Airborne Total Dust, PM 2.5, and NH_3 and Residential Proximity to Confined Animal Feeding Operations (CAFOs) and Rural Roadways

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Abstract

A novel air sampler was built to simultaneously monitor airborne contaminants at 14 sites in the Yakima Valley region of Washington State as part of an epidemiological study examining potential triggers of children's asthma. All sites were carefully placed in regards to their proximity to CAFOs and major roadways. CAFOs emit contaminants such as ammonia (NH_3)and subsequent dust particles due to the congregation of animals, feed, manure, and urine. Roadways can also be a large source of particulate in areas of dry-land agriculture. Although urban studies are common, less have examined respiratory health outcomes stemming from exposure to these potential airborne triggers in the rural environment. Samples were collected over 8 months (September 2011-April 2012), filters from the samplers were weighed on a Mettler Toledo® ultra-microbalance to determine the level of Total Dust and PM 2.5, and chemical analysis was conducted for NH_3 by ion chromatography. The proximity of site locations and grouping into tertiles was determined using high resolution satellite imaging to geocode locations of CAFOs and roadways [NASATerra images (2011) for Google Earth Pro 6.2, ArcGIS].Throughout the year, proximal sites (<2km from CAFOs) have mean levels of ammonia 38 µg/m^3, respirable dust 17 µg/m^3, and total dust 90 µg/m^3. Intermediate sites (2-3 km) have mean levels of ammonia 24 µg/m^3, respirable dust 17 µg/m^3, and total dust 85 µg/m^3. Distal sites (>3km) have mean levels of ammonia levels of 8 µg/m^3, respirable dust 14 µg/m^3, and total dust 76 µg/m^3. Sites were also examined for distance to major roadways (interstates, state highways, county parkways). Results show those sites that have proximal distances (<0.4 km) to highways have mean levels total dust 97 µg/m^3 and respirable dust 33 µg/m^3. Intermediate sites (0.4 - 1 km) showed mean levels of total dust 76 µg/m^3 and respirable dust 14 µg/m^3. Distal sites (>1km) had mean levels of total dust of 76 µg/m^3 and respirable dust 19 µg/m^3. Overall, total dust levels were high and not statistically different amount sites. However, different levels of exposure are observed for PM 2.5 and ammonia based on proximity.

Introduction

Air sampling was conducted in the Yakima Valley region of Central Washington State in response to citizens' health concerns about Confined Animal Feeding Operations (CAFO's) and their effects on the surrounding community to address multiple environmental health stressors. This agricultural region is a setting of intense orchard and row crops, food packing, and large scale dairy operations. All monitoring locations were selected regarding their proximity to confined animal feeding operations (CAFOs), agricultural fields, and major roadways. CAFOs emit contaminants such as ammonia (NH_3) and subsequent dust particles due to the congregation of animals, feed, manure, and urine. Roadways can also be a large source of particulate in areas of dry-land agriculture. Past studies have demonstrated significant differences in the prevalence of physician-diagnosed asthma among schools located near CAFOs (Sigurdarson and Kline 2005). Other studies, conducted in the same area, have concluded there is a concentration gradient of airborne contaminants with proximity to operations. Concentrations were significantly greater at homes within one-quarter mile (0.4 km) of dairy facilities, outdoor Bos d 2, ammonia, and TD were 60x, 8x, and 2x greater when compared to homes greater than three miles (4.8 km) away (Williams et al. 2011)

Methods

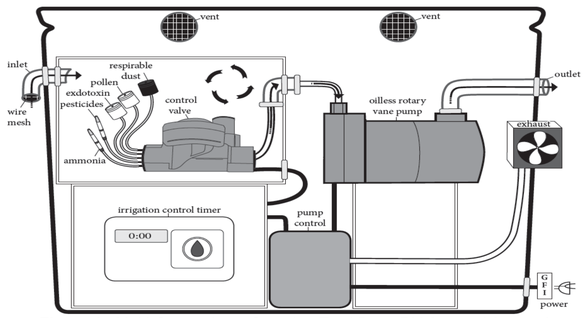


Figure 1: Multi-Contaminant Sampler: Total Dust, PM 2.5, and Ammonia

Sampler and Site Locations

- Sample collection was performed with a multi-contaminant sampler (Fig 1)
- 14 Site locations were identified based on proximity to CAFOs and major roadways (Fig 3)
- Sites were separated into tertiles based on proximity to CAFOs, roadways: CAFOS: Proximal (<2 km), Intermediate (2-3 km), and Distal (>3 km) Roadways: Proximal (<0.4 km), Intermediate (0.4-1 km), and Distal (>1 km)

Filters

- Filters for Total Dust and PM 2.5 were weighed on a Mettler-Toledo® Ultra Microbalance and saved in cassettes for future analysis

