From:	[redacted]
To:	Kelsey Peddle; [redacted]
Subject:	Fwd: Scan File Attached - Do Not Reply
Date:	May 2, 2024 3:18:03 PM
Attachments:	2806_001.pdf

To: NRCB, MD of Willow Creek, Town of Fort Macleod

Greetings:

Re: Application LA24002 - Notification Letter, Van Huigenbos Farms Ltd. SE 21-9-26-W4M

We too are engaged in agriculture, so fully understand the applicants' desire to expand their business. However, given the test results from scientific studies, I want to advocate on behalf of my young Grandson and others who live nearby, with serious allergies. He lives approximately 1.5 miles from the proposed feedlot and an expansion to 16,500 head could possibly impact his health so adversely that he would be forced to move from his home. According to studies, airborne Bos d 2 (allergen) and ammonia concentrations begin to diminish after a 3 mile distance but exposure even at this distance has known human health effects. The subject location is simply too close to Residences and too close to the Town of Fort Macleod limits. Scarcity of water supply, pollution of Willow Creek and surrounding drinking water wells, pose risks we should not be taking. This application raises serious concerns for us all and should be REJECTED.

There will be a TOWN HALL MEETING on Saturday, May 4th 10:00 am at the old Court House building on 23rd St. I have been notified that everyone is welcome to attend.

Name: Bernadette McNab & Marc McNab
Legals: NE23-9-26-W4M, SW25-9-26-W4M
[redacted]

Regards,
Bernadette McNab

NRCB | Natural Resources Conservation Board

Agriculture Centre, 100, 5401 1 Avenue S
Lethbridge, Alberta T1J 4V6
403-381-5166
www.nrcb.ca

April 11, 2024

To: Landowner or Resident

Re: Application LA24002 – Notification Letter
Van Huigenbos Farms Ltd.
SE 21-9-26 W4M

The Natural Resources Conservation Board (NRCB) has received an application from Van Huigenbos Farms Ltd. to expand a confined feeding operation (CFO) at SE 21-9-26 W4M. The application is to increase beef feeder calf numbers from 2,500 to 16,500; reduce beef feeder numbers from 1,200 to 0; construct east pens (153.4 m x 36.9 m); west pens (160.3 m x 36.9 m); north pens (160.3 m x 36.8 m); north catch basin (130 m x 40 m x 2 m deep); and south catch basin (105 m x 36.6 m x 2 m deep). Under the *Agricultural Operation Practices Act* (AOPA), the NRCB is responsible for regulating CFOs in Alberta.

The NRCB will conduct a detailed technical review of the application to ensure it meets the requirements of the Act and regulations.

This letter is being sent to all persons who own or reside on land within 1.5 miles of the CFO as identified by the MD of Willow Creek or the Town of Fort Macleod. Under AOPA, an "affected party" is entitled to receive notice of the application. The location of your land or residence is within the notification distance from the CFO, as set out by AOPA.

The application is available for viewing online at www.nrcb.ca (under Confined Feeding Operations / Notice of Applications) or at the Lethbridge office by appointment. **The notice of the application will be published in the April 17, 2024 issue of the Macleod Gazette.**

If you would like to submit a response that expresses your concern or support for the application under AOPA, please send it to my attention at the address on this letter, or by email at kelsey.peddle@nrcb.ca. Your response must be received in writing on or before **4:30 pm on May 15, 2024**. Your response must include:

- your name,
- the legal land description of the land you reside on and/or own,
- your contact information: mailing address; phone number; and email address, and,
- an explanation of your support or concern (including any relevant documents).

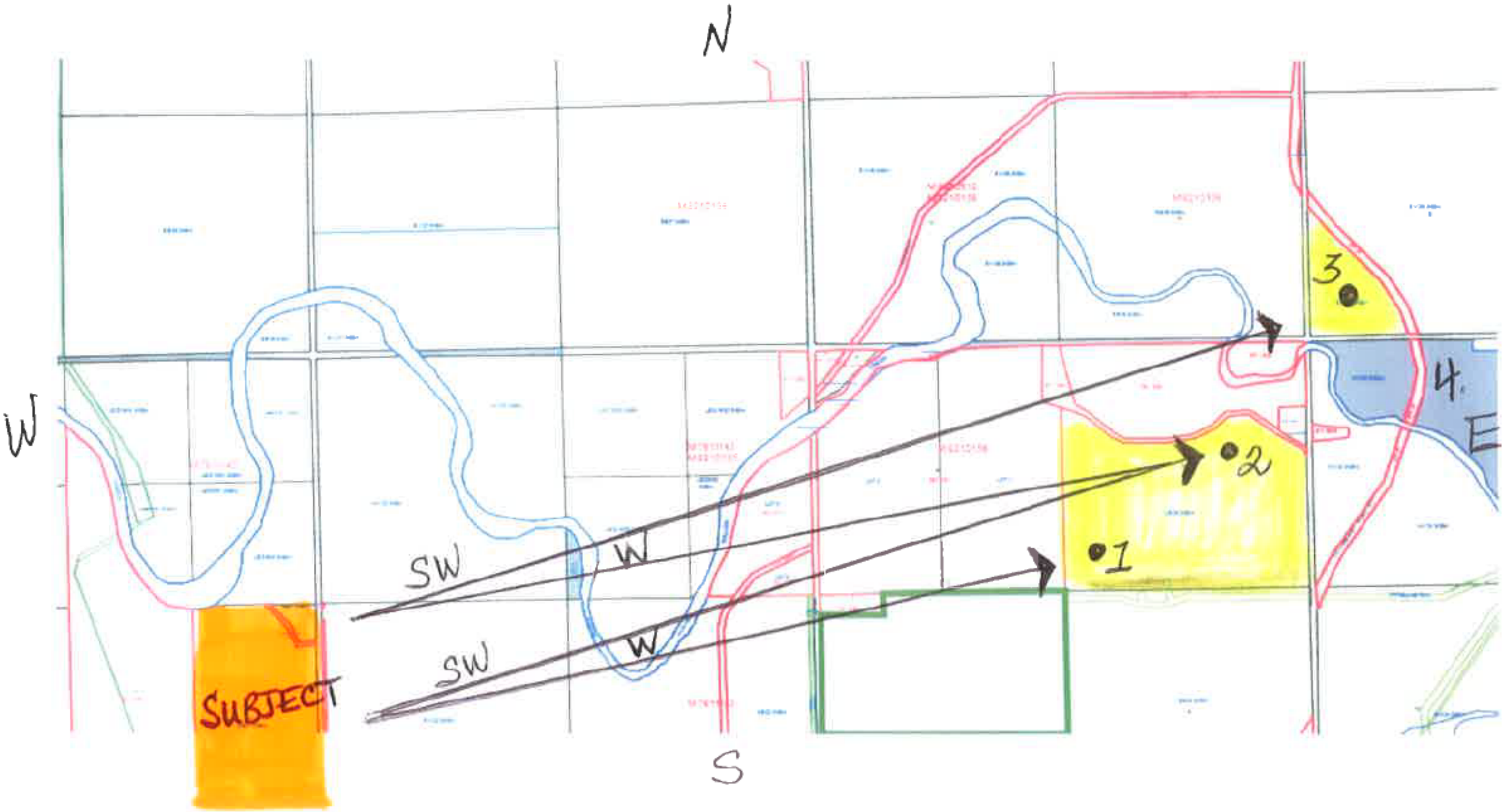
All responses are considered public documents and may be posted on the NRCB's public website. A copy will be given to the applicant. If your response includes concerns that do not fall under the authority of the NRCB, it may be forwarded to other agencies. If you would like all or part of your response to be considered confidential, please identify in your response the part(s) that should be confidential and why.

Parties who submit responses will receive a copy of the decision and may have an opportunity to request a Board review of the decision should they disagree with all, or portions of it.

If you have any questions or concerns, please contact me at 587-334-2560 or kelsey.peddle@nrcb.ca.

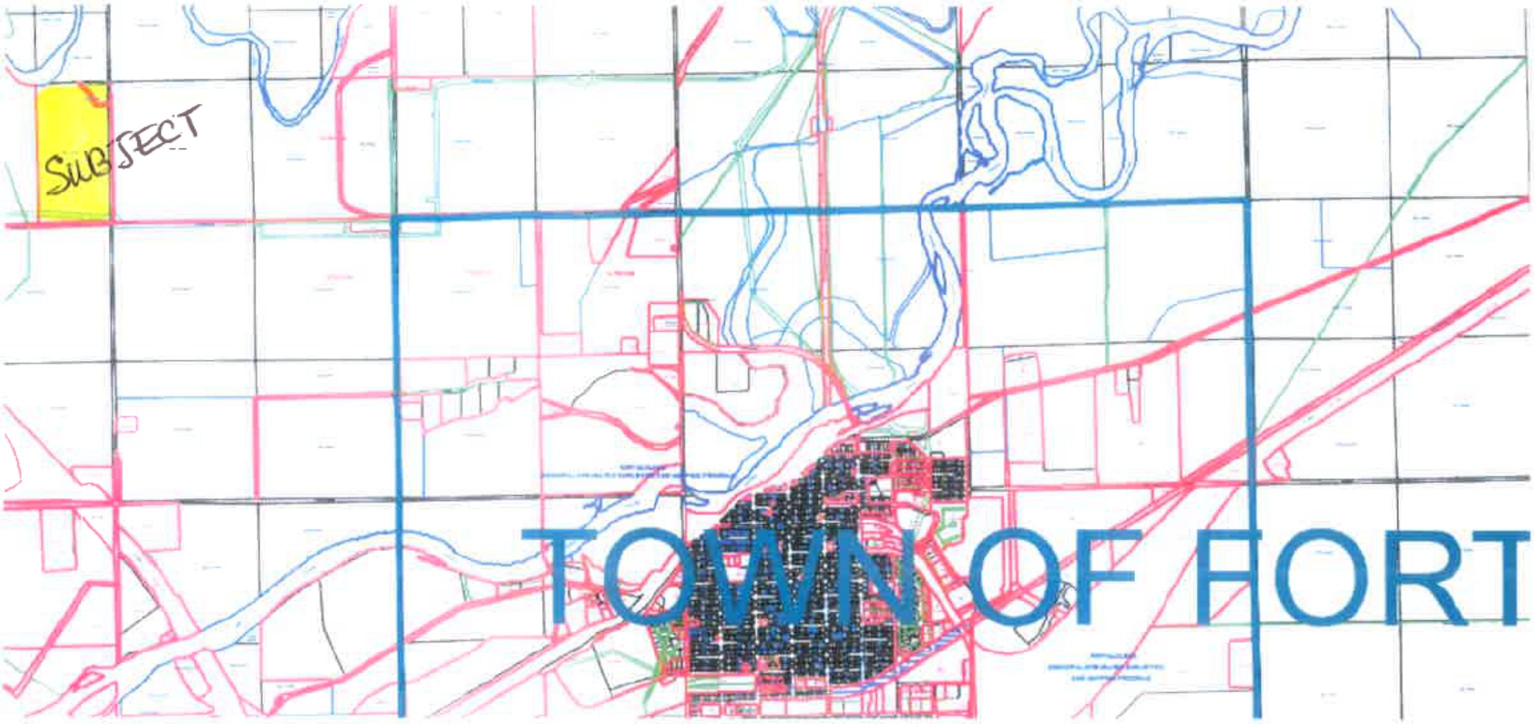
Yours truly,

Kelsey Peddle
Approval Officer



- West & Southwest Prevailing winds bring odors.
  - we have 3 residences within 1.5 to 2 miles from subject property

* my Grandson (13 yrs) lives in #1 location and he has 4 F allergy to cow. (See studies attached) He carries an epi-pen. Bos d2 and endotoxin concentrations ammonia and particulate matter is a serious problem @ 1.5 miles.
- We have concerns with proximity of subject property to the creek
- Hydrology studies indicate the groundwater travels in a NE direction, north of the Oldman River, in this area. Possible contaminants could escape and creep into drinking water wells at the 3 residences.
- concerns of excessive manganese levels in our drinking water if potassium permanganate is used at the feedlot.



