekly passive RAM averages for each site. Summary statistics tables can be found in Appendix C. Of the 121,006 one-minute samples, only two samples were above the ATSDR MRL of 1,700 ppb (both occurring at Site 4, once in each sampling event). Ammonia levels at Site 4 reached 1,732 ppb in Fall 2014 and 1,718 ppb in Summer 2015. In addition, Site 4 had the highest mean during both sampling events. None of the hourly CRDS, daily ADS, or weekly RAM averages exceeded the MRL.

The ATSDR's acute CV of 1,700 ppb is based on a study on college students that found a lowest observable adverse effect level (LOAEL) of 50,000 ppb for throat and eye irritation after 30 minutes of exposure [ASTDR 2004]. The MRL was derived by dividing the LOAEL of 50,000 ppb by an uncertainty factor of 30 (10 for variation in sensitivity among humans and 3 for use of a minimal LOAEL). During both sampling events only two 1-min samples were slightly above the CV. These levels occurred over a short time period and are more than an order of magnitude lower than effect levels documented in humans at 50,000 ppb [ATSDR 2004]. When averaged over 30 minutes for comparison to the study on which the CV was derived, the highest concentration was below the acute CV and orders of magnitude below any documented effect level in humans. Therefore, ATSDR does not expect adverse health effects are likely to occur from short-term exposures to ammonia.

One previous study in the Yakima area (discussed in the background section), measured 24- hour ammonia concentrations at AFOs west and southwest of Harrah in the range of (0.29-342 ppb)

[Loftus et al. 2015]. The sampling area in this study was closer to the highway, roughly 10-12 miles east of Harrah, and had a higher number of AFOs. For comparison, ATSDR calculated 24-hour ammonia averages from the one-minute CRDS samples (range 3.35-179.86 ppb). ADS 24-hour samples and RAM one- and two-week samples were also within this range. Both the Loftus study and ATSDR EI observed higher concentrations of ammonia during the Fall when compared to the summer and the range for 24-hour samples were similar. The Loftus study observed the potential for decreased respiratory function in sensitive asthmatics at concentrations similar to those measured in Harrah.

Long-term exposures to Ammonia

In order to assess the potential for adverse health effects from long-term exposure, ATSDR compared the average of the samples from each sampling event to ATSDR's chronic EMEG of 100 ppb. None of the CRDS, RAM, or ADS sampling event averages exceed the ATSDR EMEG/MRL of 100 ppb. Thus, ATSDR does not expect adverse health effects are likely to occur from long-term exposures to ammonia.

Effects Related to Ammonia Odors

The highest one-minute measured value during this EI was 1732 ppb, which is below the average odor threshold of 2,600 ppb [Smeets et al. 2007]. Therefore, most individuals will not smell ammonia in Harrah at the measured concentrations. ATSDR does note that although average odor detection thresholds have been documented as low as 2,600 ppb, sensitive individuals may detect the odor at lower concentrations. Thresholds of odor related irritation (roughly 30,000-60,0000 ppb) have been documented at concentrations more than 10,000 higher than those measured in this EI [Smeets et. al. 2007]. This means that the ammonia concentrations measured in the Harrah area are unlikely to cause odors and are below levels shown to cause adverse health effects. See Appendix E for a more detailed discussion of odor related effects.

Hydrogen Sulfide

Hydrogen sulfide is a gas released from both natural and manufactured sources and known for its rotten egg odor. Some industrial sources include sewage treatment facilities, manure-handling operations, pulp and paper mills, petroleum refineries, and food processing plants [ATSDR 2006]. Steel mills and cement manufacturing facilities can have operations (e.g., wastewater treatment) known to release hydrogen sulfide gases. Ambient air concentrations of hydrogen sulfide from natural sources are estimated in the range of 0.11–0.33 ppb, while concentrations in urban areas are often greater than 1 ppb [ATSDR 2006]. These ambient concentrations have no documented health effects. ATSDR has an acute EMEG/MRL of 70 ppb and an intermediate EMEG/MRL of 20 ppb. The EPA RfC for hydrogen sulfide is 1.4 ppb. Washington Department of Ecology's Air Quality Program has a 24-hr ASIL value of 1.4 ppb adopted from the USEPA RfC. Hydrogen sulfide has not been shown to cause cancer in humans and is not currently classified as a carcinogen [ATSDR 2006]. The EPA, in its most recent cancer assessment, determined that available data are inadequate to assess the carcinogenic potential of hydrogen sulfide [USEPA 2003].

ATSDR bases its acute hydrogen sulfide EMEG/MRL on health effects (i.e., headache and changes in respiratory tests suggesting bronchial obstruction) reported in some persons with asthma exposed to 2,000 ppb for 30 minutes [Jappinen et al. 1990]. ATSDR based its intermediate CV on a separate, subchronic study on rats (exposed for 6 hours /day, 7 days/week, for 10 weeks) that found a no observed adverse effect level (NOAEL) of 10,000 ppb for cellular changes in the nasal factory epithelium (the skin lining the nasal passages) [Brenneman et al. 2000].

Short-term Exposures to Hydrogen Sulfide

In the Harrah area, 209 out of 1,210,590 (0.017%), stationary 1-minute[4] measurements exceeded the 70 ppb. These exceedances were limited to three stationary air monitoring locations (Sites 2, 5, and 9), all during the Summer 2015 sampling period (0.03% of Summer 2015 samples, occurring over 11 days). The maximum 1-minute hydrogen sulfide concentrations measured at sites 2 and 5 were 89.92 ppb, and the maximum concentration at site 9 was 90.00 ppb. However, the hydrogen sulfide monitors used during the Fall 2014 and Summer 2015 sampling events had an upper reporting limit of 90 ppb. Therefore, it is possible that the actual 1-minute concentrations of H_2S could have been higher than the measured values.

Additionally, thirty-minute averages were calculated for comparison to the critical study which was used as the basis for the acute MRL. None of the 30-min averages exceeded the acute MRL. Thus, ATSDR does not expect that short-term exposure to hydrogen sulfide concentrations in the Harrah area air is likely cause harmful noncancer health effects.

Daily averages were also calculated. The highest daily average during Fall 2014 was 3.59 ppb at site 7, and the highest average during Summer 2015 was 12.87 ppb at site 9, which are well below the acute and intermediate EMEGs, thus these highest daily averages lasting between 1 to 364 days would not be expected to cause adverse effects.

Long-term Exposures to Hydrogen Sulfide

ATSDR has no chronic CV for hydrogen sulfide. ATSDR uses the EPA RfC which is based on the same study as the ATSDR intermediate CV [Brenneman et al. 2000].

Overall, hydrogen sulfide was detected in 45.6% of the samples. The means at 3 locations (Fall 2014: 1.46 ppb at site 4; Summer 2015: 1.57 ppb at Site 2 and 1.45 ppb at Site 9) were above but similar to the EPA RfC, which is considered protective against health effects from long-term exposures. No other mean concentrations exceeded the RfC. Because the highest mean is very close to the RfC and about three orders of magnitude below the lowest documented health effect levels, ATSDR does not expect that long-term exposure to hydrogen sulfide in air of the Harrah area likely to result in harmful non-cancer health effects.

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[4] This discussion on 1-minute H_2S concentrations is presented for completeness. The measurement frequency for collecting H_2S measurements was once per minute. However, the length of sampling time required for a measurement to be completed varied from 3-7 minutes. Therefore, 30-minutes averages are more representative of actual concentrations. See page B-25 of the field report for more information on H_2S measurements.

Odor Effects of Hydrogen Sulfide

Hydrogen sulfide was the only chemical detected above its odor threshold. Community concern about recurring odors throughout the Harrah area are likely associated with hydrogen sulfide in the ambient air. There are numerous studies associating hydrogen sulfide odors and health symptoms such as increased stress, headache, and nausea [ATSDR 2016]. These symptoms usually subside when the odor is gone.

ATSDR notes that when hydrogen sulfide exceeds its odor threshold (0.5 ppb) [ATSDR 2016], people who live and work near the Yakima feedlots may experience odor-related health symptoms. All stationary air monitors measured hydrogen sulfide above odor thresholds. In all 44% of the samples were greater than or equal to the odor threshold of 0.5 ppb (60% of Fall 2014 and 30% in Summer 2015.) Furthermore, during both sampling events the average concentration at every site was above the odor threshold, which means that individuals are likely to smell odors in the Harrah area, but are not likely to experience acute health effects. Sensitive individuals in the area may experience odor-related health symptoms such as headaches, nausea, and stress or annoyance when hydrogen sulfide and other gases exceeds their odor threshold. See Appendix E for a more detailed discussion of odor related effects.

Analysis of Health Outcome Data

As part of the public health evaluation process, ATSDR reviewed available, relevant health outcome data for indications of increased illness in the Yakima area. ATSDR specifically tried to identify potential health issues in Yakima that could be related to the measured $PM_{2.5}$ (which showed the potential to exceed regulatory values). According to the EPA's Integrated Science Assessment for Particulate Matter [USEPA 2009], short and long-term exposure to $PM_{2.5}$ has been determined to have a causal relationship to cardiovascular effects and mortality, and a likely causal relationship with respiratory effects.

ATSDR analyzed health outcome data from the Washington State Department of Health's Washington Tracking Network (WTN). Although these data can give us an overall understanding of the health status in the community, they cannot provide any information on the cause of the health outcomes. The health outcomes related to $PM_{2.5}$ exposures (mortality, respiratory effects and cardiovascular effects) are associated with various other factors that can occur over a person's lifetime, and ATSDR cannot determine if $PM_{2.5}$ was the cause any specific health outcome.

The WTN is a public website, developed by the Washington State Department of Health, where users can find data and information about environmental health hazards, population characteristics, and health outcomes. Health statistics were obtained from the WTN for Yakima County as well as some more site-specific statistics for the zip code 98933 and Census track 53077940001, all of which contain the town of Harrah. WTN maintains statistics on asthma hospitalizations and mortality from cardiovascular disease, which are both associated with PM (asthma hospitalizations can also be associated with environmental odors). Asthma hospitalizations were available by county and zip code; measurements of cardiovascular mortality were available by county and census tract. To protect patient confidentiality, The WTN only offers the zip code and census tract statistics in five-year intervals. All data from the WTN adjusted for age but not for race or socioeconomic status.

Asthma Hospitalizations

The asthma rates in WTN are collected from hospital discharge data [WDOH 2018].[5] Figure 3 shows rates of asthma in Harrah, Yakima County, and Washington. Using a measure of all hospitalizations includes some transfers between hospitals for the same individual for the same event. Hospitalization data are based on events not people. An individual hospitalized more than once will be counted more than once, even if hospitalized for the same condition. In addition, admission and subsequent discharge from a hospital may suggest a complication or aggravation of the underlying chronic condition and cannot be used to determine the prevalence of the disease in the community. Hospital admissions for asthma may reflect issues related to access to care, compliance, appropriate treatment plan, uncontrollable exposure to triggers, or other factors.

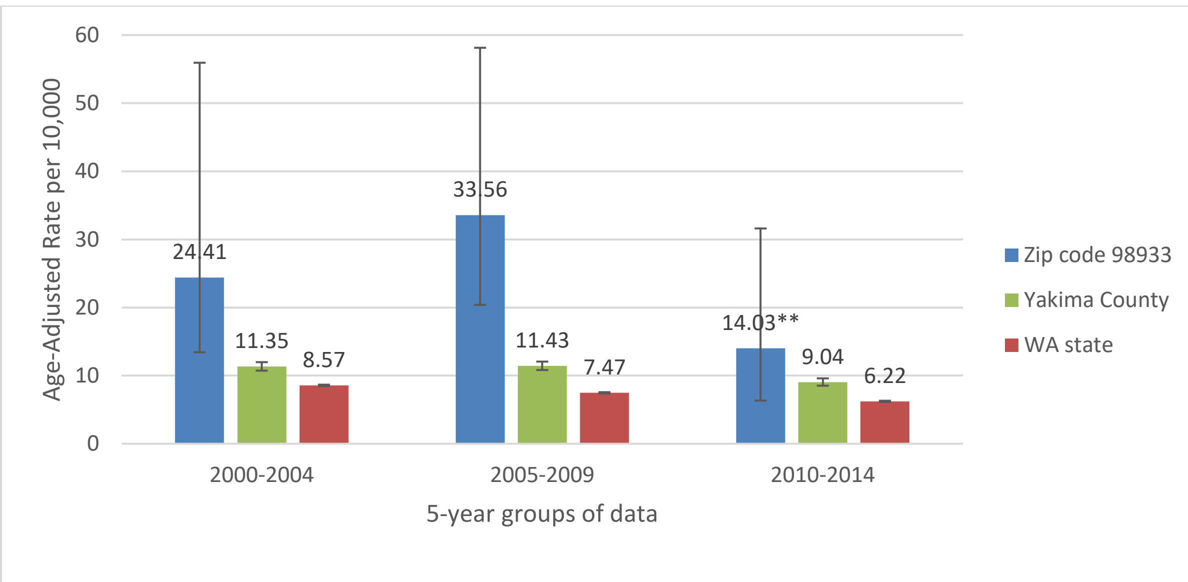

Figure 5. Asthma hospitalizations from 2000 to 2014 by Zip Code, Yakima County, and Washington State*

Source: Washington State Department of Health [WDOH 2018]
***** Washington Tracking Network collects asthma rates from hospital discharge data. Rates adjusted for age but not for race. Hospitalization data based on events not people. Rates may include transfers between hospitals for the same individual for the same event; an individual hospitalized more than once will be counted more than once, even if hospitalized for the same condition.
** Because of the low incidence in the smaller population, Washington Tracking Network designated the most recent 5-year estimate (2010-2014) for this zip code is listed as not reliable. All other elevations of Asthma hospitalizations for zip code 98933 were statistically significant.

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[5] The Washington Tracking network states [WDOH 2018] "The Tracking Network Nationally Consistent Data Measures define "asthma hospitalization" as resident hospitalizations for asthma which are coded to ICD-9-CM code 493.XX in the primary (first listed) discharge diagnosis field. Acute exacerbations of asthma (asthma attacks) most commonly present to hospital emergency departments (ED). Relatively few ED visits for asthma result in an inpatient hospital admission, and therefore asthma hospitalization data do not provide a complete picture of the burden of severe or unmanaged asthma cases among Washington residents. There is no statewide database of ED visits in Washington."

From 2000-2014, the zip code containing Harrah (98933) consistently had a higher age-adjusted rate of asthma hospitalizations than Yakima County, which was higher than that of Washington State as a whole. The elevated hospitalization rate occurred in every age group between 5 and 65 (ages 5-14, 15-34, and 35-64). For the youngest (0-4) and oldest (65+) groups the incidence of hospitalization due to asthma was not significantly different from the state average.

All the elevated rates between zip code, county and state were statistically significant except the most recent 5-year estimate (2010-2014) for the zip code, which is listed as not reliable (see Figure 4). The low incidence of asthma in this smaller population results in more uncertainty, and while the numbers of hospitalizations were elevated when compared to the county and state, they were not elevated to a level of statistical significance.

Mortality from Cardiovascular Disease

For Yakima County, in data collected from 2000-2014, mortality from cardiovascular disease was significantly higher than that of Washington State as a whole. The census track data is only available in five-year increments, thus we looked at the grouped data from 2000-2004, 2005-2009, and 2010-2014. Although this health outcome analysis helps to determine if your community has an increase in mortalities associated with the measured contaminants, it cannot determine if the measured contaminants caused the mortality because the health outcomes related to PM (mortality, respiratory effects and cardiovascular effects) are associated with a number of factors other than the concentration of PM.