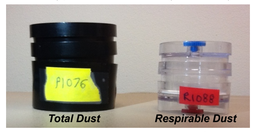


Figure 2: Total Dust and PM 2.5 Cassettes

GIS and Proximity of Sites to CAFOs, Major Roadways, Cattle Density

- GoogleEarth (Version 6.0.1.2032 (beta)) enabled NASATerra satellite imaging (2011) of sample sites, road classification, and CAFOs
- GIS Data was combined with a distance tool to calculate proximity of sample sites to nearest CAFOs and roadways in kilometers
- CAFOs reported number head in each drove, this was used to calculate cattle density in the 3 km buffer zone around each site in Head/Acre:

$$Head/Acre = \frac{X_1 + X_2 + X_3 \ldots}{\pi r^2\,(6,968\ acres)}$$

*Where X_1 = number of cattle in operation 1, X_2 = number of cattle in operation 2, etc. within 3 km buffer zone and **r** =radius, or 3 km. This was converted to acres.*

Results

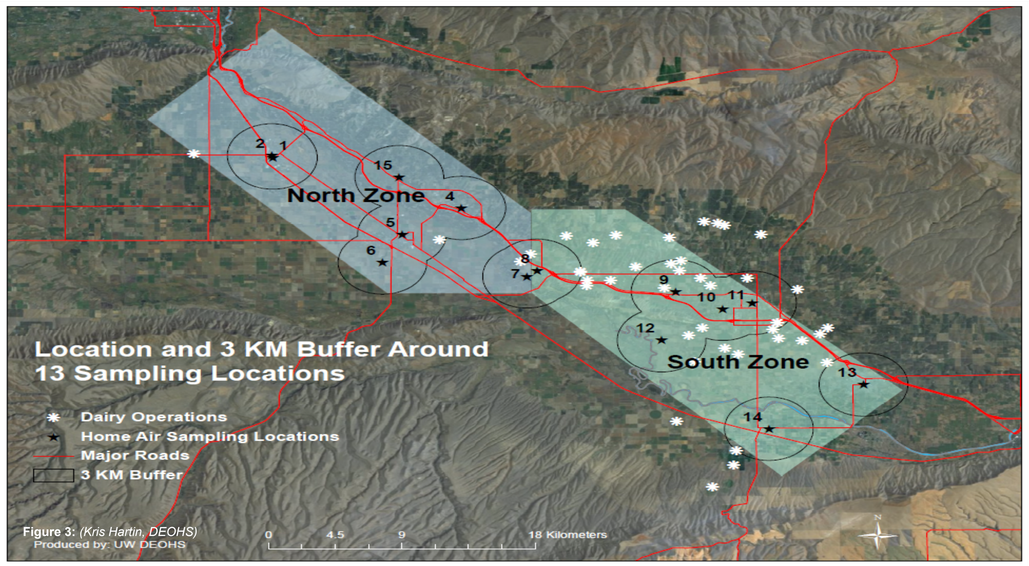


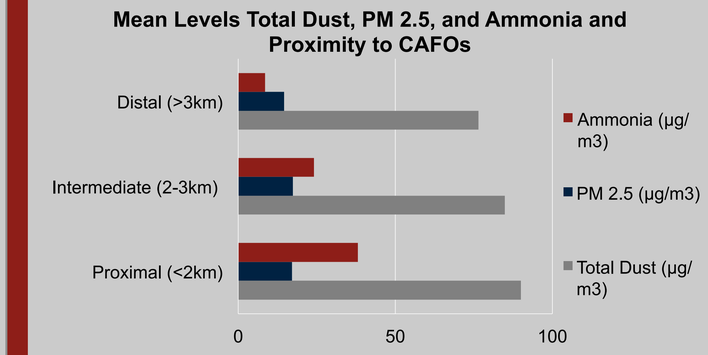
Figure 3: *(Kris Hartin, DEOHS)* Produced by: UW DEOHS