- SUBJECT PROPERTY IS LOCATED TOO CLOSE TO TOWN OF FORT MACLEOD
- TOO CLOSE TO RESIDENTIAL ACREAGES
- TOO CLOSE TO LIONS CAMPGROUD (shown as LOCATION #4)
- TOO CLOSE TO FORT MACLEOD WILDERNESS PARK
- TOO CLOSE TO FORT MACLEOD GOLF COURSE
- TOO CLOSE TO WILLOW CREEK
- TOO CLOSE FOR HEALTH AND COMFORT

Google what is a 4F allergy test result? Sign in

All Images Videos Shopping News ⋮ More Tools SafeSearch

About 587,000,000 results (0.36 seconds)

Oak Brook Allergists
https://www.oakbrookallergists.com · 2 years ago

How to Interpret Your Food Allergy Test Results

Values over 100.00 mean extremely likely. The higher the number, the more likely it is **that the food allergen is causing the allergy symptoms**.
Missing: 4F | Show results with: 4F

People also ask

* What is a level 4 allergy?

Class 4: Very high level of allergy (17.50 KUA/L – 49.99 KUA/L) indicative of very high level sensitization. Class 5: Very high level of allergy (50.00 KUA/L – 99.9 KUA/L) indicative of very high level sensitization. Class 6: Very high level of allergy (≥ 100.0 KUA/L) indicative of very high level sensitization.

healthlabtesting.com
https://www.healthlabtesting.com › Test Directory Item

ALLERGEN - CAT DANDER IgE (E1) - HealthLab

What do the numbers mean on allergy test results?

What do W and F mean on an allergy test?

Can F4 allergen?

How do you treat type 4 allergies?

What is a level 4 peanut allergy?

Feedback

DermNet
https://dermnetnz.org › topics › skin-prick-testing

Skin prick testing

Introduction. Skin prick testing is an allergy test used **to identify allergens responsible for triggering symptoms in allergic diseases**.

Spiriplex
https://spiriplex.com › uploads › 2018/04 › How-t... PDF

How to Interpret Your Allergenex Test Results

Class 4 and Above. **Very High Sensitivity**. Wheat (f4) ... The Allergenex test results ... Even allergens found at low levels that do not result in symptoms should be ...

Mayo Clinic Laboratories
https://www.mayocliniclabs.com › download-setup PDF

Test Definition: DOGPF

-Positive results for IgE to total dog dander or any potential dog allergenic components

Canada **Fort Macleod, Alberta** - From your IP address - Update location

Journal of Exposure Science and Environmental Epidemiology (2016) 26, 42–47

www.nature.com/jes

OPEN

ORIGINAL ARTICLE

Cow allergen (Bos d2) and endotoxin concentrations are higher in the settled dust of homes proximate to industrial-scale dairy operations

D' Ann L. Williams[1], Meredith C. McCormack[2], Elizabeth C. Matsui[2], Gregory B. Diette[1,2], Shawn E. McKenzie[1], Alison S. Geyh[1] and Patrick N. Breysse[1]

Airborne contaminants produced by industrial agricultural facilities contain chemical and biological compounds that can impact the health of residents living in close proximity. Settled dust can be a reservoir for these contaminants and can influence long-term exposures. In this study, we sampled the indoor- and outdoor-settled dust from 40 homes that varied in proximity to industrial-scale dairies (ISD; industrial-scale dairy, a term used in this paper to describe a large dairy farm and adjacent waste sprayfields, concentrated animal feeding operation or animal feeding operation, that uses industrial processes) in the Yakima Valley, Washington. We analyzed settled dust samples for cow allergen (Bos d2, a cow allergen associated with dander, hair, sweat and urine, it is a member of the lipocalin family of allergens associated with mammals), mouse allergen (Mus m1; major mouse allergen, a mouse urinary allergen, in the lipocalin family), dust mite allergens (Der p1 (*Dermatophagoides pteronissinus* 1) and Der f1 (*Dermatophagoides farinae* 1)), and endotoxin (a component of the cell walls of gram negative bacteria, lipopolysaccharide, which can be found in air and dust and can produce a strong inflammatory response). A concentration gradient was observed for Bos d2 and endotoxin measured in outdoor-settled dust samples based on proximity to ISD. Indoor-settled dust concentrations of Bos d2 and endotoxin were also highest in proximal homes. While the associated health effects of exposure to cow allergen in settled dust is unknown, endotoxin at concentrations observed in these proximal homes (100 EU/mg) has been associated with increased negative respiratory health effects. These findings document that biological contaminants emitted from ISDs are elevated in indoor- and outdoor-settled dust samples at homes close to these facilities and extend to as much as three miles (4.8 km) away.

Journal of Exposure Science and Environmental Epidemiology (2016) **26,** 42–47; doi:10.1038/jes.2014.57; published online 20 August 2014

Keywords: environmental monitoring; inhalation exposure; particulate matter; pulmonary disease

INTRODUCTION

In the last 50 years, the industrialization of agriculture has changed rural environments. Regulatory agencies attempting to meet federal and state air and water quality standards are progressively more concerned about emissions from industrial-scale farming facilities.[1,2] A number of hazardous airborne contaminants are produced by industrial-scale animal facilities (IAF, a term used to describe industrial farms and facilities with animals used for food production, cow, swine, and fowl) and there is a valid concern that communities located close to these facilities are at increased risk for negative health outcomes associated with exposure to particulate matter (PM) containing animal waste products and other pollutants released from IAF.[3–8]

To investigate the impact of industrial-scale dairies (ISD), facility and adjacent sprayfields, on community exposures, we conducted an assessment of settled dust content in and around residences of the Yakima Valley, an arid region in Washington State experiencing the growth of ISDs. We chose settled dust components thought to be carried through the air as PM that could be tied to the presence of dairy operations including cow allergen (Bos d2) and endotoxin. Endotoxins are ubiquitous biologically active components of bacteria and dust, and do not need to be transported by a viable organism to be a health concern. We also chose to analyze settled dust samples for mouse allergen and dust mite allergens as negative controls, since these allergens are not associated *a priori* with dust transport from dairy facilities. In a previous paper, we reported that airborne PM concentrations were 1.3 times higher inside homes close to the dairy facilities compared with homes that were farther away.[9] Bos d2, a cow allergen and component of airborne particles, was 10 times higher showing a distinct difference in the composition of airborne particulate matter based on proximity to ISD.[9] Measured components of settled dust such as allergens and endotoxin, a powerful inflammatory agent that can act synergistically with other agents to cause respiratory health effects,[6,10] can serve as important indicators for evaluating integrated exposure over time to contaminants that may be associated with home, local, or regional health hazards.[11]

To add to our previous work which investigated potentially shorter-term airborne exposure to contaminants, in this paper we report on the distribution of dairy-related animal waste contaminants found in settled dust inside and outside homes as a function of distance to the dairy facilities.

[1]Department of Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA and [2]Johns Hopkins School of Medicine, Baltimore, Maryland, USA. Correspondence: Dr. D'Ann L. Williams, Department of Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health, 615N. Wolfe St., Room E6618, Baltimore, MD 21205 USA.
Tel.: 410-614-5755. Fax: 410-955-9334.
E-mail: dwilli20@jhu.edu
Received 4 September 2013; accepted 12 May 2014; published online 20 August 2014

MATERIALS AND METHODS

Sample Population and Settled Dust Collection

A total of 40 homes in the Yakima Valley, representing a range of distances to commercial dairy facilities, were recruited for participation in this study. Methods used to identify potential homes for recruitment are discussed in detail elsewhere.[9] Homes that had a dairy worker or cows on the property and those that had smoking of any kind were excluded. In addition, the participant must have resided in the home for at least six months to be included. Settled dust samples from each house were collected and analyzed for cow allergen (Bos d2), endotoxin, mouse allergen (Mus m1), and dust mite allergen (Der p1 and Der f1). Cow allergen was chosen as a dairy-specific surrogate for determining the influence of contaminants from dairies. Endotoxin, also associated with animal waste products, is a less specific indicator, however, since there are other potential non-dairy sources (e.g., humans, grains, pets, and other animals) of dust contamination. We also chose three common indoor allergens, mouse and dust mite, not expected to be associated with proximity to dairies to serve as negative controls.

Indoor and outdoor vacuum dust samples were collected using an Oreck BB1100DB, portable vacuum cleaner (Oreck, Cookeville, TN, USA) equipped with MITEST adaptors following Indoor Biotechnologies dust collection, and processing protocols (Indoor Biotechnologies, Charlottesville VA, USA). Samples were stored in a 0 °F freezer in Yakima and shipped overnight to JHSPH at 4 °C and then stored in a − 20 °C freezer at JHSPH until blinded analysis. Dust was pre-processed using a number 50, 350 μm diameter sieve, VWR No. 57332146 (VWR, Bridgeport, CT, USA). Dust sieves were cleaned using pyrogen-free techniques and dust was stored in pyrogen-free glass vials. Dust was then aliquoted and a portion of the sample was analyzed for Bos d2, Mus m1, Der p1 and Der f1 allergens, and endotoxin.

Settled dust samples were collected in homes following established protocols.[12] Indoor-settled dust samples were collected from three surfaces: (1) from a bed and carpeting around the bed in a bedroom; (2) from an upholstered piece of furniture; and (3) from a hard surface which was off of the floor, such as an elevated shelving unit or window sill. Seven participants did not allow vacuuming in the bedroom, so an extra upholstered surface in the primary living area was vacuumed instead.

Samples from each surface were analyzed separately in three categories: bedroom, soft furniture, and hard surface when sufficient dust was available. In five homes, there was an insufficient amount of dust collected for analysis of these individual categories, so the samples from the three areas were pooled and only one indoor-settled dust value was obtained for those homes. To allow statistical comparison of all home groups, results for the three indoor samples for each home were averaged and one mean value was reported per home for all analytes. To confirm the rationale for pooling dust samples, we compared analyte results by site of sample (bedroom, soft furniture, and so on) when all three were available and found no statistical difference between sample sites using Kruskal–Wallis analysis.

Outdoor settled dust samples were collected using the same methods as indoor samples. Samples were collected in a location off of the ground in the outdoor environment that would be subjected to airborne dust accumulation. Outdoor carpets or doormats were not sampled as the dust would not entirely be representative of settled dust, since dust on these surfaces can include particles carried on shoes and other physical items. Shelving, tables, chairs/outdoor furniture were preferentially chosen when available. If these options were not available, window sills, door frames, and house siding were sampled. When more than one outdoor-settled dust sample was analyzed for individual homes, these values were averaged and one mean value was reported by home.