For the measures of mortality, the WTN includes an Information by Location (IBL) ranking. The IBL is a mapping tool that provides information about communities using relative rankings. The IBL compares each census tract with others in the state by presenting a community's rank between 1 (lowest) and 10 (highest). Each number represents 10% of the communities. For example, if your community is ranked a 7 for health disparities, it means that 60% of the communities in Washington State have a lower level of health disparity and 30% have a greater level of disparity. The IBLs for mortality from cardiovascular disease for the census tract containing Harrah are shown in Figure 4. [WDOH 2018].

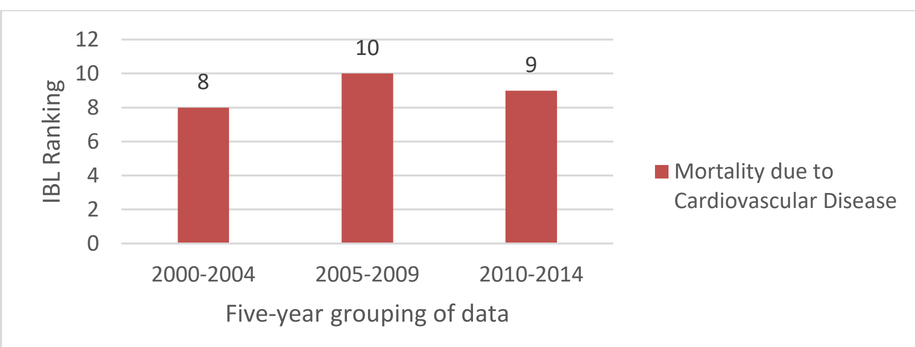

Figure 6. Information by location (IBL) rankings for Mortality by Cardiovascular Disease in the Census Tract containing Harrah (53077940001)

Source: Washington State Department of Health [WDOH 2018]

The mortality due to cardiovascular disease was significantly higher in this census tract than that of the state. The deaths by cardiovascular disease over five years per 100,000 had an IBL ranking of 8, 10, and 9 for each of the three groups (2000-2004, 2005-2009, and 2010-2014) respectively. This means that in the past up to the most recent data, this census tract has ranged between the highest thirty to ten percent in the state for deaths due to cardiovascular disease.

Child Health Considerations

Community members in Harrah expressed concerns to ATSDR regarding the proximity of some AFOs to nearby schools. To address those concerns, ATSDR installed sampling and monitoring equipment near Harrah Elementary School (Site 5).[6] Ammonia, hydrogen sulfide, and $PM_{2.5}$ were measured at Site 5 during the Fall 2014 and Summer 2015 sampling. Measured concentrations at Site 5 were close to that of other monitors. Data from Site 5 show the following:

> Ammonia- None of the 346 30-min samples exceeded the acute CV for ammonia (1700 ppb), and none of the 24-hour samples exceeded the chronic CV (100 ppb). The Site 5 mean 24-hour ammonia concentration for the entire EI was below the chronic CV, thus ammonia concentrations measured near Harrah Elementary School should not cause adverse health effects;
>
> Hydrogen Sulfide- Seventeen of 100 (17%) 24-hour samples exceeded the reference chronic CV for hydrogen sulfide (1.4 ppb), but none exceeded the intermediate (20 ppb) or acute (70) CVs. The concentration at site 5 averaged over the entire EI was also below the chronic CV. Sixty-four of 100 (64%) hydrogen sulfide 24-hour samples exceeded the odor threshold, which means on most days during the EI, individuals near Harrah Elementary School would likely smell rotten-egg like odors during some part of the day. Sensitive individuals in the area may experience odor-related health symptoms such as headaches, nausea, and stress or annoyance when hydrogen sulfide and other gases exceeds their odor threshold;
>
> $PM_{2.5}$- Forty-seven of the 84 (56%) days sampled at Harrah elementary School fall into the good AQI category; 33 of 84 (39%) fall into the moderate AQI category; and 4 of 83 (5%) are categorized as unhealthy for sensitive individuals. See Appendix A, Table A1, for the concentration range of each category and the associated public health statements; and
>
> The mean for the entire EI was 12.88 µg/m^3, which suggest that there is a potential for sensitive individuals to have health effects from $PM_{2.5}$. Daily exposure to the mean concentration of $PM_{2.5}$ may require some sensitive individuals to reduce prolonged or heavy exertion; the health of other individuals should not be affected. On days when $PM_{2.5}$ is above the NAAQS (12 µg/m^3), there is an increasing likelihood of respiratory symptoms in older adults, children, and people of lower socioeconomic status; aggravation of heart or

[6] ATSDR contacted the Harrah Community Christian School for permission to locate air monitors on the school campus. However, school officials declined to allow access to school property.

lung disease; and premature mortality in people with heart or lung disease. People who fall into this category should reduce prolonged or heavy exertion [USEPA 2016].

Because of their size, physiology, behavior, and activity level, the inhalation rates of children differ from those of adults. Factors that might contribute to enhanced lung deposition in children include higher ventilation rates, less contribution from nasal breathing, less efficient uptake of particles in the nasal airways, and greater deposition efficiency of particle and some vapor phase chemicals in the lower respiratory tract. In addition, children spend 3 times as much time outdoors as adults and engage in three times as much time playing sports and other vigorous activities [USEPA 2011b]. Based on these parameters, children are more likely to be exposed to more outdoor air pollution than adults. Further, a child's lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight.

While, it is not clear that children are more toxicologically sensitive to the specific exposures of hydrogen sulfide and ammonia, they are likely more vulnerable due to their increased exposure. In terms of PM, children (and the elderly) have increased susceptibility to PM-related respiratory effects, and the health effects observed in children could be initiated by pre and/or postnatal exposures to PM [USEPA 2009].

Limitations of the Exposure Investigation

ATSDR acknowledges that the Yakama Nation EI, like all field measuring programs, has some limitations. These include:

- Monitoring/sampling was conducted at fixed, stationary locations; however, people move around, and do not remain in one place all day long. Therefore, the data collected at the fixed locations are not directly equivalent to actual exposures that may have occurred;

- The data collected during this program represent air quality conditions from October 23, 2014, to December 18, 2014 (Fall 2014 EI event), and from June 22, 2015, to August 19, 2015 (Summer 2015 EI event). Since an EI is not intended to be a long-term study, ATSDR attempted to sample during the worst conditions (either when seasonal weather or AFO activities suggests higher concentrations of contaminants), utilizing four months of data to represent community exposures throughout the year. While this sampling strategy may result in elevated annual estimates, those predicted in this EI are within the range of annual concentrations measured at air monitoring sites surrounding Harrah;

- ATSDR conducted two separate 8-week EIs. While many of the parameters and sites were consistent between the fall and summer sampling events, sampling constrains resulted in some differences between site locations and parameters measured at certain sites that limit comparisons between the two sampling events. For example, not every contaminant was sampled at every site and some sites measured more samples than at other sites. PM_{10} was only measured for 3 days in the Summer 2015 sampling;

- ATSDR was aware of other densely AFO-concentrated areas in the Yakima Valley. However, given the large geographical area in the Yakima Valley and that the request to

ATSDR was to evaluate air quality and related health impacts on the Yakama Reservation, ATSDR focused its exposure investigation near Harrah on the Reservation;

- Although ATSDR compared the measured concentrations to wind speed and direction, no clear source could be identified for any of the measured contaminants;

- Although health outcome data can give us an overall understanding of the health status in the community, they cannot provide any information on the cause of the health outcome because the health outcomes related to PM (mortality, respiratory effects and cardiovascular effects) are associated with a number of factors other than the concentration of PM; and

- Wildfires can increase $PM_{2.5}$ concentrations. While the census track 53077940001 (containing the town of Harrah and part of Yakima County) did not report any wildfires from 2000-2015, the census track 53077940003, which borders to the south and west has documented some wildfires. This neighboring county is much larger in square miles and the true proximity of wildfires to our Harrah sampling area, and their influence on measured concentrations of $PM_{2.5}$ cannot be determined.

Conclusions

ATSDR prepared this health consultation as an in-depth public health evaluation of the pollutant concentrations of particulate matter, ammonia, and hydrogen sulfide measured during the EI. After a careful evaluation of the measured pollutant concentrations, ATSDR has come to the following conclusions relative to the populations in or near Harrah WA:

Conclusion 1. ATSDR concludes that daily exposures to air with the <u>maximum</u> concentrations of $PM_{2.5}$ at each sampling location in the Harrah area, could harm people's health. Sensitive individuals with asthma or previous respiratory conditions are most at risk.

Basis for Conclusion 1. ATSDR does not have a comparison value for particulate matter. Short-term $PM_{2.5}$ samples were evaluated using the hazard categories from EPA's AQI – good, moderate, unhealthy for sensitive people, unhealthy, very unhealthy, and hazardous. The highest measured twenty-four (24)-hour average concentration falls into the *very unhealthy* AQI category. This condition occurred at one site on one day during the fall sampling. Additionally, 3 of the 721 days (0.4% collected at two sites on three different days) during the fall sampling were categorized as unhealthy, and 27 of 721 (4%) were categorized as *unhealthy for sensitive groups* (23 of which occurred during the fall sampling event). According to the AQI, when $PM_{2.5}$ is in the *unhealthy for sensitive groups'* category, there is an increased likelihood of aggravation of respiratory symptoms and aggravation of heart or lung disease and premature mortality in sensitive individuals. These sensitive groups include older adults, children, and people with heart or lung disease. When $PM_{2.5}$ is in the *unhealthy* and *very unhealthy* categories, respiratory effects are also expected in the general population and there is a significant increase in aggravation of heart or lung disease and premature mortality in people with heart or lung disease.

Conclusion 2. ATSDR cannot currently conclude that breathing the <u>average</u> concentrations of $PM_{2.5}$ in the Harrah area could harm people's health. The short sampling duration of this EI (16 weeks), cannot be used to accurately evaluate health effects from long-term (chronic)

exposures, which are defined as having an exposure duration of one year or longer. However, if the measured concentrations during this EI represent chronic conditions in the Harrah area, long-term exposure to the average $PM_{2.5}$ concentrations at each sampling location could harm people's health.

Basis for Conclusion 2. To assess long-term exposure, data from both fall and summer sampling events were combined and averaged by site. The combined study $PM_{2.5}$ 24-hour average was 12.88 µg/m^3, which shows there is a potential to be above the WHO AQG annual average (10 µg/m^3) and the primary NAAQS annual average (12 µg/m^3).[7] The measured concentrations in the fall sampling event (mean 16.20 µg/m3) were higher than the summer sampling event (mean 10.34 µg/m3). Site averages only exceed the NAAQS during the fall sampling event.

Long-term exposure above the annual NAAQS has been determined to worsen cardiopulmonary and respiratory diseases in people with pre-existing health conditions and can increase the risk of dying from these diseases. Further, there is evidence that long-term exposure to elevated $PM_{2.5}$ can also cause the development of cardiopulmonary diseases. The epidemiological and toxicological evidence suggests that long-term exposures to $PM_{2.5}$ negatively impacts reproductive and developmental outcomes (specifically low birth weight and infant mortality, related to respiratory causes during the post-neonatal period).

Conclusion 3. ATSDR concludes that breathing PM_{10} in the Harrah area is not expected to harm the general population. However, breathing the highest concentrations measured in the Harrah area may cause respiratory effects in some sensitive individuals.

Basis for Conclusion 3. PM_{10} was only measured at one site. Only 5% (3 of 61) of the 24-hour averages for PM_{10} were in the *moderate* AQI category. Health effects caused by PM_{10} are similar to but less clearly defined than exposure to $PM_{2.5}$. The remaining 58 days were in the *good* AQI category and appear to pose little to no risk. According to the AQI, on *moderate* days, respiratory symptoms may occur in some sensitive individuals (People with heart or lung disease, older adults, children, and people of lower socioeconomic status), as well as possible aggravation of heart or lung disease in people with cardiopulmonary disease and in older adults. On *moderate* days, unusually sensitive people should consider reducing prolonged or heavy exertion.

Conclusion 4. ATSDR concludes that breathing ammonia in the Harrah area is not expected to harm people's health.

Basis for Conclusion 4. Thirty-minute averages were calculated for comparison to the 30-minute exposure duration in the critical study, which was used as the basis for the acute CV. The highest 30-minute concentration at any EI site was 907.2 parts per billion (ppb), which is below ATSDR's acute CV.

Although sampling periods (up to six weeks) were much shorter than those generally used to estimate chronic exposure (greater than a year), daily averages were used to calculate the mean over the entire sampling period and estimate the risk of adverse effects from long-term exposure to

[7] ATSDR used the nominal value of the NAAQS to screen the average $PM_{2.5}$ data over the entire EI and did not apply the EPA statistical approach for NAAQS attainment.

ammonia in air. None of the site averages in either sampling period or the combined sampling average exceeded the chronic CV. Therefore, ATSDR does not expect adverse health effects to occur from short or long-term exposures to ammonia.

Conclusion 5. ATSDR concludes that breathing hydrogen sulfide in the Harrah area is not expected to harm people's health.

Basis for Conclusion 5. Thirty-minute averages were calculated for comparison to the 30-minute exposure duration described in the toxicological study used to derive the acute CV. None of the 30-minute averages from any site exceeded the acute CV. Thus, ATSDR concludes short-term exposures to hydrogen sulfide concentrations in the Harrah area are not likely to cause adverse health effects.

Overall, hydrogen sulfide was detected in 45.6% of the samples. The average of the 24- hour values at three locations (ranging from 1.50 to 1.61 ppb) were above but similar to the chronic CV (1.4 ppb), which is considered protective of health effects from long-term exposure. These concentrations are well below levels observed to cause physical changes in the body, even in exercising asthmatics. Therefore, ATSDR does not expect long-term exposure to hydrogen sulfide concentrations in the Harrah area air to cause adverse health effects.

Conclusion 6. ATSDR concludes that the odors in the Harrah area are not expected to harm the general population, however, sensitive individuals may experience odor related symptoms such as headache and nausea and stress or annoyance when hydrogen sulfide and other gases exceeds their odor threshold.

Basis for Conclusion 6. ATSDR recognizes that community members are concerned about environmental odors in the area and whether they could lead to adverse health effects. ATSDR notes that people may experience odor-related health effects below irritant effect levels. In general, most substances that cause odors in the outdoor air are not at levels that can cause serious injury, long-term health effects, or death. However, odors may lead to odor related health effects, affect people's quality of life, and sense of well-being.

Some individuals can smell hydrogen sulfide at concentrations below its CVs. The odor threshold of the most sensitive people exposed to hydrogen sulfide in scientific studies (0.5 ppb) was exceeded during both sampling events at all sites. In all 44% of the samples were greater than or equal to the odor threshold of 0.5 ppb (60% of Fall 2014 and 30% in Summer 2015). When concentrations are above the odor threshold, but below health effect guidelines, individuals can smell odors in these areas, but are not likely to experience serious adverse health effects. Individuals vary in their response to unpleasant environmental odors. Sensitive individuals may endure odor related symptoms such as headache, nausea, and stress, which can affect people's sense of wellbeing and reduce their quality of life.

While ammonia is also often related to odors in areas with AFOs, it was not measured above its odor threshold during this EI. Both hydrogen sulfide and ammonia can also be incorporated into PM in the area; however, the concentration of the contaminants in the measured PM are unknown, and the contribution of PM to odors in the area cannot be determined.

Conclusion 7. ATSDR concludes that data from 2000-2014 show, the Harrah area had elevated rates of asthma hospitalizations and mortality from cardiovascular disease compared to the State of Washington as a whole. These health outcomes associated with PM2.5 are also associated with various other factors that can occur over a person's lifetime, and ATSDR cannot determine if PM2.5 was the cause of any specific health outcome.