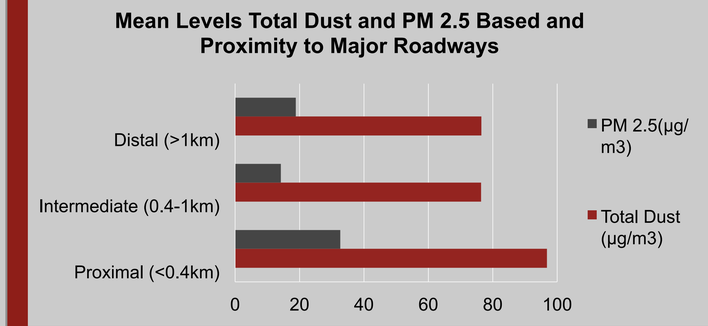
Site #	# CAFO's >3Km (Unreported)	Cattle Density Head/Acre	Total Dust (ug/m3)		PM 2.5 (ug/m3)		Ammonia (ug/m3)	
			Mean (SD)	Max	Mean (SD)	Max	Mean (SD)	Max
Proximal								
4	1 (0)	0.46	79.9 (53.1)	187.6	16.4 (14.4)	36.4	10.3 (6.8)	25.7
7	2 (2)	0.29	72.3 (56.9)	193.7	16.4 (13.0)	38.4	13.0 (11.4)	34.7
8	3 (3)	0.48	83.3 (64.2)	262.0	16.3 (13.5)	38.1	31.1 (20.1)	65.2
9	3 (5)	0.26	120.0 (199.9)	960.2	23.5 (29.2)	109.2	112.4 (65.0)	238.1
14	4 (0)	0.95	94.4 (82.3)	323.2	13.2 (13.5)	323.2	23.5 (18.3)	69.4
Total:			**89.9 (61.8)**		**17.2 (7.0)**		**38.1 (44.3)**	
Intermediate								
5	0 (1)	–	93.2 (50.1)	164.0	16.0 (15.4)	40.4	10.0 (8.1)	27.4
10	1 (3)	0.04	63.7 (68.4)	234.8	17.7 (14.6)	40.0	24.9 (18.7)	76.0
11	3 (3)	0.46	76.8 (57.7)	208.3	15.8 (14.0)	36.6	11.7 (10.5)	23.7
12	0	0.04	105.7 (154.2)	737.0	20.1 (18.9)	49.7	49.6 (45.3)	152.8
Total:			**84.8 (48.1)**		**17.4 (2.2)**		**24.1 (17.1)**	
Distal								
1	–	–	74.4 (54.5)	271.2	9.0 (13.5)	31.4	3.6 (1.7)	8.6
2	–	–	75.5 (54.1)	233.2	14.1 (14.9)	40.3	5.5 (4.7)	20.7
3	–	–	64.2 (55.6)	217.0	21.0 (19.0)	51.4	7.8 (5.7)	17.6
6	–	–	67.5 (56.4)	169.0	13.6 (14.4)	36.3	3.8 (2.9)	9.9
13	3 (0)	0.12	100.9 (61.8)	305.9	15.1 (12.1)	35.4	22.0 (13.5)	55.6
Total:			**76.5 (3.1)**		**14.6 (2.7)**		**8.5 (4.6)**	

Table 1: Mean and Max Levels of Total Dust, PM 2.5, and Ammonia Levels, Head Per Acre and Number of unlisted CAFOs within a 3 km Buffer for All Sampling Locations

Site #	Total Dust (ug/m3)		PM 2.5 (ug/m3)	
	Mean (SD)	Max	Mean (SD)	Max
Proximal				
2	75.5 (54.1)	233.2	14.1 (14.9)	40.3
5	93.2 (50.1)	164.0	16.0 (15.4)	40.4
9	120.0 (199.9)	960.2	23.5 (29.2)	109.2
13	100.9 (61.8)	305.9	15.1 (12.1)	35.4
14	94.4 (82.3)	323.2	13.2 (13.5)	323.2
Total:	**96.8 (62.8)**		**32.6 (6.9)**	
Intermediate				
1	74.4 (54.5)	271.2	9.0 (13.5)	31.4
4	79.9 (53.1)	187.6	16.4 (14.4)	36.4
6	67.5 (56.4)	169.0	13.6 (14.4)	36.3
8	83.3 (64.2)	262.0	16.3 (13.5)	38.1
11	76.8 (57.7)	208.3	15.8 (14.0)	36.6
Total:	**76.4 (4.3)**		**14.2 (.5)**	
Distal				
3	64.2 (55.6)	217.0	21.0 (19.0)	51.4
7	72.3 (56.9)	193.7	16.4 (13.0)	38.4
10	63.7 (68.4)	234.8	17.7 (14.6)	40.0
12	105.7 (154.2)	737.0	20.1 (18.9)	49.7
Total:	**76.5 (47.3)**		**18.8 (3.1)**	

Table 2: Mean and Max Levels of Total Dust and PM 2.5 Levels within a 3 km Buffer to Major Roadways and Sampling Locations





Discussion

- Airborne concentrations Total Dust and Ammonia reported in this study are orders of magnitude higher than measured in previous studies
- Sample sites that were proximal to CAFOs reported higher yearly average levels of ammonia and total dust than distal and intermediate sites
- Sample sites that were proximal to major roads reported higher yearly average levels of both total dust and P.M 2.5
- There was less of a difference in sample sites regarding proximity to CAFOs and yearly averages of P.M 2.5, highlighting the potential of other sources that were not accounted for in this study
- More in-depth analysis of specific allergens and microbes from total dust filters; and examining other potential sources will provide more information for this study
- A limitation of the study is the statistical analysis did not account for seasonality or missing data

References

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PMCID: PMC1253764

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