Housing Characteristics

Housing characteristics including house age, number of people living in the home, self-reported or observed evidence of a pet typically cats or dogs, presence of livestock other than resident cows or cattle, and presence of air conditioning were noted for each home using standardized questionnaires.[13]

Sample Analysis

Bos d2 concentrations were determined from the sieved settled dust samples by Indoor Biotechnologies Charlottesville, VA, USA using an enzyme-linked immunosorbent assay.[14] Sieved settled dust was analyzed for Mus m1 and Der f1, Der p1 in the Matsui Laboratory, Johns Hopkins School of Medicine. Mus m1, Der p1, and Der f1 were analyzed by enzyme-linked immunosorbent assay.[15,16] The analytical detection limits for the analysis of the allergens Bos d2, Mus m1, Der p1, and Der f1 were 0.03 μg/g, 3.9 ng/g, 39 ng/g, and 9.8 ng/g, respectively.

Endotoxin was measured in sieved settled dust samples using *Limulus* amebocyte lysate (*Limulus* amebocyte lysate analysis used to measure endotoxin, made from the blood of a horseshoe crab) analysis as a single batch by the Thorne Laboratory, University of Iowa. The detection limit of airborne endotoxin concentrations was 0.024 EU/ml.[17]

Statistical Analysis

Exploratory data analysis was conducted using Microsoft Excel (Redmond, WA, USA) and Stata SE 11.0 (College Station, TX, USA). Data were examined and descriptive statistics were generated to determine measures of central tendency and data distributions. Student's *t*-tests were used to compare results among proximal, intermediate and distal homes. As the data were not normally distributed, analytes were compared by group using the non-parametric Kruskal–Wallis test and the Mann–Whitney *U*-test. Samples that were below the limit of detection of the analytical method were assigned a value of one-half the limit of detection and retained for statistical analysis.[18]

RESULTS

Homes Evaluated and Housing Characteristics

A total of 83 homes were contacted and 40 homes agreed to allow environmental sampling. Homes were stratified into three groups to evaluate proximity and different exposure profiles, 20 proximal homes (0.25 mile, 0.4 km) or less to an ISD, seven intermediate homes (greater than 2.5–3 miles, 4–4.8 km) from and ISD and 13 distal homes (greater than 3 miles, greater than 4.8 km) from an ISD. Participant identification, recruitment and housing characteristics, and rationale for distance stratification are summarized in our previous publication.[9] In general, characteristics of study homes by age of home, number of people living in home, air conditioning use, and pet presence were not significantly different by home group.

Settled Dust Sample Results and Study Home Comparisons

Table 1 provides a summary of the overall sampling (indoor and outdoor) results. Bos d2 was detected in 50% of the settled dust samples. Endotoxin was detected in 100% of settled dust samples. Mus m1 was detected in most homes (77%), while dust mite

Table 1. Summary statistics of settled dust samples.

Sample	*n*	*% LOD*	*LOD*	*Mean*	*SD*	*Minimum*	*Median*	*Maximum*
Bos d2 (μg/g)	104	47	0.06	1.29	3.7	0.03	0.07	28.6
Endotoxin (EU/mg)	98	0	NA	135	240	5.4	77	1960
Mus m1 (ng/g)	99	23	2.2	472.3	1213.1	1.1	42	8960
Der p1 (ng/g)	99	84	61	305.1	1337.8	31	31	9145
Der f1 (ng/g)	99	96	35.8	32.3	83.8	18	18	781

Abbreviations: LOD, line of detection; NA, not applicable.

Table 2. Summary of outdoor-settled dust samples—proximal (P), intermediate (I) and distal (D)homes.

Analyte	*Home type*	*n (n < LOD)*	*Mean*	*SD*	*Median*	*IQR*	*Max*	*P-value*[a]	
Bos d2 (μg/g)	Proximal	19 (4)	3.9	7.1	0.52	4.6	28.6	P vs D	< 0.01
	Intermediate	7 (3)	0.18	0.22	0.08	0.27	0.62	P vs I	0.07
	Distal	13 (10)	0.99	3.4	0.03	0	12.4	D vs I	0.15
Mus m1 (ng/g)	Proximal	20 (0)	160	596	11	29	2683	P vs D	0.68
	Intermediate	5 (3)	77	169	1	4	379	P vs I	0.46
	Distal	12 (0)	34	63	3	40	211	D vs I	0.77
Endotoxin (EU/mg)	Proximal	20 (0)	194	181	132	138	712	P vs D	< 0.001
	Intermediate	5 (0)	120	135	63	70	356	P vs I	0.15
	Distal	12 (0)	42	45	28	18	170	D vs I	0.05

Abbreviations: IQR, interquartile range; LOD, limit of detection. [a]Kruskall–Wallis—*P* for trend values are the same.

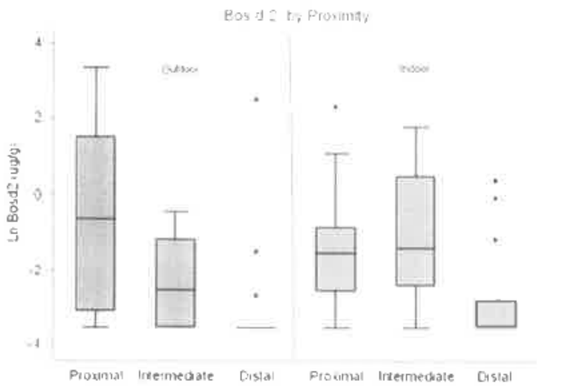


Figure 1. Box plot comparing outdoor and indoor log concentrations of Bos d2 in settled dust between proximal, intermediate, and distal homes.

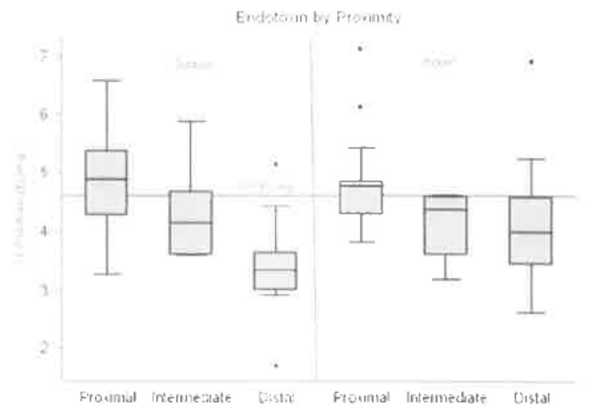


Figure 2. Box plot comparing outdoor and indoor log concentrations of endotoxin in settled dust between proximal, intermediate, and distal homes. Reference line indicates associated health effects level of 100 EU/mg.

allergen was rarely detected in settled dust samples (3 and 15% for Der p1 and Der f1, respectively).

Outdoor settled dust. Outdoor settled dust concentrations of cow allergen, mouse allergen, and endotoxin are summarized in Table 2, and illustrated in Figures 1 and 2. Cow allergen in outdoor dust followed a concentration gradient from proximal to distal homes. Cow allergen was detected in 79%, 57%, and 23% of proximal, intermediate, and distal homes, respectively. Median cow allergen concentrations in proximal homes were 17 times higher ($P < 0.01$) than distal homes. Differences in cow allergen between proximal and intermediate homes trended toward significance ($P = 0.07$), while intermediate homes were 2.7 times higher ($P = 0.15$) than distal homes.

Endotoxin was detected in 100% of outdoor samples. Similar to cow allergen, endotoxin concentrations exhibited a distinct gradient with distance. Median endotoxin concentrations in the outdoor dust of proximal homes was five times higher ($P < 0.01$) than distal homes and intermediate homes were two times higher ($P = 0.05$) than distal homes.

Median outdoor dust concentrations of mouse allergen were not significantly different between proximal and distal homes. Mouse allergen concentrations were lowest in the intermediate homes with only two out of five samples above the limit of detection. Dust mite allergens were not found in any of the outdoor-settled dust samples from distal or intermediate homes and in proximal samples only two of 20 were above the limit of detection.

Indoor-settled dust. Indoor-settled dust sampling results for proximal, intermediate, and distal homes are summarized in Table 3, and illustrated in Figures 1 and 2. Similar to outdoor dust results, indoor cow allergen was observed with 80%, 86%, and 46% of dust samples having detectable cow allergen in proximal, intermediate, and distal homes, respectively. As with the outdoor-settled dust and proximity, the indoor Bos d2 concentrations in the settled dust of proximal and intermediate homes were statistically similar as illustrated in Figure 1. Indoor concentrations of Bos d2 in both proximal and intermediate homes were higher than distal homes (six and eight times higher, respectively).

Median indoor endotoxin dust concentrations were two times greater in proximal homes compared with intermediate ($P = 0.03$) and three times greater than distal homes ($P = 0.02$). While endotoxin concentrations in distal homes were 1.3 times higher than the intermediate homes, this difference was not statistically significant. Indoor concentrations of endotoxin in settled dust significantly vary with distance to facility as illustrated in Figure 2.

No concentration gradient with distance was observed for indoor mouse allergen. Mouse allergen median concentrations in indoor-settled dust were not significantly different between proximal (1105 ng/g) and distal homes (1303 ng/g). However, Mus m1 was five times higher in the indoor dust of proximal homes compared with intermediate homes, median 1105 ng/g and 240 ng/g, respectively ($P = 0.02$), as shown in Table 3. For all homes, over 57% of indoor-settled dust mite, Der p1 and Der f1, concentrations were below the limit of detection and further statistical analysis was not conducted.

Table 3. Summary of indoor-settled dust samples—proximal (P), intermediate (I) and distal (D) homes.

Analyte	*Home type*	n (n < LOD)	*Mean*	*SD*	*Median*	*IQR*	*Max*	*P-value*[a]	
Bos d2 (μg/g)	Proximal	20 (4)	0.87	2.28	0.22	0.35	10.2	P *vs* D	0.04
	Intermediate	7 (1)	1.25	2.16	0.24	1.52	6.0	P *vs* I	0.56
	Distal	13 (7)	0.23	0.44	0.03	0.03	1.4	D *vs* I	0.04
Mus m1 (ng/g)	Proximal	20 (0)	1122	1536	450	1567	5529	P *vs* D	0.22
	Intermediate	7 (0)	233	454	46	93	1266	P *vs* I	0.02
	Distal	13 (0)	1302	3226	252	650	11 908	D *vs* I	0.19
Endotoxin (EU/mg)	Proximal	20 (0)	178	266	117	65	1237	P *vs* D	0.02
	Intermediate	7 (0)	69	35	78	62	115	P *vs* I	0.03
	Distal	13 (0)	133	264	54	67	998	D *vs* I	0.60

Abbreviations: IQR, interquartile range; LOD, limit of detection. [a]Kruskall–Wallis-*P* for trend values are the same.

DISCUSSION

Results of this study indicate that pollutants associated with waste products from ISD facilities are present at higher concentrations in the indoor- and outdoor-settled dust of proximal homes (within 0.25 miles, 0.4 km) compared with distal homes (greater than 3 miles, 4.8 km). Potential sources of cow allergen and endotoxin in the Lower Yakima Valley include a large number of ISD facilities and a single cattle feedlot. There are no other large-scale animal operations of other species in the valley. As expected, mouse allergen, a contaminant not specifically related to dairy facilities, showed no clear concentration gradient by home proximity to ISD.