Basis for Conclusion 7. As part of the public health evaluation process, ATSDR tried to identify potential health issues in Harrah that could be related to the measured $PM_{2.5}$ (which showed the potential to exceed regulatory values) or environmental odors. According to the EPA's Integrated Science Assessment for Particulate Matter [USEPA 2009], short and long-term exposure to $PM_{2.5}$ has been determined to have a causal relationship to cardiovascular effects and mortality, and a likely causal relationship with respiratory effects.

ATSDR analyzed health outcome data from the Washington State Department of Health's Washington Tracking Network (WTN) from 2000-2014. From the available data from the WTN, asthma hospitalizations for the zip code containing Harrah were consistently higher than that of Yakima County and the State of Washington as a whole. Mortality from cardiovascular disease was significantly higher in the census tract containing Harrah than that of Washington State during the same time period 2000-2014. Although these data can give us an overall understanding of the health status in the community, they cannot provide any information on the cause of the health outcomes because there are a number of factors associated with health outcomes (mortality, respiratory effects and cardiovascular effects) related to PM exposures, and this health outcome data cannot demonstrate cause and effect.

Recommendations

The EPA and the Yakama Nation may want to consider long-term efforts to reduce and monitor $PM_{2.5}$ in Harrah and other areas on the Reservation that may have elevated concentrations of $PM_{2.5}$.

The EPA, Washington Department of Ecology, the Yakima Regional Clean Air Agency, and the Yakama Nation may want to consider implementing measures to reduce odors related to animal feeding operations that impact community members and residents on the Yakama Reservation.

Public Health Action Plan

In order to facilitate the above Recommendations ATSDR will do the following:

- ATSDR will provide a copy of this report to the Yakama Reservation, the EPA, EI Participants, and other community members as requested;
- ATSDR will meet individually with EI participants to discuss the information provided in this report and to specifically discuss the data collected on their respective properties;
- ATSDR will meet with interested stakeholders to discuss the information provided in this report; and

- If requested, ATSDR will work with the EPA and the Yakama Nation to consider options to reduce exposures in the Harrah area.

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Appendix A. Description of Comparison Values Used for Screening

The purpose of this appendix is to provide information about the CVs used for screening purposes in the Yakama Valley EI. For further information on ATSDR's public health evaluation process and comparison values, please refer to the ATSDR guidance manual available at http://www.atsdr.cdc.gov/hac/PHAManual/toc.html [ATSDR2005].

CVs are intended to protect the public from adverse health effects for specific durations of exposure. They are used to screen out contaminants that are measured at concentrations that are generally safe (below the CV). A concentration above the CV does not necessarily mean that an adverse effect will occur, but it is an indication that the specific contaminant should be further investigated and compared to the health effects and doses documented in scientific literature.

The Agency for Toxic Substances and Disease Registry (ATSDR) has developed health and environmental guidelines to use as CVs when conducting the screening analysis and evaluating exposures to substances found at sites under investigation. In addition to CVs derived by ATSDR, other federal and some state agencies have developed similar types of health-based guidelines for concentrations of substances in water, soil, air, and food. ATSDR staff may use these comparison values, when appropriate, to screen substances detected in various site media.

This appendix provides a description of comparison values (CV) available from ATSDR, as well as other sources, that were used to screen the Yakama Valley air data. Non-ATSDR comparison values discussed in this appendix are Washington Department of Ecology's Acceptable Source Impact Levels (ASILs), EPA reference concentrations (RfCs), EPA National Ambient Air Quality Standards NAAQS, and WHO air quality guidelines (AQGs). The EPA Air Quality Index Calculator was also used for the health assessment of PM concentration and is discussed below. All these CVs except the NAAQS are non-enforceable health-based guidelines used for screening contaminants. For each guideline discussed, a definition and description of the derivation and applicability or intended use are provided. When available, a website reference is also provided.

ATSDR Minimal Risk Levels (MRLs)

ATSDR's minimal risk levels (MRLs) are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. MRLs are based only on non-carcinogenic effects. MRLs are screening values only and are not indicators of health effects. Exposures to substances at doses above MRLs will not necessarily cause adverse health effects and should be further evaluated.

ATSDR derives MRLs when reliable and sufficient data can identify the target organ(s) of effect or the most sensitive health effects(s) for a specific duration for a given route of exposure. MRLs are set below levels that might cause adverse health effects in most people, including sensitive populations. MRLs are derived for acute (1–14 days), intermediate (15–364 days), and chronic (365 days and longer) durations. MRLs are generally based on the most sensitive chemical-induced endpoint considered relevant to humans. ATSDR does not use serious health endpoints (e.g., irreparable damage to the liver or kidneys, birth defects) as bases for establishing MRLs. The specific approach used to derive MRLs for individual substances are detailed in ATSDR's Toxicological Profile for each substance available at http://www.atsdr.cdc.gov/toxprofiles/index.asp.

ATSDR environmental media evaluation guides (EMEGs) are media-specific chemical concentrations derived from MRLs using default exposure assumptions.

The ATSDR has derived EMEGs that are applicable to the Yakama EI for hydrogen sulfide, which has and intermediate EMEG (20ppb), and ammonia which has an acute (1700ppb) and chronic (100ppb) EMEGs.

Washington Department of Ecology Acceptable Source Impact Levels (ASILs)

The Washington Department of Ecology's Air Quality Program develops ASILs for exposure durations of 24 hours or less [Ecology 2008]. The ASILs are risk-based concentrations that from three sources, the EPA, ATSDR, and the California Office of Environmental Health Hazard Assessment (OEHHA). The Air Quality Program chooses the ASIL value based on the following strategy:

- ASILs are only derived for pollutants with a final (published) CVs, and use the most recently published value;
- If the three databases had acute, chronic, and cancer based values, the ASIL is set on the most recently adopted carcinogenetic value;
- Each pollutant would have only one ASIL and one concentration averaging time;
- Each ASIL could have either a short-term value or a long-term value but not both;
- A short-term ASIL can have a 1-hour or 24-hour averaging period;
- Chronic ASILs are set with 24-hour time weighted averages rather than with annual averages as CVs from the EPA and ATSDR. Continuous exposure is emphasized as opposed to intermittent brief high-level acute exposures not occurring daily.; and
- If the data source didn't provide an averaging period, it is set at 24-hours.

Washington Department of Ecology has a 24-hr ASIL for ammonia (100ppb) and hydrogen sulfide (1.4ppb).

EPA Reference Concentrations (RfCs)

The EPA developed chronic reference concentrations (RfCs) for inhalation. These are estimates of daily exposures to a substance likely without a discernible risk of adverse effects to the general human population (including sensitive subgroups) during a lifetime of exposure. RfCs assume that certain toxic effects have thresholds, such as for cell death or organ damage. RfCs also assume exposure to a single substance in a single media. RfCs are only derived for noncarcinogenic health effects. Doses less than the RfC are not expected to be associated with health risks. EPA has an RfC for ammonia (720 ppb) and hydrogen sulfide (1.4 ppb).

The derivation of RfCs for each chemical are described in EPA's Integrated Risk Information System available online at https://cfpub.epa.gov/ncea/iris2/atoz.cfm [USEPA 2013]

EPA National Ambient Air Quality Standard (NAAQS)

The Clean Air Act, last amended in 1990, requires EPA to set NAAQS for wide-spread pollutants from numerous and diverse sources considered harmful to public health and the environment.

The EPA has set NAAQS for six principal "criteria" pollutants: carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur dioxide. The Clean Air Act requires periodic review of the science on which the standards are based and the standards themselves. For technical information related to setting the national air quality standards, see EPA's Web site available at https://www.epa.gov/naaqs [USEPA 2012]. EPA has the following NAAQSs for PM:

PM_{10}: The 24-hour average must not exceed 150 μg/m^3 more than once per year on average over three consecutive calendar years.

$PM_{2.5}$: The annual average concentrations of $PM_{2.5}$, averaged over three consecutive calendar years, should not exceed 12 μg/m^3. Further, the 98^{th} percentile of 24-hour average $PM_{2.5}$ concentrations in one year, averaged over three consecutive calendar years, must not exceed 35 μg/m^3.

WHO Air Quality Guidelines (AQGs)

The World Health Organization (WHO) develops air quality guidelines (AQGs) to offer guidance in reducing the health impacts of air pollution. First produced in 1987, these guidelines are based on expert evaluation of current scientific evidence. The new information included in the 2005 update relates to four common air pollutants: particulate matter, ozone, nitrogen dioxide, and sulfur dioxide [WHO 2006].

WHO has the following AQGs for PM:

PM_{10}: The WHO annual average AQG is 20 μg/m^3 and the 24-hour AQG is 50 μg/m^3; and

$PM_{2.5}$: The WHO annual average AQG is 10 μg/m^3 and the 24-hour AQG is 25 μg/m^3.

EPA Air Quality Index

EPA's Air Quality Index (AQI) online tool, "AIRNow AQI Calculator" (AQI) was used to estimate potential health effects from 24-hour averages of PM_{10} and $PM_{2.5}$ measured near Harrah (see http://airnow.gov/index.cfm?action=resources.conc_aqi_calc) [USEPA 2016]. This tool offers guidance to the potential health effects associated with long-term exposure to specific concentrations of PM measured in Harrah (See Screening and Health Evaluation section, Table 4 and Table 5). The AQI categorizes 24-hour PM concentrations into six categories: good, moderate, unhealthy for sensitive populations, unhealthy, very unhealthy, and hazardous. The concentration ranges for each category, the associated public health statements, and relevant CVs are given in Table A1 below.

Table A1. EPA Air Quality Index (AQI) categories with particulate matter ranges and associated health statement compared to ambient air standards and guidelines.

AQI Category	Air Quality Index Ranges 24-hr Average Concentration ($\mu g/m^3$)		Health Messages*		Ambient Air Average Standards (EPA NAAQS) and Guidelines (WHO AQG) ($\mu g/m^3$)
	PM_{10}	$PM_{2.5}$	Health Effects Statement	Cautionary Statement	
Good	0 – 54	0 – 12.0	None.	None.	**50 (PM_{10} 24-hr AQG)** 20 (PM_{10} Annual AQG) -- 10 ($PM_{2.5}$ Annual AQG) 12 ($PM_{2.5}$ Annual NAAQS)
Moderate	55 – 154	12.1 – 35.4	Respiratory symptoms possible in unusually sensitive individuals; possible aggravation of heart or lung disease in people with cardiopulmonary disease and older adults.	Unusually sensitive people should consider reducing prolonged or heavy exertion.	**150 (PM_{10} 24-hr NAAQS)** -- **25 ($PM_{2.5}$ 24-hr AQG)** **35 ($PM_{2.5}$ 24-hr NAAQS)**
Unhealthy for Sensitive Groups	155 – 254	35.5 – 55.4	Increasing likelihood of respiratory symptoms in sensitive groups including older adults, children, and people of lower socioeconomic status; aggravation of heart or lung disease and premature mortality in people with heart or lung disease	People with heart or lung disease, older adults, children, and people of lower socioeconomic status should reduce prolonged or heavy exertion.	NA
Unhealthy	255 – 354	55.5 – 150.4	Increased aggravation of respiratory symptoms in sensitive groups including older adults, children, and people of lower socioeconomic status; increased aggravation of heart or lung disease and premature mortality in people with heart or lung disease; increased respiratory effects in general population.	People with heart or lung disease, older adults, children, and people of lower socioeconomic status should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion.	NA
Very Unhealthy	355 – 424	150.5 – 250.4	Significant aggravation of respiratory symptoms in sensitive groups including older adults, children, and people of lower socioeconomic status; significant aggravation of heart or lung disease and premature mortality in people with heart or lung disease; significant increase in respiratory effects in general population.	People with heart or lung disease, older adults, children, and people of lower socioeconomic status should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.	

AQI Category	Air Quality Index Ranges 24-hr Average Concentration ($\mu g/m^3$)		Health Messages*		Ambient Air Average Standards (EPA NAAQS) and Guidelines (WHO AQG) ($\mu g/m^3$)
	PM_{10}	$PM_{2.5}$	Health Effects Statement	Cautionary Statement	
Hazardous	425 – 604	250.5 – 500.4	Serious aggravation of respiratory symptoms in sensitive groups including older adults, children, and people of lower socioeconomic status; serious aggravation of heart or lung disease and premature mortality in people with heart or lung disease; serious risk of respiratory effects in general population.	Everyone should avoid all physical activity outdoors; people with heart or lung disease, older adults, children, and people of lower socioeconomic status should remain indoors and keep activity levels low.	NA

Source: Adapted from [USEPA 2016]: https://www3.epa.gov/airnow/aqi-technical-assistance-document-sept2018.pdf. Link copied September 2019.

Notes: AQG – World Health Organization (WHO) Air Quality Guidelines, AQI – EPA's Air Quality Index, CV – comparison value used for screening particulate matter data, EPA – U.S. Environmental Protection Agency, hr – hour; NA – not applicable, NAAQS – EPA National Ambient Air Quality Standards, PM – particulate matter for particulates smaller than 10 microns (PM_{10}) or 2.5 microns ($PM_{2.5}$); $\mu g/m^3$ – micrograms per meter cubed

*Sensitive Groups for All AQI Categories: People with heart or lung disease, older adult, children, and people of lower socioeconomic status are the most at risk.

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Appendix B. Meteorological Results and Polar Plots of Concentration, Wind Speed, and Wind Direction at Each Site, Yakama Nation Exposure Investigation, Harrah, WA

Review of Meteorological Results

Two on-site systems collected continuous meteorological measurements throughout the EI at Sites 7 and 8 [ERG 2016]. The Fall 2014 event, set to characterize colder months, was conducted from October 23rd to December 18th. The Summer 2015 event, set to characterize warmer months, was conducted from June 22nd to August 19th. Overall, meteorological conditions during the two events are summarized in Table 2.

Table B1. Summary of meteorological conditions during the Yakama Nation Exposure Investigation, Harrah, WA

Meteorological Parameter	Fall 2014		Summer 2015	
	Range	Average ± standard deviation	Range	Average ± standard deviation
Temperature	8.8-71°F	39±12°F	45–106°F	76±13°F
Relative Humidity	21–110%	79±19%	8.8–95%	41±17%
Wind Direction (from)	All (mostly N, then W-SW, some E-SE)	NA	All (mostly N or E, some NW-W-SW)	NA
Wind Speed	< 1.2 mph (34-54%) to > 19.6 mph (0.2%)	2.6 mph	< 1.2 mph (9.5-16%) to > 19.6 mph (0.2%)	3.6 mph

Source: [ERG 2016]
Notes: Meteorological Stations operated 10/23/17 to 12/18/2014 for 'Fall' conditions and 06/22/2015 to 08/19/2015 for summer conditions at two sites (7&8). Data presented were estimated from averages at both sites.
Comments: Temperature and relative humidity data were highly consistent between sites for each event (Fall/Summer Pearson Coefficients 0.98/0.99 and 0.94/0.89 respectively). Temperature reflects continuous measurements. There was a 6°F difference between early morning and daytime in Fall compared to 20°F in Summer. Wind roses between Sites 7 and 8 were different, major wind directions are noted from both sites.

The following section includes an analysis of the 1) correlation between pollutant measurements and meteorological data, 2) effect of wind on pollutant dispersion from sources, and 3) comparison of pollutants between sampling events. A full description of the meteorological data and evaluation is found in the Exposure Investigation Field Report [ERG 2016].

Correlations between Pollutant Measurements and Meteorological Data

In order to better understand the effects of wind speed, temperature, and humidity, ATSDR calculated Pearson correlation coefficients between these parameters and each pollutant for each event. For details of the analysis see the EI Field report [ERG 2016]). These correlations were calculated between the 1-minute meteorological data from Site 7 and the ambient air monitoring data collected at each monitoring site. ATSDR selected Site 7 for this analysis because it was centrally located to the monitors/samplers, and because during the Fall 2014 EI event, data collection at Site 8 began one day later than at Site 7 and Site 8 had no data for 3 days at the end of November. In general, these relationships were very weak and caution should be used in interpreting these correlations.

Comparison of Pollutants between Fall and Summer Events

All three contaminants were sampled at Sites 2, 4, and 5 during both Fall and Summer events. Appendix C summarizes the pollutant concentrations by sampling event. In general, average values were higher in the colder months for each contaminant; however, the results from the Fall event were not statistically different from those of the Summer events (See EI field report [ERG 2016]). The concentration of $PM_{2.5}$ monitored during the fall was consistently higher than Summer, although not to a level of statistical significance. While the ammonia levels were low, Site 2 had statistically higher ammonia concentrations in the fall event than during the Summer event. Site 2 is close to a feedlot and the wastewater treatment plant.

Effect of Wind and Seasonal Trends on Pollutant Concentrations (Polar Plot Analysis)

Polar plots were created for each site comparing pollutant concentrations to meteorological data collected at Site 7. For an understanding of the sources closest to the monitor/sample sites refer to Figure 2. All the sites were at residences except Site 5 (Harrah Elementary School) and Site 7 (Water Improvement Project canal gate).

Pollutant concentrations at each monitoring/sampling site were modeled to create polar plots according to meteorological data collected at Site 7.

The following summarizes the polar plots at each site:

Particulate Matter. For $PM_{2.5}$, Fall 2014 had higher levels than Summer 2015 at each site. While the highest level in Fall 2014 was at Site 2 (although all sites in the Fall had daily averages above the 24-hour NAAQS), the highest sample in Summer 2015 was at Site 7.

During Fall 2014, all sites recorded elevated concentrations when the wind speed was low (0–5 mph); Additionally, Site 2 showed an increase in concentration when the winds were moderate from the west (15–20 mph). Site 7 showed an increase in both PM_{10} and $PM_{2.5}$ with strong winds (greater than 20 mph) from the southwest. Although the Krainick feedlot is to the south and west of sites 2 and 7, this wind-directional trend was not observed in the summer sampling nor at sites 1 and 4, which are also near the Krainick feedlot.

During Summer 2015, the highest levels of $PM_{2.5}$ at each site (except Site 5) occurred when there were strong winds from the south to Southeast (15–25 mph). The only exception, Site 5, had the lowest maximum value and 2nd lowest mean during the summer. The concentration of $PM_{2.5}$ during summer 2015 could be influenced by wildfires. Although the census track 53077940001 (containing the town of Harrah and part of Yakima County) did not report any wildfires from 2000-2015, the census track 53077940003, which borders to the south and southeast has documented some wildfires during the summer of 2015. For PM_{10} (only measured at Site 7) higher levels were observed when winds were from the west.

The highest measured 24-hour samples of PM_{10} and $PM_{2.5}$ all occurred during the same eight-day period in November. The three days that PM_{10} concentrations were moderate occurred on 11/20, 11/21, and 11/27/14 at site 7. The highest 4 days of $PM_{2.5}$ were measured on 11/20 and 11/21 at site 3; 11/23 at site 2; and 11/27 at site 7.

Ammonia. Although, average measured values of ammonia were slightly higher in the fall, the maximum value was measured in the summer. The highest values were recorded at Site 4 in both fall and Summer events followed by Site 3. The Fall 2014 Polar plots at Site 4 show the highest concentrations of ammonia when the winds (5–12mph) are from the south. The Summer 2015 plots show the highest concentrations at Site 4 when winds are from the northeast, east, southeast, and southern direction (1–12 mph). The Krainick Feedlot is directly south of Site 4 and the Harrah Wastewater Treatment Plant is southeast of Site 4. Site 3 recorded significantly higher concentrations of ammonia when low to moderate winds (2–6 mph) are from the northeast (Fall 2014) or from the west (Summer 2015). The Harrah (Dolsen) Feedlot is just west of Site 3. At Site 2, higher concentrations were observed with low winds from the west (2 mph) and northeast (2-4 mph), but this only occurred during the fall sampling.

Hydrogen Sulfide. Although hydrogen sulfide was detected more frequently in the fall sampling, the highest concentrations were detected in the summer. Site 2 had the highest mean and maximum value in the summer. Site 4 had the highest mean and maximum in the fall. The polar plots for all sites during both Fall 2014 and Summer 2015 showed higher concentrations of hydrogen sulfide when the winds were low (0–5 mph).

During Fall 2014, all the sites additionally show increased concentrations resulting from moderate to strong winds from the west (10–30mph). Concentrations were also elevated at Sites 1, 5, 7 and 9 during periods with strong winds (>20 mph) from the northwest and north.

In Summer 2015, all sites have their highest concentrations during periods of little to no wind speed. Hydrogen sulfide concentrations at Sites 5 and 7 increased during periods with higher wind speeds from the southeast (15–20 mph). Hydrogen sulfide concentrations at Site 5 also increased during periods with moderate wind speeds from the west to northwest (6-12 mph).

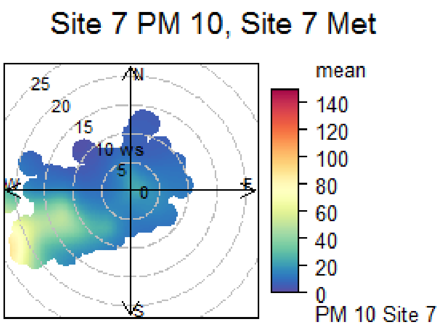
Polar Plots: Particulate Matter

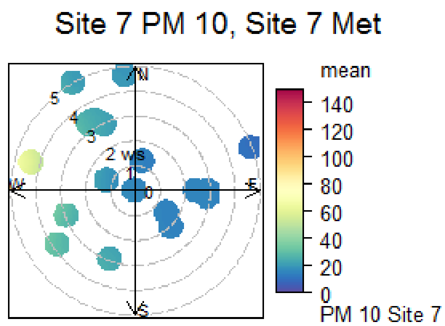
For $PM_{2.5}$ Fall 2014 had higher levels than Summer 2015 at each site. While the highest level in Fall 2014 was at Site 2 (although all sites recorded at least one daily average that exceeded the 24-hour NAAQS), the highest sample in Summer 2015 was at Site 1.

During Fall 2014, all sites recorded the elevated concentrations when the wind speed was low (0–5 mph); Additionally, Site 2 showed an increase in concentration when the winds were moderate from the west (15–20 mph). Site 7 showed an increase in both PM_{10} and $PM_{2.5}$ with strong winds (greater than 20 mph) from the southwest.

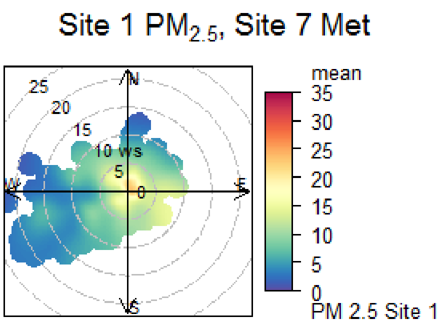
During Summer 2015, the highest levels of $PM_{2.5}$ at each site occurred when there were strong winds from the south to Southwest (15–25 mph). Wildfires may contribute to $PM_{2.5}$. While the census track 53077940001 (containing the town of Harrah and part of Yakima County) did not report any wildfires from 2000-2015, the census track 53077940003, which borders to the south and west has documented some wildfires. The only exception was Site 5, which had the lowest maximum value and 2nd lowest mean during the summer. For PM_{10} (only measured at Site 7) higher levels were observed when winds were from the west.

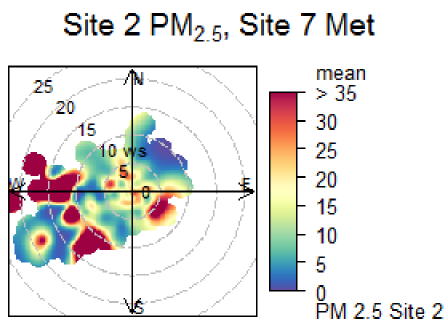
PM_{10} Fall 2014 and Summer 2015 Polar Plots



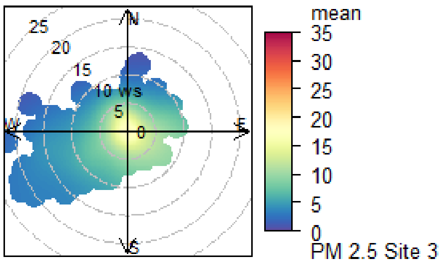


$PM_{2.5}$ Fall 2014 Polar Plots

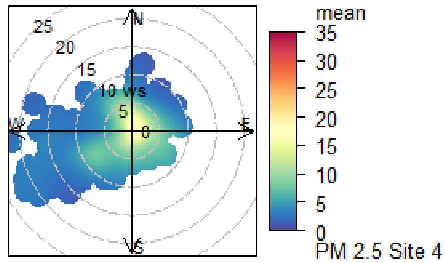




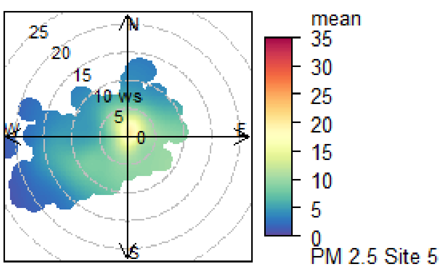
Site 3 $PM_{2.5}$, Site 7 Met



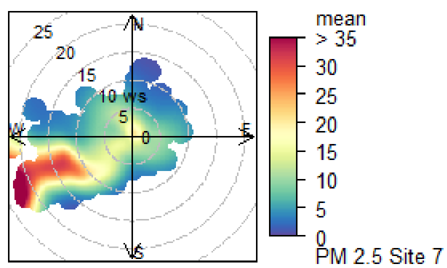
Site 4 $PM_{2.5}$, Site 7 Met



Site 5 $PM_{2.5}$, Site 7 Met

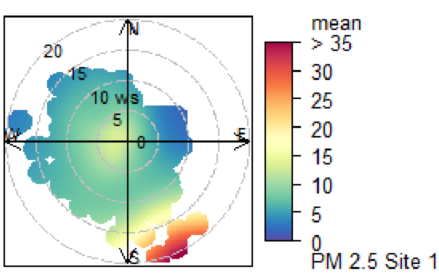


Site 7 $PM_{2.5}$, Site 7 Met

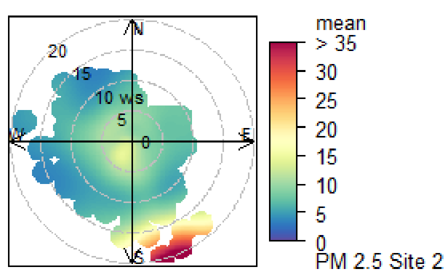


$PM_{2.5}$ Summer 2015 Polar Plots

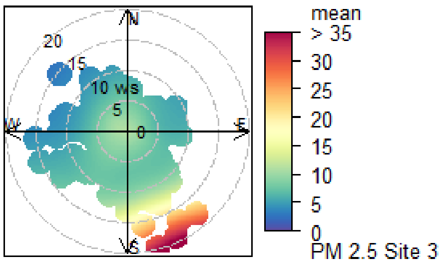
Site 1 $PM_{2.5}$, Site 7 Met



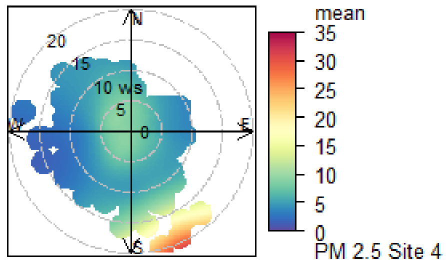
Site 2 $PM_{2.5}$, Site 7 Met



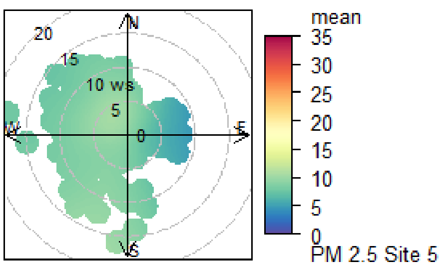
Site 3 $PM_{2.5}$, Site 7 Met



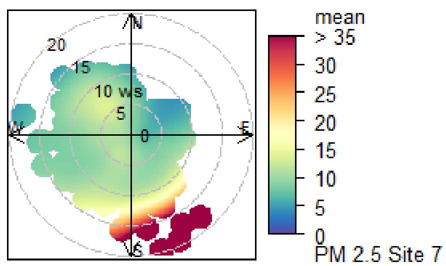
Site 4 $PM_{2.5}$, Site 7 Met



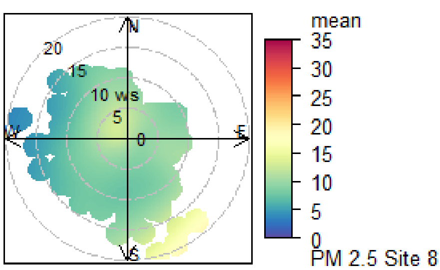
Site 5 $PM_{2.5}$, Site 7 Met



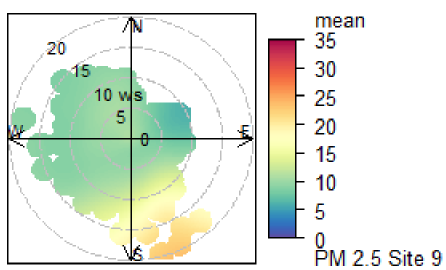
Site 7 $PM_{2.5}$, Site 7 Met



Site 8 $PM_{2.5}$, Site 7 Met



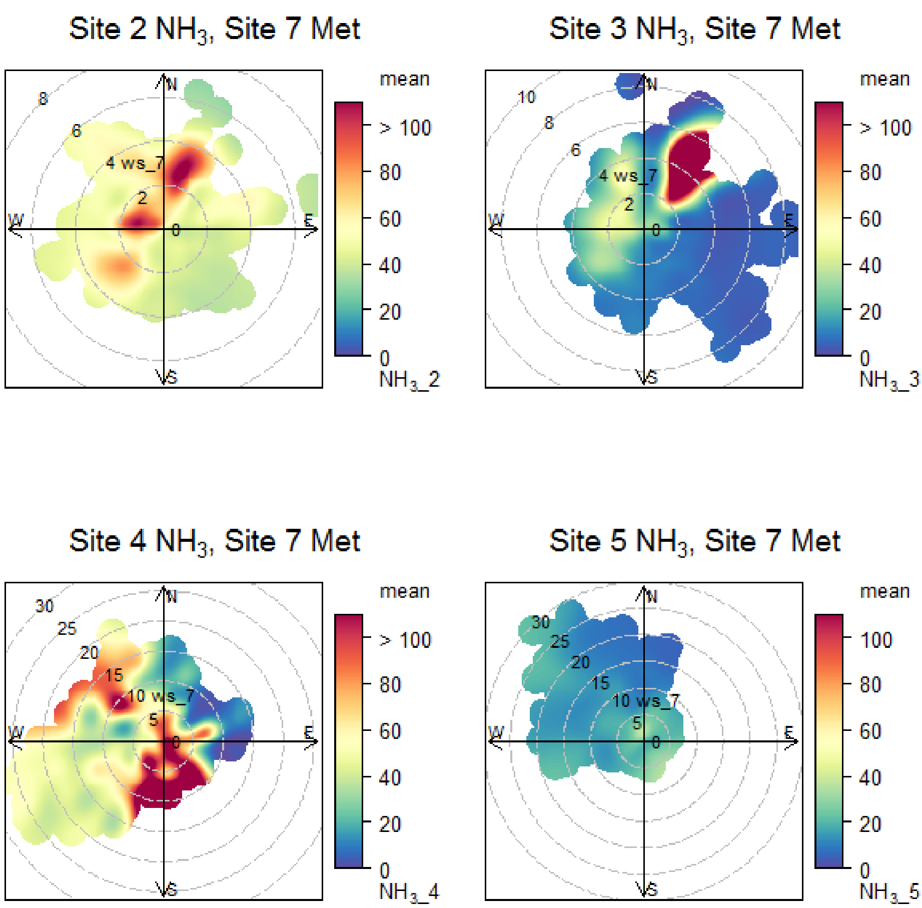
Site 9 $PM_{2.5}$, Site 7 Met



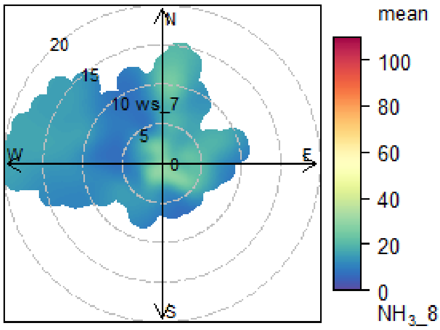
Polar Plots: Ammonia

Although, measured values of ammonia were slightly higher in the fall, the maximum value was measured in the summer. The highest values were recorded at Site 4 in both fall and summer events followed by Site 3. The acute MRL was only exceeded at Site 4 (one-minute samples, once in each phase). The Fall 2014 Polar plots at Site 4 show the highest concentrations of ammonia when the winds (5–12mph) are from the south. The Summer 2015 plots show the highest concentrations at Site 4 when winds are from the northeast, east, southeast, and southern direction (1–12 mph). The Krainick Feedlot is directly south of Site 4 and the Harrah Wastewater Treatment Plants is southeast of Site 4. Site 3 recorded significantly higher concentrations of ammonia when low to moderate winds (2–6 mph) are from the northeast (Fall 2014) or from the west (Summer 2015). The Harrah (Dolsen) Feedlot is just west of Site 3. At Site 2, higher concentrations were observed with low winds from the west (2 mph) and northeast (2-4 mph), but this only occurred during the fall sampling.