Bos d2

The detection of cow allergen is significant and was chosen as a dairy-specific surrogate to determine the spatial extent of contamination from dairies. Since homes with dairy workers or homes with resident cows were excluded from this study, the presence of cow allergen in both outdoor and indoor dust suggests that the contamination was likely due to the resuspension of waste materials from the dairy operations (or the single feedlot) or from the application of these ISD wastes to surrounding fields. Its detection suggests that cow allergen may be an important health risk for allergic sensitization and disease, as well as an asthma trigger for sensitized individuals.[4,19–21] In our study, cow allergen was detected in 31% of the distal homes that were more than 3 miles from an ISD. In addition, the detection of cow allergen serves as a surrogate for other potentially harmful exposures that may also be present in affected communities due to the dispersal of waste contaminants from the facilities.

The health consequences of the accumulation of dairy associated waste products in the homes in the Lower Yakima Valley are uncertain but warrant future investigation. Health studies of IAF workers report that workers suffer from a range of adverse health effects including but not limited to, cardiovascular and respiratory diseases, skin disorders, cancer and non-cancer diseases related to pesticides.[22–25] Occupational studies which investigated Bos d2 found exposures can induce respiratory inflammation, rhinitis, and dermatitis among sensitized dairy workers.[20,26,27] Elevated concentrations of cow allergen have been found inside barns, sheds, stables, and the living quarters of current dairy farm workers and in homes of former dairy workers.[19,28]

In our study, six indoor dust samples had concentrations of Bos d2 in settled dust above 1 μg/g. Three of the 20 proximal homes in this study had Bos d2 concentrations above 10 μg/g, with one sample found to contain 28 μg/g Bos d2. These concentrations fall into a range relevant to health as discussed below. It is important to note that the analysis of Bos d2 is not commonly conducted and that results obtained using different analytical methods to detect allergens should be compared with caution.[29] Hinze et al.[19] measured settled dust concentrations of Bos d2 in the homes of German dairy workers which were not attached to barns, ranging from 40 to 82 μg/g. Living quarters that were located in the same building as the cows had settled dust Bos d2 concentrations ranging from 103 to 150 μg/g. For workers who were sensitized to cow allergen, IgE responses occurred at Bos d2 concentrations ranging from 1 to 20 μg/g in dust collected from floors in their homes which were part of a dairy farm.[30] These findings suggest that even relatively low concentrations can elicit systemic responses in sensitized individuals. Our findings for homes in close proximity to, but not located on an ISD are in the lower end of ranges reported for occupational exposures.

Our study results indicate that outdoor cow allergen demonstrated a clear pattern of decrease from proximal to intermediate to distal. However, while indoor concentrations of Bos d2 in settled dust were significantly greater in proximal compared with distal homes, proximal and intermediate homes were statistically indistinguishable. The penetration of pollutants from outdoors to indoors is governed by many complex factors that can be influenced by the air-exchange rates from outdoors to indoors that were not assessed as a part of this study. These include type of heating and air conditioning, the opening and closing of doors and windows, the housing style and construction, the amount of insulation, among other factors. These factors may explain why the pattern of decrease in indoor cow allergen was not the same as observed for outdoor samples.

While we don't have direct evidence that the cow allergen came from dairy facilities, the spatial association with distance provides strong indirect evidence that the dairies are the source of the pollution and suggest that dairy facilities could impact in-home dust concentrations at a distance of up to 3 miles (4.8 km) from ISD. It is possible that cross-reactivity with other allergens may be interfering with the cow allergen assay contributing some of the variability.[31] The paucity of data on cow allergen concentration in typical houses precludes comparison with household cow allergen exposure in the general population.

Endotoxin

As a component of animal manure, endotoxin is generally found in greater amounts in agricultural environments but can vary greatly depending on the environment and agricultural processes used.[17,32–36] Mueller-Anneling et al.[37] conducted an evaluation of endotoxin in air samples of various agricultural environments in California. In the California study, the highest airborne concentrations of endotoxin were found in the ambient air of a community in close proximity to industrial dairy production and were associated primarily with PM_{10}. In Iowa, the same group measured airborne endotoxin at sites in close proximity to a swine facility and also found elevated concentrations close to facilities.[37,38] While we did not measure airborne endotoxin as a part of our study, settled dust is considered a reservoir for airborne materials through surface deposition. Our settled dust results are therefore consistent with the above-mentioned studies that found higher airborne endotoxin close to swine and dairy facilities.

Waser et al.[39] studied settled dust in farm and non-farm homes in Germany, Austria, and Switzerland and concentrations of endotoxin in farming homes were up to two times higher than those of non-farming homes depending on country and sample location.[39] Schram et al.[40] also found that endotoxin concentrations in settled dust were 1.2–3.6 times greater in farm environments as compared with other non-faming environments. Endotoxin concentrations measured in our study in the United States extend the findings of these European studies with indoor proximal (rural) environments being approximately two times higher than distal environments and outdoor proximal environments being approximately 4.5 times higher than distal (urban) environments.

Thorne et al.[21] report that the influence of IAF on airborne endotoxin levels diminish to background at about 500 ft (0.15 km) from the facility to the "no effect level" of 50 $\mu g/m^3$. The relationship observed in this study between endotoxin levels in settled dust and distance to facility suggests that airborne PM from these facilities can influence endotoxin levels in airborne and settled dust across a much wider geographical area, greater than 3 miles (4.8 km) or 15 840 ft.

Thorne et al.[41] also found that endotoxin concentrations in settled dust were highly correlated with increased asthma diagnosis, asthma symptoms, asthma medication use, and wheeze in the National Survey of Lead and Allergens in Housing study. Concentrations on the order of 100 EU/mg, found in urban home-settled dust were associated with infant wheeze during the first year of life.[42] Over 55% of the proximal homes in this study had indoor concentrations of endotoxin that were over this threshold of 100 EU/mg; in contrast, these health-relevant concentrations were observed in only 23% of distal homes.

Outdoor concentrations of endotoxin followed the same trend. Thirteen of 20 proximal homes *vs* only one distal home had outdoor endotoxin concentrations greater than 100 EU/mg. We found dust concentrations of endotoxin that are relevant to respiratory health effects in both the indoor and outdoor environments of proximal homes. These health-relevant concentrations will likely affect exposed populations which include children, atopic individuals, the elderly, and other susceptible populations at distances far greater than just those immediately adjacent to dairy facilities.[41,42]

Like Bos d2, endotoxin was also spatially associated with proximity to dairy facilities. While endotoxin has other sources and is therefore not exclusively the result of living close to dairies, the overlapping patterns of increasing dust concentration with proximity to dairies for both cow allergen and endotoxin strongly suggest that living close to ISD results in an increase in exposure to waste products which accumulate in dust both inside and outside of the home and may be relevant to health outcomes. These contaminants can include microorganisms associated with animal wastes including *Escherichia coli* and other bacteria; chemicals, growth hormones and antibiotics used in dairy operations and excreted by the animals.[43–45]

Limitations

As in most observational studies, there are associated limitations. This cross-sectional study gives us only a snapshot of the exposure profile and the applicability of these results must be interpreted with some caution. A more comprehensive assessment should include measurements over longer periods of time and across multiple seasons.

Comparisons using the intermediate homes are limited by sample size ($n = 7$). Another limitation is that information on home cleanliness, recreational exposure to cattle, and use of cow manure as a home fertilizer was not collected. Other information that was not collected was wind direction and orientation to facility. The absence of current and accurate information on the specific farming processes used, number of facilities, number of cows, actual facility size including sprayfields and other factors that may play a significant role for exposure could account for the observed variability in both Bos d2 and endotoxin concentrations in this study.

We did not take wind direction into account in our interpretation of the impact of proximity. The absence of wind information is not a significant limitation, since the dust samples were collected from locations thought to represent long-term (months) accumulation. While the prevailing wind direction is west to east, the wind direction at any location is highly variable from day to day depending on the time of year and local weather events.

CONCLUSION

This study provides additional evidence that contaminants associated with waste products from ISD facilities are found in settled dust inside and outside homes up to a distance of greater than 3 iles (4.8 km) away. More than half of the homes within 0.25 mile (0.4 km) of a dairy facility had elevated endotoxin concentrations in settled dust which were observed at concentrations relevant to adverse health outcomes. In addition, Bos d2 concentrations observed in this study may be a source of exposure to sensitized individuals, leading to health effects, as allergen exposure has been found to be a risk factor for asthma exacerbation. These findings reinforce community concerns about exposure to waste-related pollutants associated with ISD and substantiate the need for larger, well-designed health studies of communities influenced by ISD facilities.

CONFLICT OF INTEREST

The authors declare no conflict of interest

ACKNOWLEDGEMENTS

This research was supported by The Johns Hopkins Center for a Livable Future, The National Institute of Environmental Health Sciences (PO1ES09606), U.S. Environmental Protection Agency (POR-826724) and The Johns Hopkins NIEHS Center in Urban Environmental Health (P30ES03819).

REFERENCES

1 Centner TJ. Regulating concentrated animal feeding operations to enhance the environment. *Environ Sci Policy* 2003; **6**: 433–440.
2 Centner TJ. Enforcing environmental regulations: concentrated animal feeding operations. *MO Law Rev* 2004; **69**: 697.
3 Thu KM. Public health concerns for neighbors of large-scale swine production operations. *J Agr Saf Health* 2002; **8**: 175–184.
4 Mirabelli M, Wing S, Marshall S, Wilcosky T. Asthma symptoms among adolescents who attend public schools that are located near confined swine feeding operations. *Pediatrics* 2006; **118**: 66–75.
5 Radon K, Schulze A, Ehrenstein V, van Strien RT, Praml G, Nowak D *et al.* Environmental exposure to confined animal feeding operations and respiratory health of neighboring residents. *Epidemiology* 2007; **18**: 300–308.
6 Thorne P. Environmental health impacts of concentrated animal feeding operations: anticipating hazards–searching for solutions. *Environ Health Persp* 2007; **115**: 296–297.
7 Wing S, Horton R, Marshall S, Thu K, Tajik M, Schinasi L *et al.* Air pollution and odor in communities near industrial swine operations. *Environ Health Persp* 2008; **116**: 1362–1368.
8 Centner TJ. Nuisances from animal feeding operations: reconciling agricultural production and neighboring property rights. *Drake J Agr Law* 2006; **11**: 5.
9 Williams DL, Breysse PN, McCormack MC, Diette GB, McKenzie S, Geyh AS *et al.* Airborne cow allergen, ammonia and particulate matter at homes vary with distance to industrial scale dairy operations: an exposure assessment. *Environ Health* 2011; **72**: 10–1186.

10 Park JH, Spiegelman DL, Burge HA, Gold DR, Chew GL, Milton DK *et al*. Longitudinal study of dust and airborne endotoxin in the home. *Environ Health Persp* 2000; **108**: 1023–1028.

11 Butte W, Heinzow B. Pollutants in house dust as indicators of indoor contamination. *Rev Environ Contam T* 2002; **175**: 150–156.

12 Eggleston PA. Home environmental intervention in inner-city asthma: a randomized control trial. *Ann Allerg Asthma Im* 2005; **95**: 518–524.

13 Hansel NN, Breysse PN, McCormack MC, Matsui EC, Curtin-Brosnan J, Williams DL *et al*. A longitudinal study of indoor nitrogen dioxide levels and respiratory symptoms in inner-city children with asthma. *Environ Health Persp* 2008; **116**: 1428–1433.