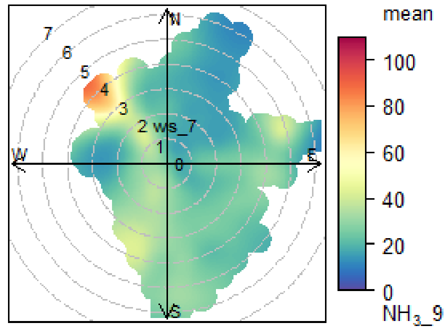
Ammonia Fall 2014 Polar Plots



Site 8 NH_3, Site 7 Met

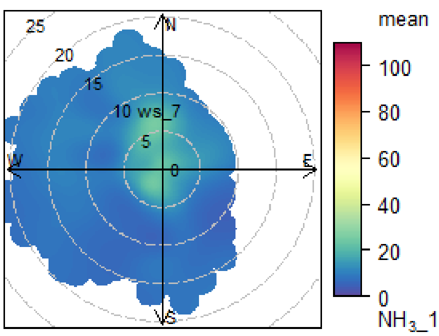


Site 9 NH_3, Site 7 Met

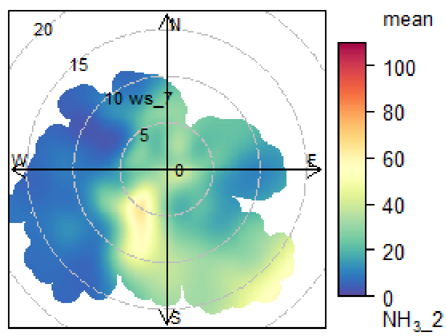


Ammonia Summer 2015 Polar Plots

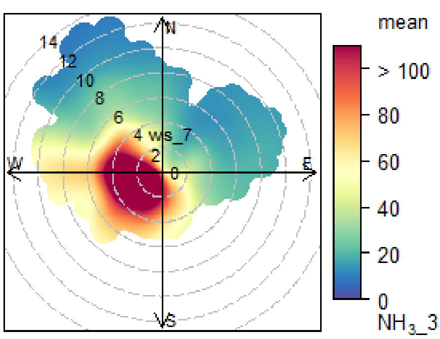
Site 1 NH_3, Site 7 Met



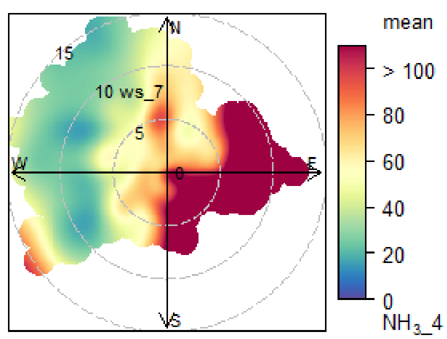
Site 2 NH_3, Site 7 Met

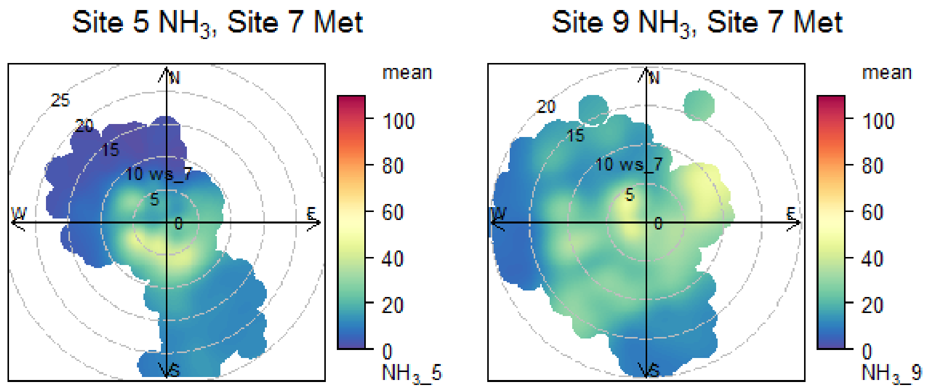


Site 3 NH_3, Site 7 Met



Site 4 NH_3, Site 7 Met





Hydrogen Sulfide

Although hydrogen sulfide was detected more frequently in the fall sampling, the highest concentrations were detected in the summer. In the summer 167 (0.80%) of the 30- min samples exceeded the intermediate EMEG while there were only 27 (0.13%) in the fall. Site 2 had the highest mean and maximum value in the summer but was third highest in the fall. Site 4 had the highest average in Fall 2014.

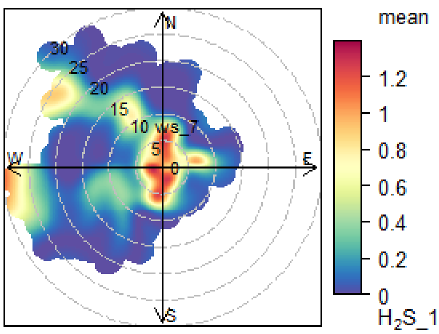
The polar plots for all sites during both Fall 2014 and Summer 2015 showed higher concentrations of hydrogen sulfide when the winds were low (0–5 mph). Only Sites 2, 5, and 9 had 1–min samples that exceeded the acute MRL (all during Summer 2015). The maximum level measured at each site was roughly 90 ppb.

During Fall 2014, all the sites additionally show increased concentrations resulting from moderate to strong winds from the west (10–30mph). Concentrations were also elevated at Sites 1, 5, 7 and 9 during periods with strong winds (>20 mph) from the northwest and north.

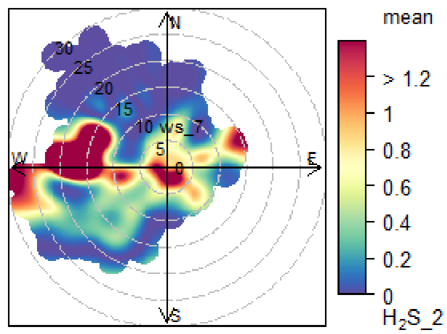
In Summer 2015, all sites have their highest concentrations during periods of little to no wind speed. Hydrogen sulfide concentrations at Sites 5 and 7 increased during periods with higher wind speeds from the southeast (15–20 mph). Hydrogen sulfide concentrations at Site 5 also increased during periods with moderate wind speeds from the west to northwest (6-12 mph).

Hydrogen Sulfide Fall 2014 Polar Plots

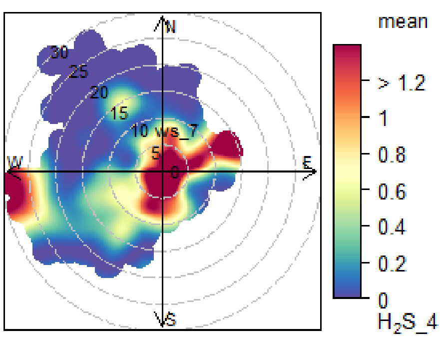
Site 1 H_2S, Site 7 Met



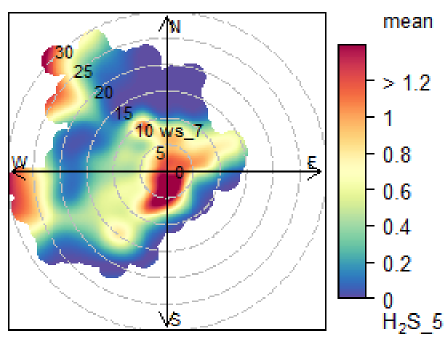
Site 2 H_2S, Site 7 Met



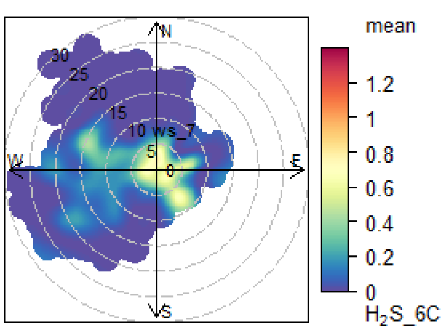
Site 4 H_2S, Site 7 Met



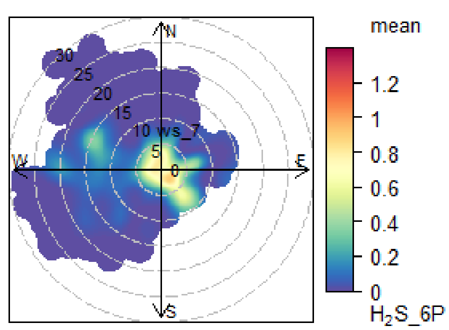
Site 5 H_2S, Site 7 Met



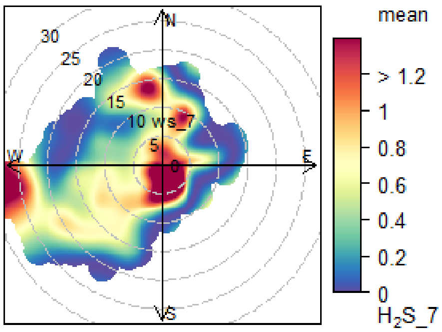
Site 6C H_2S, Site 7 Met



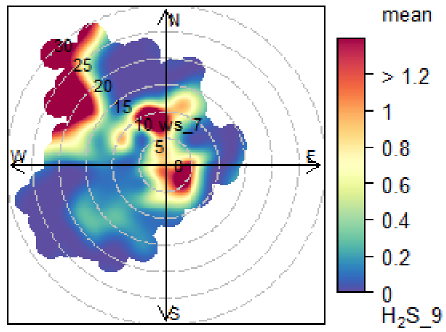
Site 6P H_2S, Site 7 Met



Site 7 H_2S, Site 7 Met

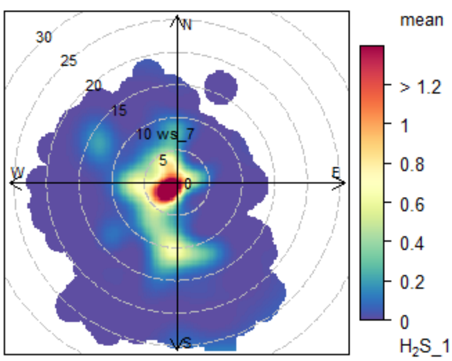


Site 9 H_2S, Site 7 Met

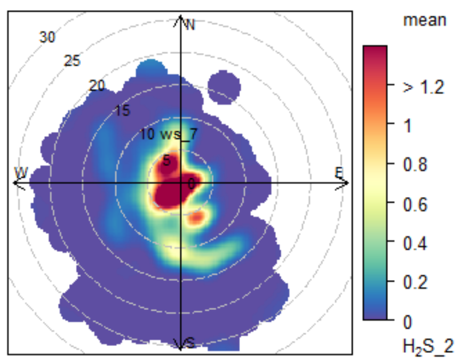


Hydrogen Sulfide Summer 2015 Polar Plots

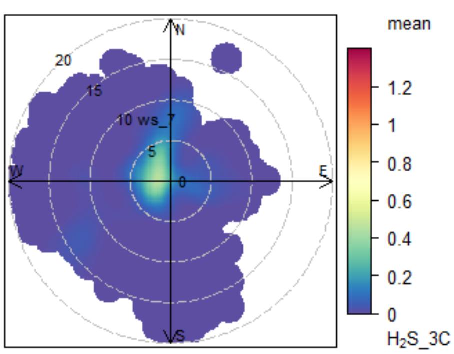
Site 1 H_2S, Site 7 Met



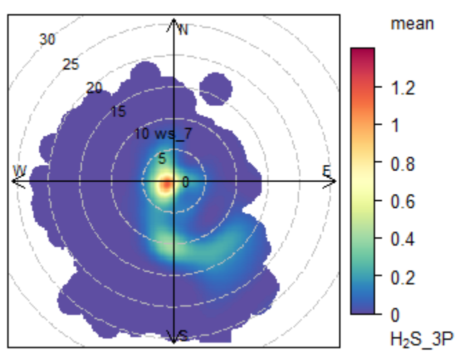
Site 2 H_2S, Site 7 Met



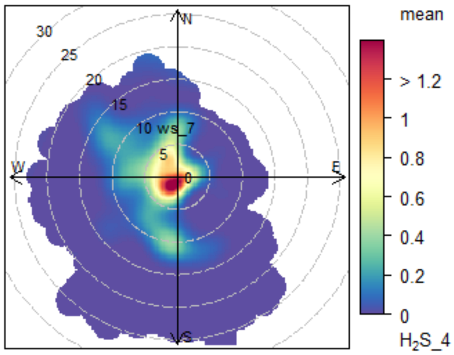
Site 3C H_2S, Site 7 Met



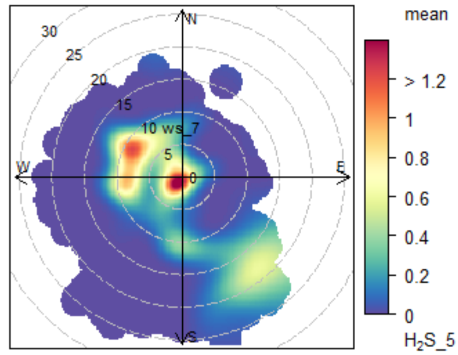
Site 3P H_2S, Site 7 Met



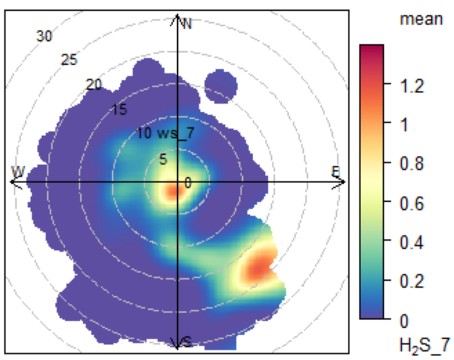
Site 4 H_2S, Site 7 Met



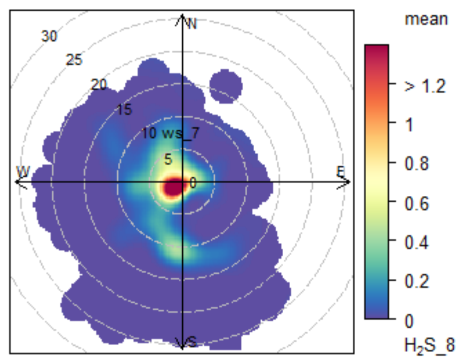
Site 5 H_2S, Site 7 Met



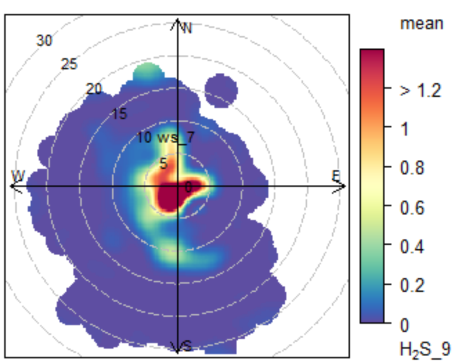
Site 7 H_2S, Site 7 Met



Site 8 H_2S, Site 7 Met



Site 9 H_2S, Site 7 Met



Appendix C – Summary Statistics and Screening Tables

Appendix C presents the summary data generated from the Yakama Nation Exposure Investigation.