14 Virtanen T, Zeiler T, Rautiainen J, Taivainen A, Pentikainen J, Rytkonen M *et al*. Immune reactivity of cow-asthmatic dairy farmers to the major allergen of cow (BDA20) and to other cow-derived proteins. The use of purified BDA20 increases the performance of diagnostic tests in respiratory cow allergy. *Clin Exp Allerg* 1996; **26**: 188–196.

15 Chapman MD, Heymann PW, Wilkins SR, Brown MJ, Platts-Mills TA. Monoclonal immunoassay for major dust mite (Dermatophageides) allergens, Der p I and Der f I, and quantitative analysis of the allergen content of mite and house dust extracts. *J Allergy Clin Immun* 1987; **80**: 184–194.

16 Korpi A, Mäntyjärvi R, Rautiainen J, Kaliste E, Kalliokoski P, Renström A *et al*. Detection of mouse and rat urinary aeroallergens with an improved ELISA. *J Allergy Clin Immun* 2004; **113**: 677–682.

17 Thorne PS. Inhalation toxicology models of endotoxin- and bioaerosol-induced inflammation. *Toxicology* 2000; **152**: 13–23.

18 Helsel D. *Nondetects and Data Analysis: Statistics for Censored Environmental Data*. Wiley-Interscience: Hoboken, NJ, USA, 2005.

19 Hinze S, Bergmann K, Lowenstein H, Hansen G. Cow hair allergen (Bos d2) content in house dust: correlation with sensitization in farmers with cow hair asthma. *Int Arch Allergy Imm* 1997; **112**: 231–237.

20 Zeiler T, Taivainen A, Mantyjarvi R, Tukiainen H, Rautiainen J, Rytkonen-Nissinen M *et al*. Threshold levels of purified natural Bos d2 for inducing bronchial airway response in asthmatic patients. *Clin Exp Allergy* 2002; **32**: 1454–1460.

21 Thorne PS, Ansley AC, Perry SS. Concentrations of bioaerosols, odors, and hydrogen sulfide inside and downwind from two types of swine livestock operations. *J Occup Environ Hyg* 2009; **6**: 211–220.

22 Schenker MB, Christiani D, Cormier Y, Dimich-Ward H, Doekes G, Dosman J *et al*. Respiratory health hazards in agriculture. *Am J Resp Crit Care* 1998; **158**: S1–S76.

23 Cole D, Todd L, Wing S. Concentrated swine feeding operations and public health: a review of occupational and community health effects. *Environ Health Persp* 2000; **8**: 685–699.

24 Kirkhorn S, Schenker MB. Human health effects of agriculture: physical diseases and illnesses. Agricultural Safety and Health Conference: Using Past and Present to Map Future Actions 2001.

25 Liebers V, Bruning T, Raulf-Heimsoth M. Occupational endotoxin-exposure and possible health effects on humans. *Am J Ind Med* 2006; **49**: 474–491.

26 Spiewak R, Dutkiewicz J, Skorska C. Detection of specific IgE as a screening tool for cow and swine breeders' occupational allergic dermatoses. *Ann Agr Environ Med* 2000; **7**: 145–147.

27 Berger I, Schierl R, Ochmann U, Egger U, Scharrer E, Nowak D *et al*. Concentrations of dust, allergens and endotoxin in stables, living rooms and mattresses from cattle farmers in southern Bavaria. *Ann Agr Environ Med* 2005; **12**: 101–107.

28 Kullman GJ, Thorne PS, Waldron PF, Marx JJ, Ault B, Lewis DM *et al*. Organic dust exposures from work in dairy barns. *Am Ind Hyg Assoc J* 1998; **59**: 403–413.

29 van Hengel AJ. Food allergen detection methods and the challenge to protect food-allergic consumers. *Anal Bioanal Chem* 2007; **389.1**: 111–118.

30 Hinze S, Bergmann KC, Løwenstein H, Hansen GN. Different threshold concentrations for sensitization by cattle hair allergen Bos d2 in atopic and non-atopic farmers. *Pneumologie* 1996; **50**: 177.

31 Restani P, Beretta B, Fiocchi A, Ballabio C, Galli CL. Cross-reactivity between mammalian proteins. *Ann Allergy Asthma Immunol* 2002; **89**: 11–15.

32 Purdy CW, Straus DC, Chirase N, Parker DB, Ayers JR, Hoover MD *et al*. Effects of aerosolized feedyard dust that contains natural endotoxins on adult sheep. *Am J Vet Res* 2002; **63**: 28–35.

33 Spaan S, Wouters IM, Oosting I, Doekes G, Heederik D. Exposure to inhalable dust and endotoxins in agricultural industries. *J Environ Monitor* 2006; **8**: 63–72.

34 Madsen AM. Airborne endotoxin in different background environments and seasons. *Ann Agr Environ Med* 2006; **13**: 81–86.

35 Purdy CW, Clark RN, Straus DC. Analysis of aerosolized particulates of feedyards located in the Southern High Plains of Texas. *Aerosol Sci Tech* 2007; **41**: 497–509.

36 Purdy CW, Clark RN, Straus DC. Ambient and indoor particulate aerosols generated by dairies in the southern High Plains. *J Dairy Sci* 2009; **92**: 6033–6045.

37 Mueller-Anneling L, Avol E, Peters JM, Thorne PS. Ambient endotoxin concentrations in PM10 from Southern California. *Environ Health Persp* 2004; **112**: 583–588.

38 Mueller-Anneling L, O'Neill M, Thorne P. Biomonitoring for assessment of organic dust-induced lung inflammation. *Eur Respir J* 2006; **27**: 1096–1101.

39 Waser M, Schierl R, von Mutius E, Maisch S, Carr D, Riedler J *et al*. Determinants of endotoxin levels in living environments of farmers' children and their peers from rural areas. *Clin Exp Allergy* 2004; **34**: 389–397.

40 Schram D, Doekes G, Boeve M, Douwes J, Riedler J, Ublagger E *et al*. Bacterial and fungal components in house dust of farm children, Rudolf Steiner school children and reference children–the PARSIFAL Study. *Allergy* 2005; **60**: 611–618.

41 Thorne PS, Kulhankova K, Yin M, Cohn R, Arbes SJ, Zeldin DC *et al*. Endotoxin exposure is a risk factor for asthma - The National Survey of Endotoxin in United States Housing. *Am J Resp Crit Care* 2005; **172**: 1371–1377.

42 Park JH, Spiegelman DL, Gold DR, Burge HA, Milton DK. Predictors of airborne endotoxin in the home. *Environ Health Persp* 2001; **109**: 859–864.

43 Thedell TD, Mull JC, Olenchock SA. A brief report of gram-negative bacterial endotoxin levels in airborne and settled dusts in animal confinement buildings. *Am J Ind Med* 1980; **1**: 3–7.

44 Green CF, Gibbs SG, Tarwater PM, Mota LC, Scarpino PV. Bacterial plume emanating from the air surrounding swine confinement operations. *J Occup Environ Hyg* 2006; **3**: 9–15.

45 Pew Charitable Trusts. Putting meat on the table: Industrial farm animal production in America. *A Report of the Pew commission on industrial Farm Animal Production*. A project of the Pew Charitable trusts and John Hopkins Bloomberg School of Public Health, Baltimore, MD, USA, 2008.

Williams *et al. Environmental Health* 2011, **10**:72
http://www.ehjournal.net/content/10/1/72

ENVIRONMENTAL HEALTH

RESEARCH Open Access

Airborne cow allergen, ammonia and particulate matter at homes vary with distance to industrial scale dairy operations: an exposure assessment

D'Ann L Williams[1*], Patrick N Breysse[1,2], Meredith C McCormack[1,2], Gregory B Diette[1,2], Shawn McKenzie[1] and Alison S Geyh[1]

Abstract

Background: Community exposures to environmental contaminants from industrial scale dairy operations are poorly understood. The purpose of this study was to evaluate the impact of dairy operations on nearby communities by assessing airborne contaminants (particulate matter, ammonia, and cow allergen, Bos d 2) associated with dairy operations inside and outside homes.

Methods: The study was conducted in 40 homes in the Yakima Valley, Washington State where over 61 dairies operate.

Results: A concentration gradient was observed showing that airborne contaminants are significantly greater at homes within one-quarter mile (0.4 km) of dairy facilities, outdoor Bos d 2, ammonia, and TD were 60, eight, and two times higher as compared to homes greater than three miles (4.8 km) away. In addition median indoor airborne Bos d 2 and ammonia concentrations were approximately 10 and two times higher in homes within one-quarter mile (0.4 km) compared to homes greater than three miles (4.8 km) away.

Conclusions: These findings demonstrate that dairy operations increase community exposures to agents with known human health effects. This study also provides evidence that airborne biological contaminants (i.e. cow allergen) associated with airborne particulate matter are statistically elevated at distances up to three miles (4.8 km) from dairy operations.

Background

The United States has witnessed the industrialization of the dairy industry over the last 40 years [1]. As a result, larger dairy facilities are now concentrated into fewer regions around the nation. The US Department of Agriculture (USDA) reports that between 1970 and 2000 the number of dairies nationwide decreased from 650,000 to 90,000. However, the number of dairy cows only declined from 12 to nine million while the average herd size increased 500% [1]. Though dairies are found in all 50 states, over a third of the all dairy animals are currently found in only two states [2]. For the purposes of this paper industrial scale dairies will be defined as operations that house over 500 animals.

Industrial food-animal production (IFAP) facilities are often located within or close to communities and reports of odors and concerns about health effects are common [3-5]. A number of airborne contaminants are produced by IFAP facilities, many which are unregulated. These include biological and biogenic aerosols, and gases such as ammonia, methane, and hydrogen sulfide. Unlike industrial sources, little is known about the airborne emissions from IFAP or potential community exposures. This is in part due to the virtual absence of agricultural air emission regulations and rural monitoring programs [6-9]. A Workgroup on Health Effects of Airborne Exposures from Industrial Scale Animal Operations concluded that there is a lack of data on community exposure to and health effects of odors and

* Correspondence: dlwillia@jhsph.edu
[1]Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health, 615 N. Wolfe Street, Baltimore, Maryland 21205, USA
Full list of author information is available at the end of the article

complex mixtures emanating from animal operations [10,11].

Within pre-existing communities in many areas of the country animal facilities have expanded both in size and processes in the last 10 to 15 years [2]. As a result, residents within these communities often found themselves suddenly living next to sprayfields where facility animal wastes are applied or barns containing thousands of animals. A few studies have suggested that the distance between a home and the facility may be an important determinant of exposure [12-16] however these studies did not specifically measure pollutant concentrations both inside and outside of homes nor did they evaluate pollutant concentrations at homes that were potentially unaffected.

To assess the impact of IFAP facilities on local community exposures to dairy-related contaminants, we conducted a study in Yakima Valley, Washington State where industrial dairy operations are concentrated in close proximity to surrounding communities. Dairy operations in the Yakima Valley are very large in terms of herd size and animal density. The 2009 Lower Yakima Valley Groundwater Quality Report identified 61 dairies between Prosser and the City of Yakima (49 mi, 79 km) housing approximately 207,000 cows [17] (Figure 1). While the 2007 USDA Agricultural Census reported that only 5% of all dairy operations have 500 cows or more, 72% of the operations in the Yakima Valley housed over 500 cows [2,18].

Agricultural dusts and crustal components typically make up the majority of airborne particles in farming communities. When airborne particulate matter (PM) settles, it can become resuspended by human activity, erosion and wind. It can remain airborne for weeks,

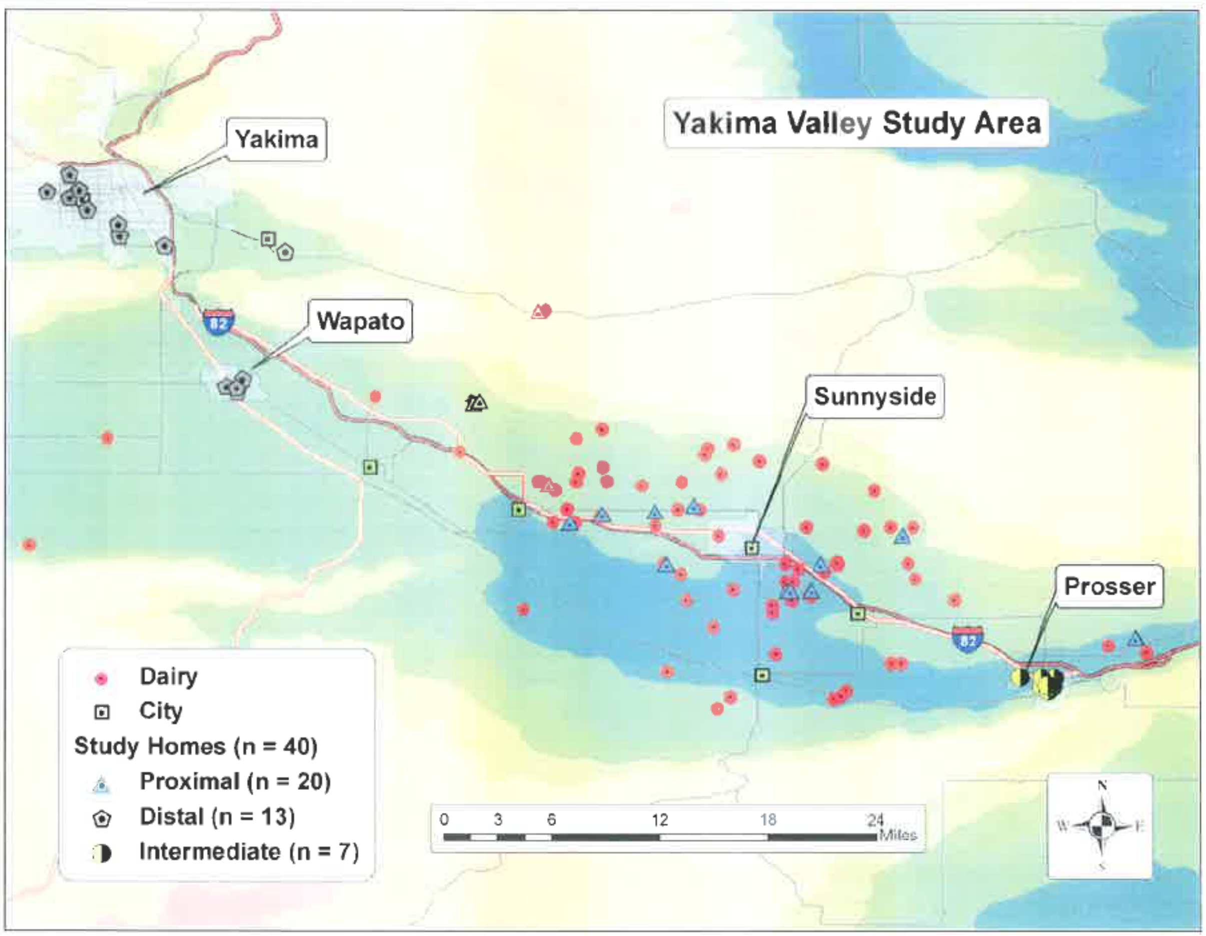


Figure 1 Study area in Yakima Valley, Washington This figure geographically presents cities, dairies and study homes. The background color illustrates the elevation of the Central Yakima Valley. The lowest elevation of the valley follows Interstate 82 and is represented in blue-green. The valley is bounded to the north and south by ridges which run east-west and are shown by the color dark yellow which represents the highest elevation. Elevations range from ~680-1580 ft above sea level

and be transported for hundreds of miles [19,20]. Airborne particles from industrial scale animal operations can act as vectors for transmission of adsorbed chemicals, endotoxin, allergens and other biological agents [21-24].

Cows are the only source of Bos d 2, thus making it a specific indicator of dairy facilities in homes without resident cows. Bos d 2, a member of the family of lipocalins, allergic proteins, is associated with cow dander, sweat and urine. Cow allergen has been found at elevated concentrations in the air and dust inside barns, sheds, stables and the living quarters of dairy workers [25,26].

Ammonia is a gaseous contaminant resulting from the breakdown of manure and urine. It has a low odor threshold and is one of the primary factors in the diminishment of quality of life for residents of communities impacted by IFAP facilities [4,27]. It is corrosive and can be a powerful irritant to skin, eyes, and digestive and respiratory tissues [28].

In this paper we compare the distribution of dairy-related air pollutants (particulate matter and ammonia) and an allergen (Bos d 2 cow allergen) in homes close to dairy facilities compared to homes that are farther away.

Methods

Study Population

The study was approved by the Johns Hopkins Bloomberg School of Public Health and the Fred Hutchinson Cancer Research Center Institutional Review Boards. To be eligible for the study the consenting adult must have lived in the home for a minimum of six months. Exclusion criteria included homes that contained a resident dairy facility worker, cows on the premises, or individuals who worked in orchards or vineyards where manure spreading occurred. Homes that allowed smoking of any kind were also excluded as smoking influences PM concentrations.

Target recruitment included 20 homes defined as proximal and 20 homes defined as distal to a dairy operation. Proximal homes were defined as those within a ¼ mile (0.4 km) of an active dairy facility or adjacent sprayfield where dairy operation waste is applied. Distal homes were defined as those three miles (4.8 km) or more from an active dairy facility or sprayfield. Geographic areas of interest were identified in a two-stage approach using data available in ArcView GIS 9.2 (Redlands, CA). Georeferenced buffers were constructed which incorporated dairy facility and sprayfield location using data accessed through publicly available state databases [18,29]. Buffers were layered onto a parcel basemap from the Yakima County Government [30]. Associated parcel information was extracted from the Yakima County Tax Assessors [31] database. A total of 850 eligible proximal parcels with homes and more than 10,000 potentially eligible distal parcels with homes were identified.

Environmental Monitoring

Environmental monitoring focused on airborne pollutants including PM, cow allergen (Bos d 2) and ammonia. While ammonia is not specific to cow waste, in this study there were no known ambient sources other than the animal facilities that would influence ammonia concentrations. In each home, matched indoor and outdoor samples were collected over a period of five days from June 10 to August 19, 2008. For each sampling event one proximal home and one distal home were paired and sampled on the same days.

Each air sampling set-up included a total dust (TD), ammonia (NH_3), and a second hand smoke (SHS) sampler. The indoor set-up was placed in a common living area approximately 1.5 m off of the floor. The outdoor set-up was placed on a table or elevated surface that was approximately 1.5 m off the ground. Outdoor set-ups were protected by a weather resistant housing.

Airborne TD samples were collected using a closed-face VWR 37 mm sampling cassettes (VWR, Bridgeport, CT) pre-loaded with 37 mm Teflo® filters, (Pall-Gelman, Ann Arbor, MI) at the Johns Hopkins Bloomberg School of Public Health (JHSPH). BGI sampling pumps (BGI, Waltham, MA) were pre- and post-calibrated using a Bios DryCal primary standard (Bios International, Butler, NJ). After sampling, filters were unloaded in a clean environment and stored in sealed petri-dishes at -20°C and then shipped overnight to JHSPH at 4°C and then stored at 4°C until analysis. Airborne TD samples were collected in order to collect a wide particle size range since the particle size associated with biogenic materials (e.g., cow allergen) is not known. Airborne TD mass concentration was determined by gravimetric analysis at JHSPH. Filters were pre- and post-weighed in a temperature and humidity controlled weighing room using a Mettler-Toledo MT5 microbalance (Mettler-Toledo, Inc., Columbus, OH) following EPA standard protocol, 40CFR50 Appendix L [32].

Airborne Bos d 2 concentrations were determined from the TD samples and analyzed by Indoor Biotechnologies, Inc. Charlottesville, VA. An ELISA assay, which had been modified based on previous immunoassay protocols to test for Bos d 2, was used for this analysis [33].

To confirm the nonsmoking status of the house, airborne nicotine concentrations were assessed using SHS monitors constructed at JHSPH. After sampling, monitors were stored at -20°C, shipped overnight to JHSPH at 4°C and then stored at 4°C until analyzed. Analysis for nicotine was conducted by gas chromatography with nitrogen-phosphorus detection as previously reported [34].

NH_3 concentrations were measured using the Gradko passive NH_3 sampler (Gradko International LTD, UK). The Gradko sampler has been validated for measurements of NH_3 concentrations ranging from > 2.5 to 1000 μg/m^3 (3.6 to 1436 ppb) [35,36]. After sampling, samplers were stored in a -20°C, shipped overnight to JHSPH at 4°C, then stored at -20°C until analyzed. Ammonia analysis was conducted by ion chromatography (Model 600 × IC, Dionex Corp. Sunnyvale CA) following the protocol described by Dionex [37].

All samples were submitted for laboratory analysis with proximity identifiers removed. Sample concentrations were blank corrected and duplicate samples were averaged and reported as one value. Values that were below the LOD were reported as 1/2 the LOD value [38].

Home Characteristics

Housing characteristics including house age, number of people living in the home, dog and/or cat living in the house, presence of livestock, and presence of air conditioning were collected for each home by survey.

Statistical Analysis

Exploratory data analysis was conducted using Microsoft Excel (Redmond, WA) and Stata SE11.0 (College Station, TX). Data were examined and descriptive statistics were generated to determine measures of central tendency and data distributions. Since environmental data are typically log-normally distributed, the Shapiro-Wilk test was used to determine normality to assess the appropriateness of the Student's t-test as a statistical method. The data were compared by group using the non-parametric Kruskal-Wallis test with a p-value threshold value of 0.05.

Results

Study Homes and Housing Characteristics

A convenience sample of 40 homes was recruited. Informed consent was obtained from the adult resident of the home who was to be the primary study contact. Of the 40 homes, 20 were designated proximal and 20 were designated distal. After the field study was concluded, additional ground truthing was conducted to reconfirm categorical assignment using satellite images. Distances were measured from dairy operations and adjacent sprayfields to study homes using the Google Earth "distance" tool. Seven of the homes originally categorized as "distal" homes were found to be within three miles (4.8 km) from dairy facility adjacent sprayfields. These homes were re-categorized as "intermediate" homes since they fell between the ¼ and three mile (0.4 km and 4.8 km) distance criteria. The reassignment of the intermediate homes created a total of 20 proximal, seven intermediate, and 13 distal homes (Figure 1). Analysis was conducted on these three groups.