For PM_{10} and $PM_{2.5}$, hourly data were combined to create 24-hour averages. The maximum 24 –hour value was compared to the 24- hour NAAQS and AQG, and the mean 24-hour concentration was compared to the annual NAAQS and AQG.

For ammonia and hydrogen sulfide, the tables list summary statistics for the 30-minute averages of the monitoring data. Each table compares the minimum, median, mean, 95th percentile, and maximum with the appropriate screening level described in Appendix A. For hydrogen sulfide, the values were compared to the ATSDR intermediate Environmental Media Evaluation Guide (EMEG), the EPA Reference Concentration (RfC) and the odor threshold. For ammonia, the values were compared to the acute and chronic EMEG.

Samples collected during this EI were not treated separately when below the detection limit. However, data that was coded as an error due to various machine malfunctions (e.g. start-up effect, power outage, etc.) were removed. For PM, negative values were incorporated into the hourly averages, which seemed to be more accurate and cut down on noise.

The following tables are in this Appendix:

Table C1. Statistics for Particulate Matter smaller than 2.5 microns ($PM_{2.5}$, µg/m^3) on 24-hour averages (using hourly data) compared to the 24-hour and annual Primary National Ambient Air Quality Standards for $PM_{2.5}$;

Table C2. Statistics for Particulate Matter smaller than 10 microns (PM_{10}, µg/m^3) on 24-hour averages (using hourly data) compared to the 24-hour Primary National Ambient Air Quality Standards and WHO Air Quality Guidelines for PM_{10};

Table C3. Ammonia 1-minute averages (ppb), measured by Cavity Ring Down Spectroscopy (CRDS): Exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA;

Table C4. Ammonia 30-minute Averages (ppb), measured by Cavity Ring Down Spectroscopy (CRDS): Exceedences of comparison values and odor threshold;

Table C5. Ammonia 24-hour averages (ppb), measured by Cavity Ring Down Spectroscopy (CRDS): Exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA;

Table C6. Ammonia 24-hour samples (ppb), measured by Annular Denuder System (ADS): Exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA;

Table C7. Ammonia 1-week samples (ppb), measured by Rapid Air Monitor (RAM): exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA;

Table C8. Ammonia 2-week samples (ppb), measured by Rapid Air Monitor (RAM): exceedances of comparison values, Yakama Nation Exposure Investigation, Harrah, WA;

Table C9. Hydrogen Sulfide 1-minute Averages (ppb): Exceedences of comparison values and odor threshold;

Table C10. Hydrogen Sulfide 30-minute Averages (ppb): Exceedences of comparison values and odor threshold; and

Table C11. Hydrogen Sulfide Daily Averages (ppb): Exceedences of comparison values and odor threshold.

Table C1. Statistics for particulate matter smaller than 2.5 microns ($PM_{2.5}$, µg/m^3) 24-hour averages (using hourly data) compared to the 24-hour and annual EPA National Ambient Air Quality Standards and WHO Air Quality Guidelines, Yakama Nation Exposure Investigation, Harrah, WA

Site	Mean	24-hour 95th UCL	Max	Number of 24- hour averages Per Site	Samples above Primary NAAQS		Samples above WHO AQG	
					24-hour (35 µg/m^3) Number (Percent)	Annual (12 µg/m^3) Number (Percent)	24-hour (25 µg/m^3) Number (Percent)	Annual (10 µg/m^3) Number (Percent)
Fall 2014								
Site 1	16.40	16.98	54.95	51	4 (7.84)	29 (56.86)	8 (15.69)	36 (70.6)
Site 2	21.69	22.85	153.56	51	6 (11.76)	34 (66.67)	12 (23.53)	38 (74.51)
Site 3	15.26	15.92	58.00	51	4 (7.84)	25 (49.02)	7 (13.73)	29 (56.86)
Site 4	14.20	14.84	53.87	51	4 (7.84)	26 (51.0)	6 (11.76)	29 (56.86)
Site 5	15.17	15.76	51.86	53	4 (7.55)	30 (56.6)	7 (13.2)	33 (62.3)
Site 7	14.67	15.34	60.02	55	5 (9.09)	26 (47.27)	8 (14.5)	31 (56.4)
Summer 2015								
Site 1	10.92	11.32	40.18	60	1 (1.67)	16 (26.67)	6 (10.00)	22 (36.67)
Site 2	10.61	10.96	30.32	59	0 (0)	19 (32.20)	2 (3.39)	22 (37.29)
Site 3	11.09	11.55	31.42	29	0 (0)	8 (27.59)	4 (13.79)	8 (27.59)
Site 4	8.19	8.53	27.07	59	0 (0)	12 (20.34)	2 (3.39)	16 (26.67)
Site 5	9.10	9.35	21.95	31	0 (0)	7 (22.58)	0 (0)	11 (35.48)
Site 7	10.91	11.35	47.22	60	2 (3.33)	17 (28.33)	4 (6.67)	22 (36.67)
Site 8	11.32	11.64	30.86	54	0 (0)	19 (35.19)	2 (3.70)	27 (50.00)
Site 9	10.48	10.85	40.35	57	1 (1.75)	15 (26.32)	2 (3.51)	20 (35.09)
Totals								
Fall 2014	16.20	16.95	153.56	312	27 (8.65)	170 (54.49)	48 (15.38)	196 (62.82)
Summer 2015	10.34	10.72	47.22	409	4 (0.98)	113 (27.63)	22 (5.38)	148 (36.19)
Both events	12.88	13.47	153.56	721	31 (4.30)	283 (39.25)	70 (9.71)	344 (47.71)

Abbreviations: 95th UCL – 95th percentile upper confidence limit on the mean NAAQS – EPA National Ambient Air Quality Standards, PM2.5 – particulate matter smaller than 2.5 microns- (**µg/m^3**), AQG- Air Quality Guidelines, WHO-World Health Organization
Notes: Met One Instruments E-BAM real-time beta attenuation monitors, Method detection range (ND-65 µg/m3). One-minute $PM_{2.5}$ samples were averaged every hour from 10/23/14-12/18/14 (Fall) and 6/22/15-8/19/15 (Summer). Limitations/gaps: Averaging hourly data to twenty-four-hour values may introduce some bias. During the fall sampling event 67,048 1-min values were recorded as Not applicable (N/A), and 148,716 negative values were censored and reformatted as 0 by ERG (this may have caused some bias in the 24-hour averaging). During the Spring Sampling event 2,594 1-minute values were recorded as N/A, and 206,248 were censored and reformatted as 0 by ERG.
Comments: Both 24-hour and annual primary NAAQS require long-term monitoring for compliance purposes. This monitoring effort was not done to determine NAAQS compliance.

Table C2. Statistics for Particulate Matter smaller than 10 microns (PM_{10}, µg/m^3) on 24-hour averages (using hourly data) compared to the 24-hour Primary National Ambient Air Quality Standards and WHO Air Quality Guidelines for PM_{10}, Yakama Nation Exposure Investigation, Harrah, WA

Site	Mean	95th UCL	Max	Number of Samples Per Site	Samples above 24-hour Primary NAAQS (150 µg/m3)	Samples above 24-hour AQG (50 µg/m3)
					Number (Percent)	Number (Percent)
Fall 2014						
Site 7	19.81	20.76	119.72	57	0 (0)	3 (5.45)
Summer 2015						
Site 7	20.34	20.71	29.40	4	0 (0)	0 (0)
Totals						
Both events	19.84	20.77	119.72	61	0 (0)	3 (4.92)

Abbreviations: 95th UCL – 95th percentile upper confidence limit on the mean, NAAQS – EPA National Ambient Air Quality Standards, PM_{10} – particulate matter smaller than 10 microns- (µg/m^3), AQG- Air Quality Guidelines, WHO-World Health Organization
Notes: Met One Instruments E-BAM, MDL (0-65 µg/m^3) Twenty-four hour values were calculated from PM_{10} samples taken every minute from 10/23/14-12/18/14 (Fall) and 6/22/15-6/24/15 (Summer) and averaged to one hour. Limitations/gaps: During the fall sampling event 5,237 records were recorded as N/A, and 26,946 negative values were censored and reformatted as 0 by ERG (this may have caused some bias in the 24-hour averaging). During the Spring sampling event 579 samples were censored and reformatted as 0 by ERG. Samples were only taken at site 7.
Comments: Both 24-hour and annual primary NAAQS require long-term monitoring in order to determine exceedances. This monitoring effort was not done to determine NAAQS exceedance.

Table C3. Ammonia 1-minute averages (ppb), measured by Cavity Ring Down Spectroscopy (CRDS): Exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA

Site	Min	Median	Mean	95th Percentile	Max	# of Valid Samples	Samples above Acute EMEG (1,700 ppb)	Samples above Chronic EMEG (100 ppb)
							Number (Percent)	Number (Percent)
Fall 2014								
Site 2	25.45	51.57	62.83	150.56	258.89	4,243	0 (0.00)	439 (10.35)
Site 3	0.00	11.37	33.84	142.36	729.22	4,118	0 (0.00)	294 (7.14)
Site 4	0.00	49.80	79.04	235.34	1,732.11	28,802	1 (0.00)	6,184 (21.47)
Site 5	2.98	19.08	25.75	67.30	129.74	2,900	0 (0.00)	45 (1.55)
Site 8	0.93	23.07	23.80	43.36	68.18	7,063	0 (0.00)	0 (0.00)
Site 9	5.62	20.30	24.18	49.54	161.87	5,553	0 (0.00)	30 (0.54)
Summer 2015								
Site 1	0.00	13.88	17.43	42.49	128.07	6,491	0 (0.00)	22 (0.34)
Site 2	0.00	24.51	28.27	63.69	215.19	8,657	0 (0.00)	132 (1.52)
Site 3	0.00	39.40	76.62	303.30	1,441.43	8,601	0 (0.00)	1,700 (19.77)
Site 4	7.33	53.92	84.47	246.45	1,718.51	19,948	1 (0.01)	4,427 (22.19)
Site 5	0.00	19.95	22.36	49.50	144.93	7,314	0 (0.00)	57 (0.78)
Site 9	0.00	25.26	30.98	72.56	394.02	17,316	0 (0.00)	420 (2.43)
Totals								
Fall 2014	0.00	36.30	58.08	181.14	1,732.11	52,679	1 (0.00)	6,992 (13.27)
Summer 2015	0.00	29.49	49.79	156.31	1,718.51	68,327	1 (0.00)	6,758 (9.89)
Both events	0.00	32.28	53.4	167.68	1,732.11	121,006	2 (0.00)	13,750 (11.36)

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry, EMEG – Environmental Media Evaluation Guide (ATSDR) based off the acute, intermediate, or chronic duration MRL, MDL – method detection limit, MRL – ATSDR Minimal Risk Level, NH_3 – ammonia, ppb – parts per billion, UCL- upper confidence limit of the mean.

Notes: Portable Ammonia Analyzer MDL (0.35 – 69,535 µg/m3), NH_3 samples were taken every minute from 11/8/14-12/18/14 (Fall) and 6/23/15-8/18/15 (Summer). Limitations/gaps: Ambient sampling for NH_3 for less than 24 hours to obtain peak concentrations is difficult to achieve due to method and technology limitations. During the fall sampling event two samples were taken every minute and averaged together to arrive at a minute concentration. One hundred and fifteen were coded as having both a negative minimum and maximum value, these values were censored to zero by ERG. Over half of the samples were taken at site 4. During the Spring sampling event

four samples were collected 19 seconds apart every minute and averaged together to arrive at a concentration for each minute. 11,717 were coded as N/A due to a detector error or data gap error, 140 values were negative and censored to zero by ERG
Comments: Acute EMEGs are designed to be protective of exposure durations of 2 weeks or less.
Chronic EMEGs are designed to be protective of exposure durations of 1 year or longer.

No samples exceeded the acute EMEG of 1700 ppb; None of the samples exceeded the odor threshold of 2,600 ppb

Table C4. Ammonia 30-minute averages (ppb), measured by Cavity Ring Down Spectroscopy (CRDS): Exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA

Site	Min	Median	Mean	95th Percentile	Max	# of Valid Samples	Samples above Acute EMEG (1,700 ppb)	Samples above Chronic EMEG (100 ppb)
							Number (Percent)	Number (Percent)
Fall 2014								
Site 2	28.91	52.03	62.79	141.16	208.28	142	0 (0)	13 (9.15)
Site 3	0.42	11.39	33.72	145.23	309.84	139	0 (0)	12 (8.63)
Site 4	0.94	52.08	78.8	237.39	700.85	967	0 (0)	219 (22.65)
Site 5	5.9	18.77	25.62	68.27	106.6	98	0 (0)	1 (1.02)
Site 8	4.86	23.36	23.84	43.67	65.1	236	0 (0)	0 (0)
Site 9	7.81	20.11	24.2	48.33	92.07	186	0 (0)	0 (0)
Summer 2015								
Site 1	1.12	14.18	17.33	42.21	92.02	222	0 (0)	0 (0)
Site 2	1.11	24.42	28.6	65.83	171.16	293	0 (0)	4 (1.37)
Site 3	0.88	41.38	76.32	274.45	604.86	289	0 (0)	60 (20.76)
Site 4	9.59	57.79	84.74	250.91	907.2	670	0 (0)	168 (25.07)
Site 5	0.11	19.92	22.52	49.85	107.85	248	0 (0)	2 (0.81)
Site 9	1.04	25.71	31.06	71.8	297.03	580	0 (0)	12 (2.07)
Totals								
Fall 2014	0.42	36.95	57.94	185.14	700.85	1,768	0 (0)	245 (13.86)
Summer 2015	0.11	30	49.81	159.28	907.2	2,302	0 (0)	246 (10.69)
Both events	0.11	33.01	53.34	170.95	907.2	4,070	0 (0)	491 (12.06)

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry, EMEG – Environmental Media Evaluation Guide (ATSDR) based off the acute, intermediate, or chronic duration MRL, MDL – method detection limit, MRL – ATSDR Minimal Risk Level, NH_3 – ammonia, ppb – parts per billion, UCL- upper confidence limit of the mean.