Housing characteristics are summarized in Table 1. Overall, homes contained between three and four residents and had a mean housing age of 57 years. Distal and intermediate homes tended to be older than proximal homes with mean ages of 64, 79 and 45 years, respectively; only the difference between intermediate and proximal homes was statistically significant. Home characteristics based on number of people living in the home, the presence of air conditioning and pet ownership did not differ significantly by proximity.

Airborne Sample Results and Comparison of Study Homes

A summary of sampling results is presented in Table 2. TD concentrations ranged from two to 385 μg/m^3 (median: 22 μg/m^3). Approximately 16% of airborne Bos d 2 samples were below detection with concentrations ranging from < 0.2 to 1.9 μg/m^3 (median: 0.4 μg/m^3). Only nine percent of ammonia samples were below the limit of detection with results ranging from < 0.9 to 56 ppb (median: 6.0 ppb).

Outdoor Air

Outdoor sampling results by distance classification are presented in Table 3. Outdoor results for airborne Bos d 2 showed the highest concentrations outside of proximal homes and lowest concentrations outside distal homes suggesting a concentration gradient. Median outdoor airborne cow allergen concentrations were 0.66 μg/m^3, 0.17 μg/m^3, and 0.01 μg/m^3 for proximal, intermediate and distal homes, respectively. Box plots showing log concentrations of outdoor Bos d 2 by distance group are presented in Figure 2. Ammonia concentrations (Figure 3) demonstrated a similar gradient (median 8.7 ppb proximal, 1.3 ppb intermediate, 1.1 ppb distal), with concentrations outside proximal homes significantly greater than concentrations outside homes classified as intermediate and distal. Following the same pattern, TD concentrations, presented in Figure 4, are significantly greater in outdoor environments of proximal (median: 29 μg/m^3) compared to distal homes (median: 15 μg/m^3), but not significantly greater than intermediate homes (median: 18 μg/m^3). Median outdoor Bos d 2, ammonia, and TD were 60, eight and two times higher respectively, in the proximal as compared to the distal.

Indoor Air

Indoor air results classified by distance are summarized in Table 4. Median indoor Bos d 2 concentrations were significantly greater in proximal, (0.12 μg/m^3), compared

Table 1 Housing Characteristics of Study Homes

Characteristics	Total (N = 40) mean ± SD (range)	Proximal (N = 20) mean ± SD (range)	Distal (N = 13) mean ± SD (range)	Intermediate (N = 7) mean ± SD (range)
Distance to facility (miles)*	3.42 ± 3.99 (0.4 - 11.5)	0.17 ± 0.61 (0.04 - 0.3)	8.65 ± 2.1 (5 - 12)	3.01 ± 0.28 (2.45 - 3.4)
# of people living in house	3.7 ± 4.88 (1 - 8)	3.3 ± 1.6 (1 - 6)	4 ± 2.2 (1 - 3)	4 ± 2.2 (2 - 8)
Age of house (years)	57 ± 31 (3 - 109)	45 ± 46 (5 - 107)	64 ± (3 - 99)	79 ± 22 (57 - 109)
	Total (N = 40) n (%)	Proximal (N = 20) n (%)	Distal (N = 13) n (%)	Intermediate (N = 7) n (%)
Dog (outside house)	27 (68)	14 (70)	8 (63)	4 (57)
Dog (inside house)	18 (45)	9 (45)	7 (54)	1 (14)
Cat (outside house)	12 (30)	8 (38)	3 (19)	3 (43)
Cat (inside house)	8 (20)	5 (25)	2 (13)	3 (43)
Other (chicken, horse, goat)	6 (15)	5 (25)	0 (0)	1 (14)
Live adjacent to sprayfield	15 (38)	15 (75)	0 (0)	0 (0)
Any air conditioning	28 (70)	11 (55)	10 (77)	7 (100)

*measured using Google Earth.

to intermediate, (0.01 μg/m^3), and distal (0.01 μg/m^3) homes (Figure 2). Ammonia concentrations inside proximal homes (12 ppb) were greater than intermediate (4.9 ppb) and distal homes (5.7 ppb) (Figure 3). Differences between proximal and distal, and proximal and intermediate were statistically significant, while differences between intermediate and distal were not. Median indoor airborne Bos d 2 and ammonia concentrations were approximately 10 and two times higher respectively, in proximal as compared to distal homes. Indoor TD concentrations were similar for all three home classifications (Figure 4). No significant difference was seen between indoor concentrations for intermediate and distal homes for any airborne contaminant.

Indoor and Outdoor Concentrations

Indoor and outdoor concentrations of airborne contaminants were also compared within home type. Median outdoor airborne concentrations of Bos d 2 were significantly higher at proximal and intermediate homes (0.66 vs. 0.17 μg/m^3) compared to indoor concentrations (0.12 vs. 0.01 μg/m^3). This difference was not noted in distal homes, since concentrations were much lower and often below the limit of detection. Indoor concentrations of ammonia were higher than outdoor concentrations in all three groups; however, no significant difference was observed between indoor and outdoor ammonia concentrations in proximal homes (12 vs. 9 ppb). For intermediate and distal homes, a significant difference was found between indoor and outdoor ammonia concentrations with indoor levels being greater, 5 vs. 1 ppb and 6 vs. 1 ppb respectively. TD was significantly higher indoors compared to outdoors in distal homes, 23 vs. 15 μg/m^3, while there were no significant differences in proximal or intermediate homes, 29 vs. 29 μg/m^3 and 22 vs. 18 μg/m^3 respectively.

As non-smoking participants were selected for this study, nicotine sampling was used to determine compliance with this criterion and to evaluate potential discrepancies in observed PM levels. Only one proximal home had measurable airborne nicotine. As a result indoor measurements of TD for this home were not included in any of the analyses presented above.

Discussion

In this study we showed that outdoor PM, ammonia and cow allergen concentrations displayed a gradient with the highest concentrations inside and outside of homes closest to dairies (within a ¼ mile, 0.4 km) and the lowest concentrations outside of homes farthest from dairies (greater than three miles, 4.8 km). While many pollutants associated with dairy facilities can have multiple sources, complicating source attribution, cow allergen was selected because it is uniquely associated with the presence of cows. Homes with resident cows or homes where there was an individual that worked with cows were excluded to minimize the influence of occupational exposures on indoor environments. As a result,

Table 2 In Home Airborne Sample Concentrations

Sample Type	samples (n)	% < LOD	LOD	mean	SD	min	median	max
Bos d 2 μg/m^3	70	16	0.02	0.3	0.4	< 0.02	0.4	1.9
NH_3 ppb	79	9	0.9	8.8	10.6	< 0.9	6.0	56.0
TD μg/m^3	75	0	1.1	35.0	54.7	2	22	385

Williams *et al. Environmental Health* 2011, **10**:72
http://www.ehjournal.net/content/10/1/72

Table 3 Outdoor Air Samples - Proximal, Intermediate and Distal Homes

Analyte	Home Type	n(< LOD)	mean	sd	median	IQR	max		*p* value*
Bos d 2 μg/m^3	Proximal	19 (0)	0.77	0.56	0.66	0.79	1.87	P vs D	< 0.01
	Intermediate	6 (0)	0.28	0.44	0.17	0.1	0.292	P vs I	< 0.01
	Distal	12 (3)	0.028	0.026	0.011	0.03	0.096	D vs I	< 0.01
NH_3 ppb	Proximal	19 (0)	9.4	5.8	8.7	6.3	28.0	P vs D	< 0.01
	Intermediate	7 (1)	1.9	2.0	1.3	1.1	6.4	P vs I	< 0.01
	Distal	13 (6)	1.0	0.6	1.1	0.8	2.5	D vs I	0.24
TD μg/m^3	Proximal	19 (0)	33	24	29	23	104	P vs D	0.02
	Intermediate	6 (0)	18	5	18	6	25	P vs I	0.09
	Distal	13 (0)	37	82	15	9	310	D vs I	0.38

*Kruskal-Wallis

P = proximal, D = distal and I = intermediate home types.

the presence of cow allergens inside and outside of homes is most likely attributed to emissions from dairy facilities. Similarly the ammonia concentration gradient implicates dairy operations as they are the only known major ambient source of ammonia in the study area. While PM can have multiple sources, our data also implicate dairies as a source of elevated PM concentrations outside households within a ¼ mile (0.4 km) of the facilities as compared to homes farther away.

Another key finding is that indoor pollutant concentrations also exhibit a concentration gradient with distance from dairy operations. In addition, indoor and outdoor concentrations of ammonia at homes within a ¼ mile (0.4 km) are indistinguishable, while the difference in indoor and outdoor ammonia concentrations in intermediate and distal homes is significantly different, with indoor being higher. These results indicate that being inside homes close to dairy operations provides little or no protection.

While the public health relevance of chronic exposure to cow allergen has yet to be established, occupational studies of health effects related to Bos d 2 allergen and sensitization in exposed dairy workers suggests that concentrations do not need to be extremely high for sensitization to occur [33,39-41]. For residents adjacent to dairy operations, exposure to cow allergen may have important health implications because sensitized individuals can experience allergic symptoms. Allergen exposure among sensitized individuals with asthma may serve as a trigger of respiratory symptoms and have been linked to the increased need for medication use and health care services [42,43]. To the extent that cow allergen can serve as a marker for biological components of dairy-related PM it is reasonable to conclude that other components not measured in this study, such as chemical agents, endotoxin, antibiotics, and/or microorganisms, are likely also to be elevated in the air outside and inside homes closest to dairy facilities.

In the case of ammonia, our results are consistent with Atkins who found that people and pets can be important contributors to indoor concentrations of ammonia [44]. In distal and intermediate homes, indoor ammonia concentrations were significantly greater than those measured outdoors. However, for proximal

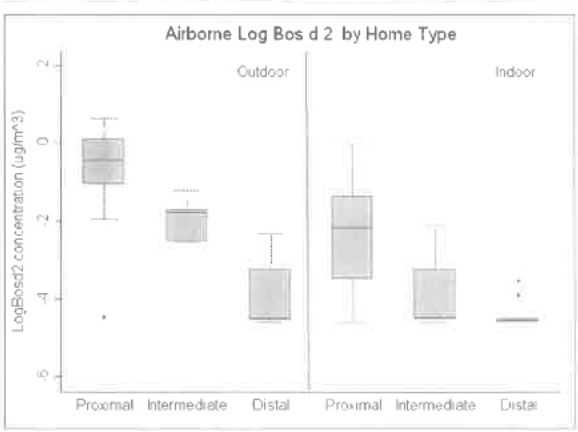


Figure 2 Comparison of outdoor and indoor airborne concentrations of Bos d 2 between proximal, intermediate and distal homes.

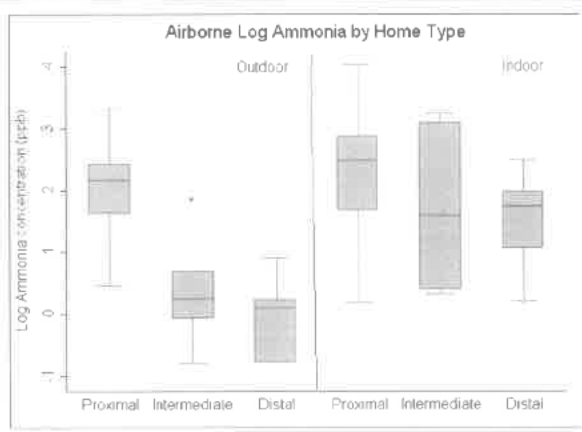


Figure 3 Comparison of outdoor and indoor airborne concentrations of ammonia between proximal, intermediate and distal homes.