Notes: Portable Ammonia Analyzer MDL (0.35 – 69,535 µg/m3), NH_3 samples were taken every minute from 11/8/14-12/18/14 (Fall) and 6/23/15-8/18/15 (Summer). Limitations/gaps: Ambient sampling for NH_3 for less than 24 hours to obtain peak concentrations is difficult to achieve due to method and technology limitations. During the fall sampling event two samples were taken every minute and averaged together to arrive at a minute concentration. One hundred and fifteen were coded as having both a negative minimum and maximum value, these values were censored to zero by ERG. Over half of the samples were taken at site 4. During the Spring sampling event four samples were collected 19 seconds apart every minute and averaged together to arrive at a concentration for each minute. 11,717 were coded as N/A due to a detector error or data gap error, 140 values were negative and censored to zero by ERG

Comments: Acute EMEGs are designed to be protective of exposure durations of 2 weeks or less.
Chronic EMEGs are designed to be protective of exposure durations of 1 year or longer.
No samples exceeded the acute EMEG of 1700 ppb; None of the samples exceeded the odor threshold of 2,600 ppb

Table C5. Ammonia 24-hour averages (ppb), measured by Cavity Ring Down Spectroscopy(CRDS): Exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA

24-hr NH3 CRDS Comparison Value and Odor Exceedances										
Site	**Min**	**Median**	**Mean**	**95th Percentile**	**Max**	**# of Samples Per Site**	**# of Samples Above Acute EMEG/MRL (1,700ppb)**	**% of Samples Above Acute EMEG/MRL**	**# of Samples Above Chronic EMEG/MRL (100ppb)**	**% of Samples Above Chronic EMEG/MRL**
Fall 2014										
Site 2	48.88	61.77	63.49	78.82	81.54	4	0	0.00	0	0.00
Site 3	3.35	28.01	36.16	77.35	85.25	4	0	0.00	0	0.00
Site 4	10.21	78.44	79.78	141.51	179.86	25	0	0.00	8	32.00
Site 5	17.42	26.21	24.19	28.68	28.96	3	0	0.00	0	0.00
Site 8	15.65	24.58	24.13	30.54	30.70	6	0	0.00	0	0.00
Site 9	21.17	23.52	23.96	26.52	26.73	5	0	0.00	0	0.00
Summer 2015										
Site 1	4.96	16.74	14.89	22.01	22.59	8	0	0.00	0	0.00
Site 2	15.78	30.02	30.56	48.07	54.89	8	0	0.00	0	0.00
Site 3	23.30	70.65	80.85	138.54	143.99	8	0	0.00	2	25.00
Site 4	42.31	82.01	89.24	142.75	153.27	17	0	0.00	5	29.41
Site 5	6.80	22.83	23.45	38.72	41.84	8	0	0.00	0	0.00
Site 9	14.14	31.26	31.18	44.98	47.24	13	0	0.00	0	0.00
Totals										
Fall	3.35	39.31	58.09	136.87	179.86	47	0	0.00	8	17.02
Summer	4.96	35.14	50.33	128.28	153.27	62	0	0.00	7	11.29
Total	3.35	37.96	53.68	136.40	179.86	109	0	0.00	15	13.76

Portable Ammonia Analyzer MDL (0.35 – 69,535μg/m^3), NH_3 samples were taken every minute from 11/8/14-12/18/14 (Fall) and 6/23/15-8/18/15 (Summer).
Limitations/gaps: Ambient sampling for NH3 for less than 24 hours to obtain peak concentrations is difficult to achieve due to method and technology limitations

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry, EMEG – Environmental Media Evaluation Guide (ATSDR) based off the acute, intermediate, or chronic duration MRL, MDL – method detection limit, MRL – ATSDR Minimal Risk Level, NH_3 – ammonia, ppb – parts per billion, UCL- upper confidence limit of the mean.
Notes: Portable Ammonia Analyzer MDL (0.35 – 69,535 µg/m3), NH_3 samples were taken every minute from 11/8/14-12/18/14 (Fall) and 6/23/15-8/18/15 (Summer). Limitations/gaps: Ambient sampling for NH_3 for less than 24 hours to obtain peak concentrations is difficult to achieve due to method and technology limitations. During the fall sampling event two samples were taken every minute and averaged together to arrive at a minute concentration. One hundred and fifteen were coded as having both a negative minimum and maximum value, these values were censored to zero by ERG. Over half of the samples were taken at site 4. During the Spring sampling event four samples were collected 19 seconds apart every minute and averaged together to arrive at a concentration for each minute. 11,717 were coded as N/A due to a detector error or data gap error, 140 values were negative and censored to zero by ERG
Comments: Acute EMEGs are designed to be protective of exposure durations of 2 weeks or less.
Chronic EMEGs are designed to be protective of exposure durations of 1 year or longer.
No samples exceeded the acute EMEG of 1700 ppb.
No samples exceeded the odor threshold of 2600 ppb

Table C6. Ammonia 24-hour samples (ppb), measured by Annular Denuder System (ADS): Exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA

Site	Min	Median	Mean	95th Percentile	Max	# of Samples	Samples above Acute EMEG (1,700 ppb)		Samples above Chronic EMEG (100 ppb)	
							Number	Percent	Number	Percent
Fall 2014										
Site 4	9.41	70.56	70.55	131.82	151.59	35	0	0	9	25.71
Summer 2015										
Site 4	0	26.19	29.04	49.02	58.99	40	0	0	0	0
Totals										
Both events	0	38.93	47.49	114.92	151.59	75	0	0	9	12

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry, EMEG – Environmental Media Evaluation Guide (ATSDR) based off the acute, intermediate, or chronic duration MRL, MDL – method detection limit, MRL – ATSDR Minimal Risk Level, NH_3 – ammonia, ppb – parts per billion, UCL- upper confidence limit of the mean.
Notes: Site 4 was adjacent to feedlot. Annular Denuder System (ADS), MDL (0.25 µg/m3), NH3 samples were taken daily from 11/2/14-12/17/14 (Fall) and 6/23/15-8/13/15 (Summer).
Limitations/gaps: Samples were only collected at site 4 and do not represent entire study area.
Comments: The highest maximum value was an order of magnitude below the MRL.
None of the samples exceeded the odor threshold of 2,600 ppb.
Acute EMEGs are designed to be protective of exposure durations of 2 weeks or less.
Chronic EMEGs are designed to be protective of exposure durations of 1 year or longer.
No samples exceeded the acute EMEG of 1700 ppb.

Table C7. Ammonia 1-week samples (ppb), measured by Rapid Air Monitor (RAM): exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA

Site	Min	Median	Mean	95th Percentile	Max	# of Samples	Samples Above Chronic EMEG (100 ppb)	
							Number	Percent
Fall 2014								
Site 1	22.09	30.58	36.64	67.93	88.65	10	0	0
Site 2	30.20	56.39	54.33	72.56	75.78	10	0	0
Site 4	37.33	63.75	66.78	108.01	122.90	10	1	10.00
Site 5	17.94	27.62	26.92	32.47	32.60	10	0	0
Site 6	37.80	80.44	81.88	114.70	118.73	10	2	20.00
Site 7	27.76	44.03	45.16	60.97	68.78	10	0	0
Site 8	9.59	23.24	21.22	31.23	35.36	10	0	0
Site 9	20.15	35.51	36.90	51.33	53.51	9	0	0
Summer 2015								
Site 1	23.07	35.73	37.81	52.63	53.97	10	0	0
Site 2	21.43	28.44	29.30	36.73	37.03	10	0	0
Site 3	31.29	49.77	52.36	72.47	74.38	10	0	0
Site 4	34.35	72.02	67.84	90.09	95.79	18	0	0
Site 5	14.39	23.19	23.75	33.33	36.60	10	0	0
Site 7	22.14	34.18	35.15	45.20	45.80	10	0	0
Site 8	11.59	17.73	19.59	28.95	31.19	10	0	0
Site 9	29.08	37.70	41.87	54.33	56.47	9	0	0
Totals								
Fall 2014	9.59	40.22	46.35	89.88	122.9	79	3	4.24
Summer 2015	11.59	36.35	41.12	83.90	95.79	87	0	0
Both events	9.59	37.13	43.61	88.42	122.9	166	3	1.81

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry, EMEG – Environmental Media Evaluation Guide (ATSDR) based off the acute, intermediate, or chronic duration MRL, MDL – method detection limit, MRL – ATSDR Minimal Risk Level, NH_3 – ammonia, ppb – parts per billion, Rapid Air Monitor (RAM), UCL- upper confidence limit of the mean.
Notes: RAM MDL was ~2.5 µg/m3 for 1-week collections and ~1.5 µg/m3 for 2-week collections). RAM measurements included collection of 2-week samples in case 1-week samples were not above the MRL; since not exceeded, these data are not presented.
Limitations/gaps: RAM samples were compared to Chronic comparison values only.
Comments: None of these samples were above acute EMEG, 1,700 ppb, and the highest maximum value was an order of magnitude below the acute EMEG.
None of the samples exceeded the odor threshold of 2,600 ppb
Chronic EMEGs are designed to be protective of exposure durations of 1 year or longer.

Table C8. Ammonia 2-week samples (ppb), measured by Rapid Air Monitor (RAM): exceedences of comparison values, Yakama Nation Exposure Investigation, Harrah, WA

Site	Min	Median	Mean	95th Percentile	Max	# of Samples	Samples Above Chronic EMEG (100 ppb)	
							Number	Percent
Fall 2014								
Site 1	22.22	25.79	32.95	49.96	52.94	5	0	0
Site 2	33.12	57.62	54.50	62.87	63.32	5	0	0
Site 4	30.04	69.07	64.58	81.75	83.90	6	0	0
Site 5	21.04	23.38	24.93	30.96	32.58	5	0	0
Site 6	51.57	85.97	91.50	121.04	121.43	5	2	40.00
Site 7	39.28	43.93	44.56	52.31	53.97	5	0	0
Site 8	15.45	19.28	24.02	40.88	44.93	5	0	0
Site 9	20.85	36.13	31.62	37.71	37.89	3	0	0
Totals								
Fall 2014	15.45	39.95	47.3	89.32	121.43	39	2	5.13

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry, EMEG – Environmental Media Evaluation Guide (ATSDR) based off the acute, intermediate, or chronic duration MRL, MDL – method detection limit, MRL – ATSDR Minimal Risk Level, NH_3 – ammonia, ppb – parts per billion, Rapid Air Monitor (RAM), UCL- upper confidence limit of the mean.
Notes: RAM MDL was ~2.5 µg/m3 for 1-week collections and ~1.5 µg/m3 for 2-week collections). RAM measurements included collection of 2-week samples in case 1-week samples were not above the MRL; since not exceeded, these data are not presented.
Limitations/gaps: RAM samples were compared to Chronic comparison values only.
Comments: None of these samples were above acute EMEG, 1,700 ppb, and the highest maximum value was an order of magnitude below the acute EMEG.
None of the samples exceeded the odor threshold of 2,600 ppb
Chronic EMEGs are designed to be protective of exposure durations of 1 year or longer.

Table C9. Hydrogen Sulfide 1-minute Averages (ppb): Exceedences of comparison values and odor threshold, Yakama Nation Exposure Investigation, Harrah, WA

Site	Min	Median	Mean	95th Percentile	Max	# of Valid Samples*	Samples above Acute MRL (70 ppb)		Samples above Intermediate MRL (20 ppb)		Samples above Odor Threshold (0.5 ppb)	
							Number	Percent	Number	Percent	Number	Percent
Fall 2014												
Site 1	0	1.00	0.98	2.41	22.54	71,731	0	0.00	45	0.06	44,349	61.83
Site 2	0	0.63	1.03	3.11	34.23	73,286	0	0.00	122	0.17	40,971	55.91
Site 4	0	1.38	1.50	3.16	46.95	77,359	0	0.00	531	0.69	53,433	69.07
Site 5	0	1.00	1.03	2.77	8.44	74,515	0	0.00	0	0.00	52,903	71.00
Site 6C	0	0.61	0.65	2.02	8.13	76,456	0	0.00	0	0.00	39,086	51.12
Site 6P	0	0.63	0.66	2.02	19.41	76,451	0	0.00	0	0.00	40,410	52.86
Site 7	0	1.02	1.23	3.19	36.37	71,629	0	0.00	240	0.34	47,658	66.53
Site 9	0	0.69	0.83	2.83	19.41	61,460	0	0.00	0	0.00	30,961	50.38
Summer 2015												
Site 1	0	0	0.97	4.42	36.92	80,878	0	0.00	558	0.69	25,377	31.38
Site 2	0	0	1.61	4.59	89.92	71,964	47	0.07	1,420	1.97	26,603	36.97
Site 3C	0	0	0.16	1.05	6.48	39,096	0	0.00	0	0.00	5,229	13.37
Site 3P	0	0	0.51	1.78	41.04	79,213	0	0.00	375	0.47	17,693	22.34
Site 4	0	0	0.76	2.53	51.71	79,406	0	0.00	340	0.43	33,387	42.05
Site 5	0	0	0.74	2.19	89.92	62,793	16	0.03	510	0.81	16,844	26.82
Site 7	0	0	0.56	2.50	21.99	80,296	0	0.00	30	0.04	29,921	37.26
Site 8	0	0	0.79	3.19	32.25	58,832	0	0.00	577	0.98	12,865	21.87
Site 9	0	0	1.52	3.58	90.00	75.225	146	0.19	1,710	2.27	20,452	27.19
Totals												
Fall 2014	0	0.97	0.99	2.77	46.95	582,887	0	0.00	938	0.16	349,771	60.01
Summer 2015	0	0	0.88	2.86	90.00	627,703	209	0.03	5,520	0.88	188,371	30.01
Both events	0	0	0.934	2.80	90.00	1,210,590	209	0.02	6,458	0.53	538,142	44.45

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry, EMEG – Environmental Media Evaluation Guide based off the ATSDR MRL, EPA – U.S. Environmental Protection Agency, H_2S – hydrogen sulfide, MDL – method detection limit, MRL – ATSDR Minimal Risk Level, NA – not available, ppb – parts per billion, RfC – EPA reference concentration, UCL- upper confidence limit of the mean, C- Collocated, P- Primary.
Notes: Zellweger Single Point Monitor (MDL 2-90 ppbv, calibrate for 0-90 ppbv), H2S samples were taken every minute from 10/23/14-12/18/14 (Fall) and 6/23/15-8/19/15 (Summer). Limitations/gaps: Linear detection range is 52-1,200 ppbv, During the fall sampling period 51,861 samples were coded as N/A (removed from analysis when calculating summary statistics), and 230,611 were recorded as negative values and coded as zero by ERG. During the Spring sampling period 35,294 samples were coded as N/A (removed from analysis when calculating summary statistics), 221 samples were coded as zero with the comment “Power outage; data removed”, these values were also converted to N/A, and 428,102 were recorded as negative values and coded as zero by ERG.
Comments: Acute MRLs are designed to be protective of exposure durations of 2 weeks or less.
Intermediate MRLs are designed to be protective of exposure durations of 2 weeks to 1 year.