Williams *et al. Environmental Health* 2011, **10**:72
http://www.ehjournal.net/content/10/1/72

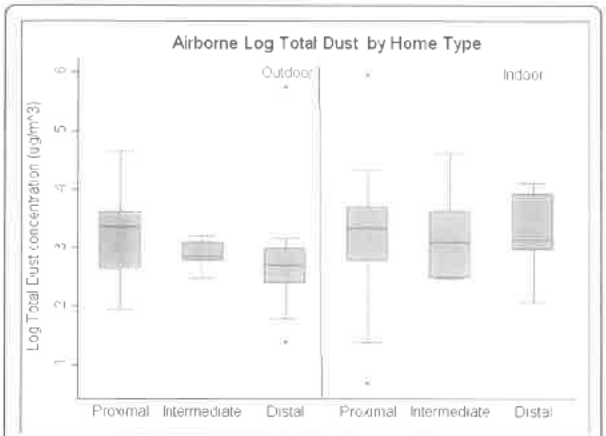


Figure 4 Comparison of outdoor and indoor airborne concentrations of total dust between proximal, intermediate and distal home environments

homes, indoor ammonia concentrations were only slightly and non-significantly higher than outdoors. These results suggest that ammonia penetration from outdoors is a significant contributor to indoor ammonia concentrations for homes close to dairy operations. The five-day average proximal outdoor concentrations measured in our study are similar to other studies that have measured ammonia using comparable methods around swine facilities [15,36,45]. While we did not measure health outcomes or quality of life indicators, other studies of communities located within two to three miles (3.2 to 4.8 km) of an IFAP facility [12,15,16], found that odors and ammonia can contribute to poor quality of life even at ammonia concentrations currently considered not to be a risk to health. Our findings demonstrate that exposure to ammonia increases as distance to the facility decreases. This suggests that quality of life may be even further diminished as the indoor environment in proximate homes provides no refuge from this gas.

Agricultural dusts, which are primarily composed of particles in the larger size fractions, can have profound effects on local populations that are chronically exposed [46,47]. It has been shown that larger particles can be carriers of important biological agents [23,48,49]. In addition, inhalable particles have been associated with increased asthma, sinusitis, rhinitis and upper airway diseases in agricultural workers [11,50-55]. Several studies have found evidence that indoor coarse particles may be associated with increased incidence of asthma symptoms in urban populations [56-59]. Population based studies, which have evaluated PM concentrations in ambient environments, also support the importance of the size and composition of ambient PM to morbidity and mortality [60-62]. These studies have been conducted primarily in urban environments and currently there is limited data about the influence of PM on morbidity and mortality in rural and agricultural environments.

There are a number of limitations to this study. Since the data collection was cross-sectional, trends over time or across seasons cannot be evaluated. The sample size, while sufficiently large to address the issue associated with proximity, is too small to provide a comprehensive assessment of the ranges of exposures associated with living close to industrial dairy operations. In addition, 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.

Airborne PM samples collected in this study utilized a 37-mm close-faced sampling cassette. This sampler was used to estimate airborne PM concentrations and to assess airborne cow allergen concentrations. This sampler has been shown to underestimate the inhalable fraction of airborne PM in general and in swine barns in particular it has a > 80% collection efficiency for particles up to approximately 10 μm in diameter [63,64]. The degree to which the TD sampler underestimates inhalable dust exposure will depend on the particle size distribution, face-velocity, and wind speed [64]. In swine

Table 4 Indoor Air Samples - Proximal, Intermediate and Distal Homes

Analyte	Home Type	n(< LOD)	mean	sd	median	IQR	max		*p* value*
Bos d 2 μg/m^3	Proximal	16 (1)	0.20	0.27	0.12	0.24	0.97	P vs D	< 0.01
	Intermediate	5 (1)	0.04	0.01	0.01	0.29	0.12	P vs I	0.05
	Distal	12 (6)	0.010	0.006	0.011	0.001	0.029	D vs I	0.15
NH_3 (ppm)	Proximal	20 (0)	15.7	15.1	12	12.6	56.0	P vs D	0.01
	Intermediate	7 (0)	10.0	9.9	4.9	20.5	25.5	P vs I	0.28
	Distal	13 (0)	5.9	3.3	5.7	4.4	12	D vs I	0.66
TD μg/m^3	Proximal	18 (0)	47	85	29	25	385	P vs D	0.70
	Intermediate	7 (0)	34	31	22	26	100	P vs I	0.90
	Distal	12 (0)	33	19	23	32	61	D vs I	0.67

*Kruskal-Wallis

P = proximal, D = distal and I = intermediate home type.

barns the TD sampler underestimated inhalable fraction by about 14% [63]. If a significant fraction of allergen-containing particles are greater than 10 μm in aerodynamic diameter, TD sampling will underestimate cow allergen concentrations

Information on home cleanliness, use of cow manure in home gardens, wind direction, orientation to facility, specific farming processes used, number of facilities, facility size, and actual number of animals should be collected in future studies to allow for a better assessment of concentration distributions and source attribution.

Conclusions

This is one of the first studies to provide evidence of a gradient of pollutant concentrations by distance of homes to industrial scale dairy operations. Concentrations of Bos d 2, ammonia, and PM were significantly higher for homes within a ¼ mile (0.4 km) of a facility or associated sprayfield compared with homes more than three miles (4.8 km) away. These 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. In addition these results have important implications for dairy facility siting policy decisions, nutrient management plans, and zoning of IFAP when located close to communities. Furthermore, these results highlight the need to consider developing IFAP emissions standards and air pollution regulations in order to protect public health.

List of abbreviations

Bos d 2: a cow allergen; FRM: Federal Reference Method; GIS: Geographic Information System; IFAP: Industrial Food Animal Production; JHSPH: Johns Hopkins Bloomberg School of Public Health; LOD: Limit of detection; NH_3: ammonia; PM: particulate matter; $PM_{2.5}$: particulate matter less than or equal to 2.5 microns in aerodynamic diameter; $PM_{10-2.5}$: PM less than10 but greater than 2.5 microns in aerodynamic diameter; PM_{10}: PM less than or equal to10 microns in aerodynamic diameter; TD: total dust; USDA: United States Department of Agriculture; US EPA: United State Environmental Protection Agency

Acknowledgements

The authors thank Dr. Beti Thompson, Fred Hutchinson Cancer Research Center, Seattle Washington, The Center for Hispanic Health Promotion, Sunnyside Washington, the locally established researchers and Spanish speaking field staff for their assistance with this study. In addition we would like to thank Timothy Green, Jana Mihalic and Christine Torrey for laboratory support, sample analysis and their contributions to the study. This research was supported by the Johns Hopkins Center for a Livable Future, the National Institute of Environmental Health Sciences (NIEHS) (P01ES09606), U S. Environmental Protection Agency (POR 826724), and the Johns Hopkins NIEHS Center in Urban Environmental Health (P30ES03819)

Author details

[1]Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health, 615 N. Wolfe Street, Baltimore, Maryland 21205, USA. [2]Pulmonary and Critical Care Medicine, Johns Hopkins University School of Medicine, 1830 E Monument Street, Baltimore, Maryland 21205, USA

Authors' contributions

DLW obtained funding for the work. In addition she designed, executed, and conducted data analysis for the study. She was also the lead author. PNB obtained funding for the work, contributed to the study design, result interpretation and contributed the drafting of the article. MCM contributed to the design of the study, result interpretation and provided substantial revisions to the document. GBD contributed to the editing and revision of the document. SM helped with the conceptual design, result interpretation and revisions to the document. ASG contributed to the study design, result interpretation and contributed substantially to the drafting of the article. All authors read and approved the final manuscript.

Competing financial interest declaration

The authors declare that they have no competing interests.

Received: 4 March 2011 Accepted: 12 August 2011
Published: 12 August 2011

References

1. U.S. Department of Agriculture: **Economic Research Service - Briefing Room, Dairy: Background**.[http://www.ers.usda.gov/Briefing/Dairy/Background.htm]
2. U.S. Department of Agriculture: **2008 Agricultural Census Data - National Agricultural Statistics Service**.[http://www.agcensus.usda.gov/]
3. Centner TJ: **Nuisances from animal feeding operations: Reconciling agricultural production and neighboring property rights.** *Drake Journal of Agricultural Law* 2006, 11:5-23.
4. Cole D, Todd L, Wing S: **Concentrated swine feeding operations and public health: A review of occupational and community health effects.** *Environ Health Perspect* 2000, **108**:685-699.
5. Donham KJ, Wing S, Osterberg D, Flora JL, Hodne C, Thu KM, Thorne PS: **Community health and socioeconomic issues surrounding concentrated feeding operations.** *Environ Health Perspect* 2007, **115**:317-320.
6. Centner TJ: **Regulating concentrated animal feeding operations to enhance the environment.** *Environ Sci and Pol* 2003, **6**:433-440.
7. Centner TJ: **Enforcing environmental regulations: Concentrated animal feeding operations.** *Missouri Law Review* 2004, **69**:697-730.
8. U.S. Government Accountability Office: **Livestock agriculture: Increased EPA oversight will improve environmental programs for concentrated animal feeding operations. GAO-03-285.** *US Government Accountability Office* 2003.
9. U.S. Government Accountability Office: **Concentrated animal feeding operations: EPA needs more information and a clearly defined strategy to protect air and water quality from pollutants of concern. GAO-08-944.** *US Government Accounting Office* 2008.
10. Bunton B, O'Shaughnessy P, Fitzsimmons S, Gering J, Hoff S, Lyngbye M, Thorne PS, Wasson J, Werner M: **Monitoring and modeling of emissions from concentrated animal feeding operations: Overview of methods.** *Environ Health Perspect* 2007, **115**:303-307.
11. Heederik D, Sigsgaard T, Thorne PS, Kline JN, Avery R, Bonlokke JH, Chrischilles EA, Dosman JA, Duchaine C, Kirkhorn SR, Kulhankova K, Merchant JA: **Health effects of airborne exposures from concentrated animal feeding operations.** *Environ Health Perspect* 2007, **115**:298-302.
12. Thu K, Donham K, Ziegenhorn R, Reynolds S, Thorne PS, Subramanian P, Whitten P, Stookesberry J: **A control study of the physical and mental health of residents living near a large-scale swine operation.** *J Agric Saf Health* 1997, **3**:13-26.
13. Thu KM: **Public health concerns for neighbors of large-scale swine production operations.** *J Agric Saf Health* 2002, **8**:175-184.
14. Mirabelli M, Wing S, Marshall S, Wilcosky T: **Asthma symptoms among adolescents who attend public schools that are located near confined swine feeding operations.** *Pediatrics* 2006, **118**:66-75.
15. Wilson SM, Serre ML: **Examination of atmospheric homes, and schools ammonia levels near hog CAMS, in Eastern North Carolina.** *Atmos Environ* 2007, **41**:4977-4987.
16. Wing S, Horton RA, Marshall SW, Thu K, Tajik M, Schinasi L, Schiffman SS: **Air pollution and odor in communities near industrial swine operations.** *Environ Health Perspect* 2008, **116**:1362-1368.
17. Washington State Department of Ecology: **Lower Yakima Valley groundwater report - preliminary assessment and recommendations document, #10-10-009.** 2009.