Table C10. Hydrogen Sulfide 30-minute Averages (ppb): Exceedences of comparison values and odor threshold, Yakama Nation Exposure Investigation, Harrah, WA

Site	Min	Median	Mean	95th Percentile	Max	# of Valid Samples*	Samples above Intermediate MRL (20 ppb)		Samples above EPA RfC (1.4 ppb)		Samples above Odor Threshold (0.5 ppb)	
							Number	Percent	Number	Percent	Number	Percent
Fall 2014												
Site 1	0	0.99	0.98	2.41	21.70	2,396	1	0.04	523	21.82	1,444	60.27
Site 2	0	0.72	1.03	3.12	26.01	2,452	3	0.12	542	22.10	1,336	54.49
Site 4	0	1.22	1.50	3.24	44.68	2,585	16	0.62	1,056	40.85	1,783	68.97
Site 5	0	0.99	1.03	2.74	8.01	2,490	0	0	583	23.41	1,692	67.95
Site 6C	0	0.45	0.65	1.83	6.94	2,555	0	0	360	14.09	1,253	49.04
Site 6P	0	0.52	0.66	1.87	18.58	2,555	0	0	312	12.21	1,288	50.41
Site 7	0	1.03	1.25	3.34	27.51	2.399	7	0.29	683	28.47	1,567	65.32
Site 9	0	0.51	0.83	2.71	10.50	2,059	0	0	487	23.65	1,031	50.07
Summer 2015												
Site 1	0	0	0.97	4.72	29.86	2,700	16	0.59	359	13.3	919	34.04
Site 2	0	0	1.61	5.03	67.96	2,410	45	1.87	489	20.29	901	37.39
Site 3C	0	0.01	0.16	0.97	3.61	1,306	0	0	24	1.84	176	13.48
Site 3P	0	0.01	0.51	1.73	36.00	2,647	9	0.34	189	7.14	572	21.61
Site 4	0	0	0.76	2.49	32.39	2,651	11	0.41	394	14.86	1,084	40.89
Site 5	0	0	0.74	2.31	56.71	2,097	16	0.76	175	8.35	546	26.04
Site 7	0	0	0.56	2.49	15.28	2,680	0	0	350	13.06	955	35.63
Site 8	0	0	0.79	4.05	29.6	1,963	12	0.61	172	8.76	406	20.68
Site 9	0	0	1.53	4.88	66.07	2,521	58	2.3	376	14.91	681	27.01
Totals												
Fall 2014	0	0.85	0.99	2.64	44.68	19,491	27	0.14	4,546	23.32	11,394	58.46
Summer 2015	0	0	0.88	2.96	67.96	20,975	167	0.8	2,528	12.05	6,240	29.74
Both events	0	0.04	0.94	2.79	67.96	40,466	194	0.48	7,074	17.48	17,634	43.58

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry, EMEG – Environmental Media Evaluation Guide based off the ATSDR MRL, EPA – U.S. Environmental Protection Agency, H_2S – hydrogen sulfide, MDL – method detection limit, MRL – ATSDR Minimal Risk Level, NA – not available, ppb – parts per billion, RfC – EPA reference concentration, UCL- upper confidence limit of the mean, C- Collocated, P- Primary.
Notes: Zellweger Single Point Monitor (MDL 2-90 ppbv, calibrate for 0-90 ppbv), H2S samples were taken every minute from 10/23/14-12/18/14 (Fall) and 6/23/15-8/19/15 (Summer). Limitations/gaps: Linear detection range is 52-1,200 ppbv, During the fall sampling period 51,861 samples were coded as N/A (removed from analysis when calculating summary statistics), and 230,611 were recorded as negative values and coded as zero by ERG. During the Spring sampling period 35,294 samples were coded as N/A (removed from analysis when calculating summary statistics), 221 samples were coded as zero with the comment “Power outage; data removed”, these values were also converted to N/A, and 428,102 were recorded as negative values and coded as zero by ERG.
Comments: EMEG/MRL (70ppb) was omitted from this graph and replaced with EPA RfC of 1.4 ppb, no 30-minute average were above 70ppb.
RfCs are designed to be protective of exposure durations of 1 year or longer.
Intermediate MRLs are designed to be protective of exposure durations of 2 weeks to 1 year.

Table C11. Hydrogen Sulfide Daily Averages (ppb): Exceedences of comparison values and odor threshold, Yakama Nation Exposure Investigation, Harrah, WA

Site	Min	Median	Mean	95th Percentile	Max	# of Valid Samples*	Samples above Intermediate MRL (20 ppb)		Samples above EPA RfC (1.4 ppb)		Samples above Odor Threshold (0.5 ppb)	
							Number	Percent	Number	Percent	Number	Percent
Fall 2014												
Site 1	0	1.03	0.97	1.82	2.00	53	0	0	9	16.98	44	83.02
Site 2	0	0.98	1.01	1.88	3.22	55	0	0	13	23.64	42	76.36
Site 4	0	1.44	1.46	2.55	3.39	56	0	0	29	51.79	49	87.50
Site 5	0.02	1.01	1.00	1.88	2.35	54	0	0	15	27.78	41	75.93
Site 6C	0	0.59	0.65	1.38	1.83	55	0	0	3	5.45	31	56.36
Site 6P	0.03	0.70	0.66	1.23	1.72	55	0	0	2	3.64	35	63.64
Site 7	0.04	1.19	1.30	2.59	3.59	55	0	0	18	32.73	52	94.55
Site 9	0	0.66	0.80	1.78	2.19	47	0	0	6	12.77	33	70.21
Summer 2015												
Site 1	0.23	0.90	0.98	1.92	3.99	58	0	0	12	20.69	43	74.14
Site 2	0	1.38	1.57	3.61	7.29	56	0	0	28	50.00	45	80.36
Site 3C	0	0.13	0.16	0.43	0.47	29	0	0	0	0.00	0	0.00
Site 3P	0	0.33	0.52	1.72	2.00	57	0	0	7	12.28	19	33.33
Site 4	0	0.67	0.76	1.49	2.74	57	0	0	8	14.04	38	66.67
Site 5	0	0.50	0.73	1.38	5.52	46	0	0	2	4.35	23	50.00
Site 7	0.05	0.52	0.56	1.01	1.33	57	0	0	0	0.00	30	52.63
Site 8	0	0.67	0.80	1.87	2.30	42	0	0	6	14.29	27	64.29
Site 9	0.01	0.90	1.45	5.39	12.87	56	0	0	14	25.00	42	75.00
Totals												
Fall 2014	0	0.98	0.99	2.09	3.59	430	0	0	95	22.09	327	76.05
Summer 2015	0	0.63	0.88	2.08	12.87	458	0	0	77	16.81	267	58.30
Both events	0	0.80	0.93	2.09	12.87	888	0	0	172	19.37	594	66.89

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry, EMEG – Environmental Media Evaluation Guide based off the ATSDR MRL, EPA – U.S. Environmental Protection Agency, H_2S – hydrogen sulfide, MDL – method detection limit, MRL – ATSDR Minimal Risk Level, NA – not available, ppb – parts per billion, RfC – EPA reference concentration. UCL- upper confidence limit of the mean, C- Collocated, P- Primary.
Notes: Zellweger Single Point Monitor (MDL 2-90 ppbv, calibrate for 0-90 ppbv), H2S samples were taken every minute from 10/23/14-12/18/14 (Fall) and 6/23/15-8/19/15 (Summer). Limitations/gaps: Linear detection range is 52-1,200 ppbv, During the fall sampling period 51,861 samples were coded as N/A (removed from analysis when calculating summary statistics), and 230,611 were recorded as negative values and coded as zero by ERG. During the Spring sampling period 35,294 samples were coded as N/A (removed from analysis when calculating summary statistics), 221 samples were coded as zero with the comment “Power outage; data removed”, these values were also converted to N/A, and 428,102 were recorded as negative values and coded as zero by ERG.
Comments: EMEG/MRL (70ppb) was omitted from this graph and replaced with EPA RfC of 1.4 ppb.
RfCs are designed to be protective of exposure durations of 1 year or longer.
Intermediate MRLs are designed to be protective of exposure durations of 2 weeks to 1 year.

Appendix D. Explanation and Interpretation of Boxplots

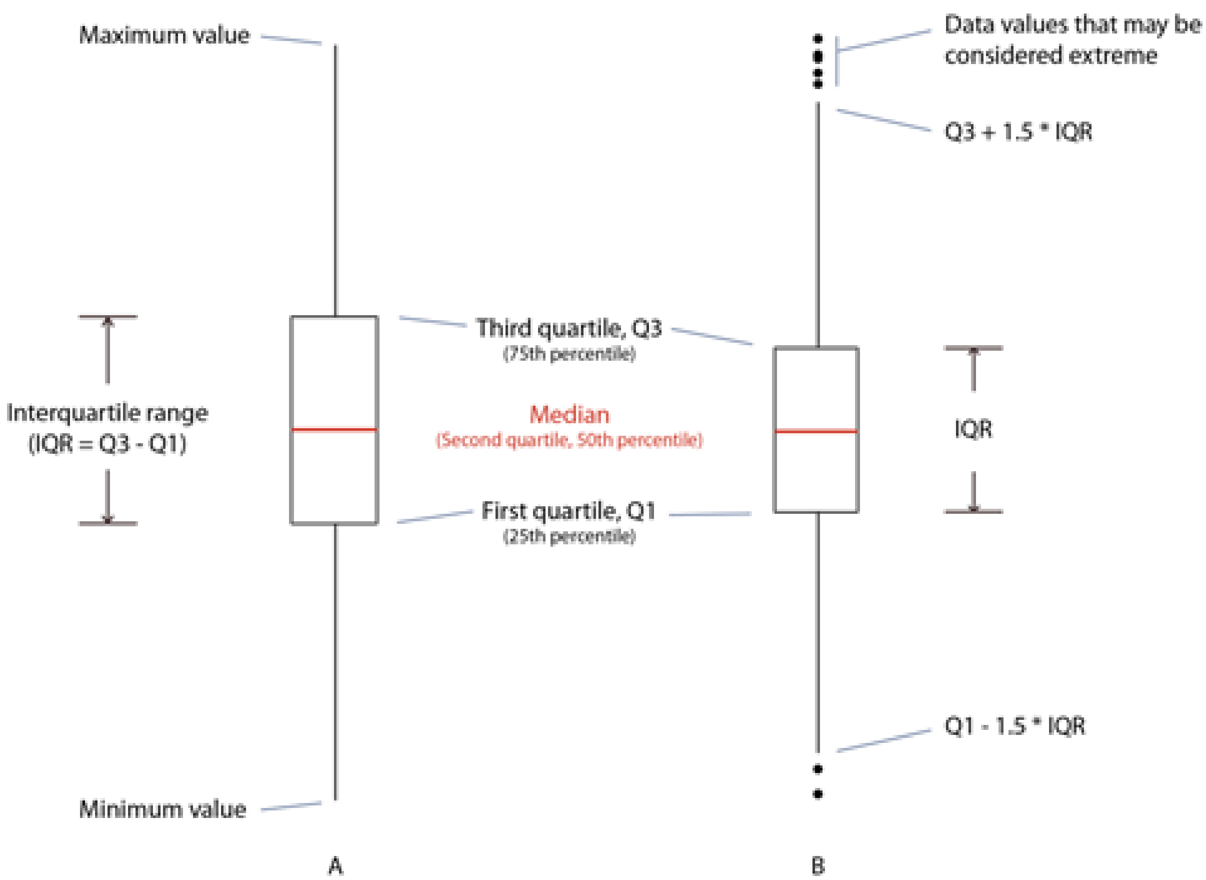


Figure 1. Boxplot with whiskers (vertical lines above and below the box) representing (A) maximum and minimum data values, and (B) an extent defined as 1.5 times the IQR.

How can I read a boxplot?

The components of the boxplot illustrate what is often called the five-number summary of a data set: the median, minimum, maximum, and first and third quartiles.

- The **median**, also called the second quartile or 50th percentile, is a measure of the center of the data. The median is the value that is in the middle of the data, so 50% of the data will be above the median and 50% of the data will be below the median. The average–which is another measure of the center of the data–is obtained by summing together all of the data values and dividing by the number of values (n). Because the median is less affected by extreme values in the data, it can be a better central measure than the average. The average often is not shown on a boxplot.

- The **minimum** and **maximum** refer to the lowest and highest values, respectively.
- The **first** and **third quartiles,** or 25th and 75th percentiles, respectively, correspond to the outer edges of the box and represent the mid-points between the median and the minimum and maximum values in the data. Specifically, 25% of the data are below the first quartile and 25% of the data are above the third quartile.

The **interquartile range** (IQR) is the range between the first and third quartiles (Q3-Q1) and corresponds to the span or the extent of box itself. The extent of the box visually represents 50% of the data. The lines extending from the box can represent different quantities. Sometimes the lines are extended to the minimum and maximum values of the data. Alternately the lines may be extended to the last data value that is within 1.5 times the IQR from the first and third quartiles (e.g., Q3 + 1.5 *IQR). In the latter case, any data values that lie outside of the defined extent often are symbolized individually as data points that may be considered more extreme values.

Appendix E. More Information on Odors

Since Harrah and Yakima area residents have expressed concerns about recurring odors in the air from nearby animal feeding operations and other agricultural sources in the area, general information about odors is presented below.

Odors and Health

Unpleasant environmental odors can affect people's sense of wellbeing and reduce their quality of life. Odors can also be a warning of potential risk and might cause symptoms in sensitive persons [Schiffman and Williams 2005]. Exactly how odors relate to health varies by chemical and by person. For many chemicals, people can smell odors at levels far lower than the levels known to cause symptoms or diseases. Conversely, some chemicals might have harmful effects at levels below their odor thresholds, which is the concentration that can be first detected by smell. Further, some chemicals, such as carbon monoxide, do not exhibit any odor at all. So, odoriferous air does not mean chemicals are present at harmful levels and the absence of odors does not mean that the air is harmless to breathe.

Not everyone reacts to odors in the same way. Some people might adversely react to an environmental odor, while others might have no reaction at all. Many factors, including personal traits and habits, affect how someone responds to environmental odors. People with lung diseases, such as asthma and chronic obstructive pulmonary disease (COPD), migraines, and depression might be particularly sensitive to odor effects.

When an airborne chemical is near its odor threshold, people can first *detect* the odor. As the chemical's airborne levels increase, people can *recognize* the specific odor type and might exhibit various health symptoms, such as headache and nausea. As noted previously, a chemical's harmful levels are sometimes above and sometimes below odor thresholds. In some cases, health symptoms might be due to a non-odorous chemical in the air at harmful levels rather than an odorous chemical.

Several factors help explain a person's reaction to environmental odors. Health symptoms might happen when a person breathes an odorous chemical at levels that also cause irritation or other toxicological (harmful) effects. In this instance, the irritation rather than the odor likely causes the health symptoms. Basically, when an odorous chemical in the air stimulates odorant receptors mediated by the olfactory nerve in the nasal cavity, the odor sensations produced are described as floral, fruity, earthy, fishy, and other such adjectives. When, however, the chemical also activates the trigeminal nerve endings in the upper and lower respiratory system, sensations such as irritation, burning, stinging, scratching, and itching can occur. Although both odor and irritant sensations occur simultaneously, irritation more likely causes the health symptoms, rather than odor [Schiffman and Williams 2005].

Health symptoms from odors might also occur at nonirritating levels above the odor threshold, especially when the odor is unpleasant. People are genetically coded in a way that pleasant and unpleasant odors activate different parts of the brain, and a biological imperative appears to alert people reflexively to avoid unpleasant odors. If unpleasant odors are strong, shallow and irregular breathing can occur. Breathing unpleasant odors can also exacerbate illnesses because the odors impair mood and induce stress. Further, in the absence of flu virus or allergy, learned associations might play a role; for example, if an unpleasant odor has previously been associated with flu or allergic symptoms, the odor alone might subsequently recreate these symptoms [Schiffman and Williams 2005].

Olfactory fatigue is another important reaction to environmental odors. Continuous exposure to an odor results in the disappearance of the odor even though the chemical remains in the air. If the exposure is not too prolonged, the odor might return after the person breathes fresh air for a few minutes. On the other hand, workers chronically exposed to strong odors can experience olfactory fatigue that persists for weeks [Amoore and Hautala 1983].

ATSDR's Web site has general information on odors and health at:
http://www.atsdr.cdc.gov/odors/.

References

Amoore JE, Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatilities for 214 industrial chemicals in air and water dilution. J Appl Toxicol 3(6):272-290.

Schiffman SS and Williams CM. 2005. Science of Odors as a Potential Health Issue. Journal of Environmental Quality 34: 129-138.