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Air Quality and Community Health Impact of Animal Manure Management

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evidence review

Summary

- Nearly 200 million tonnes of livestock manure are generated in Canada each year.[1] Manure storage and land application tends to produce odour, greenhouse gases, microbes, and particulate matter, which can negatively impact the environment and human health.
- Occupational exposures of manure management have been linked to psychological stress and adverse effects on the respiratory system and heart function.
- Community health risks may result from poor local air quality related to manure management. Limited studies suggest respiratory and psychological health impacts on residents living in proximity to manure management operations.
- There are research gaps on comprehensive assessments of manure management and its effects on air quality and community health.
- These gaps deserve attention since many Canadians live on or near livestock farms.

Introduction

Animal manure is a primary by-product of the livestock industry. In 2006, Canada's livestock farm cash receipts amounted to $17.7 billion, ranking third in total agriculture receipts.[2] The corresponding manure generation was 181 million tonnes.[1]

Animal manure has complex composition with various nutrient components like nitrogen, phosphorus, and potassium. Manure from different animals varies in density, water content, and nutrient content.[3] Livestock farms conventionally store the manure for months and apply it to land as fertilizer.[4] This practice results in emissions to air and water, caused by microbial decomposition of the organic matter in manure.

This report reviews evidence of air quality and community health risks from animal manure management. Community health tends to focus on people within geographic communities rather than the general public (public health) or people with a common occupation(occupational health).[5] The review covers up-to-date literature and reports from on-line databases and institutions; see Appendix A for methodology used to conduct the literature review. Key research and policy gaps are presented.

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Manure Management

Manure on farms is usually stored for property stabilization and to meet fertilizable timing. Manure storage systems generally fall into three categories: stockpile, tank, and lagoon. Stockpiles consist of heaps of solid manure above ground, whereas tanks and lagoons contain mainly liquid manure and semi-solid manure. Tanks are built vessels or rooms above ground or underground, and lagoons are natural or artificial underground pits.[6]

Stored manure will eventually be applied on land manually or mechanically. There are basically five ways to apply manure[7,8]:

1) **Broadcasting** is spreading the manure evenly on top of the soil;
2) **Incorporating** involves blending the fertilizer with top soil and usually follows broadcasting;
3) **Banding** specifically takes place while planting seeds; the fertilizer is placed in a *band* a few inches to the side and below the seed row;
4) **Injection**, similar to banding, also injects fertilizer into the soil but not necessarily during the planting process;
5) **Fertigation** is the practice of integrating water and fertilizers together so that nutrients are applied when the plants are irrigated.

Broadcasting and injection are most commonly used for land crops and fertigation is usually applied in commercial greenhouses.

Emissions from Manure Management

When manure is stored, microorganisms in manure decompose the organic matter and release a number of pollutants. The greatest proportion of air pollution emissions from manure management takes place during manure storage because it is concentrated and continuous, putting farm workers at high risk. Factors influencing manure storage emissions include animal species, storage system structures, and local environment. Specifically, the original nutrient content, ambient temperature, and aeration conditions directly determine the digestion of the organic matter and thus the final emissions. Similar to manure storage, soil microorganisms along with manure microorganisms continue the decomposition process after land application. Soil conditions and local weather will additionally influence the micro-environment and therefore the decomposition processes. Emissions from manure application are released gradually for months and will eventually disperse. Hence the impact on community health basically results from manure land application.

O'Neill and Phillips reported nearly 200 compounds emitted from animal manure management,[9] with volatile organic compounds (VOCs), ammonia (NH_3), hydrogen sulphide (H_2S) and particulate matter (PM) being those most relevant for potential human health impacts. A brief description of these pollutants follows:

- VOCs are formed when the biological macromolecules in manure begin to degrade. Examples are volatile fatty acids, phenols, indoles, and alkane.[4,9] Some of these VOCs are identified as respiratory tract, skin or eye irritants[4]. If the environment is oxygen deficient, VOCs can be converted to mainly CH_4. Under aerobic conditions, VOCs can be completely oxidized to CO_2 and water.
- NH_3 emitted from manure can be produced following urea (mammals) or uric acid (poultry) hydrolysis.[10] When manure is stored for long periods of time or applied in the soil, formation of NH_3 will also occur with the microbial breakdown of organic nitrogen under both aerobic and anaerobic conditions.[11] NH_3 irritates the eyes at 20-50 ppm and can cause nausea after inhalation.[12]
- H_2S is derived from sulphur-containing organic compounds in manure under anaerobic conditions.[12] It is considered the most dangerous gas in manure handling because a worker can be killed after inhalation at a concentration above 800 ppm.[12] H_2S at low levels (1-5 ppm) can cause nausea and headaches.[13]
- PM or dusts derived from manure handling are mainly aerosolized particles combined with organisms like bacteria, fungi, and moulds.[14] Bioactive substances like endotoxins and glucans originate from the cell wall of the microorganisms and have been identified as toxins and inflammatory mediators in many studies.[15-17] These particulate pollutants are usually generated from solid manure storage and composting; however, livestock feeding operation is an important source of PMs in barns. Eighty percent

of these particles inside swine and poultry barns are less than 5 μm in diameter, which can be inhaled into the lungs.[18]

- CH_4 and CO_2 are both final products of organic matter decomposition; the proportions are determined by aeration conditions. CH_4 is generated from incomplete oxidization under anaerobic conditions, while CO_2 is generated from complete oxidization in aerobic conditions. CH_4 does not have immediate health impact potential at a low concentration but it is a greenhouse gas with a global warming potential 25 times that of CO_2.[19]
- N_2O is produced as a by-product from combined nitrification and de-nitrification of nitrogen species as a consequence of changes in the aeration conditions.[20,21] The overall emission of N_2O depends on the nitrogen and carbon content of manure and ambient environment parameters.[22] N_2O is also a greenhouse gas with no immediate health impact potential in this case, but the global warming potential is 298 times that of CO_2.[19]

Generally speaking, more VOCs, H_2S, and CH_4 are generated under anaerobic conditions and NH_3, N_2O, and CO_2 production is favoured in aerobic conditions.[20,23,24] Covered storage of liquid manure tends to create an anaerobic environment while open storage and land application mainly involve aerobic processes.[25,26] Table 1 shows the national inventory of typical emissions from manure management available from 2005 to 2008.[27,28] Data were obtained from census and necessary calculations.

Table 1. *Emissions inventory of manure management in Canada 2005-2008, reported by Environment Canada*

	NH_3 (kt)	VOC (kt)	TPM (kt)	PM_{10} (kt)	$PM_{2.5}$ (kt)	CH_4 (Mt CO_2eq)	N_2O (Mt CO_2eq)
2005	368.8	300.5	334.2	213.3	32.3	3.1	5.0
2006	326.5	291.1	338.2	215.5	32.0	3.1	4.9
2007	324.1	291.1	338.2	215.5	32.0	3.0	4.8
2008	308.2	312.9	344.8	220.4	33.9	2.8	4.7

kt – kilotonne = 1,000 tonnes; Mt – megatonne = 1,000,000 tonnes
TPM – total particulate matter
CO_2eq – carbon dioxide equivalent value; calculated by multiplying the amount of the gas by its associated 100-year global warming potential (GWP).

Efforts have been made to mitigate emissions from manure management. These include dietary modification, storage control, application of pre-treatment, and other manure utilization technologies, such as anaerobic digestion.[29-31] Nevertheless, the effectiveness of the mitigation approaches is limited and air pollutant emissions from manure management remain a problem.

Community Health Impacts from Manure Management

Air pollution emissions from animal manure may pose a health threat to workers and community residents.[17] Occupational health issues with regard to manure management have been more extensively studied than community health issues. Workers on intensive livestock farms can be directly exposed to air pollution from animal manure. These exposures have been associated with respiratory and cardiovascular effects, impacts on psychological well-being, and even acute poisoning or death. Common symptoms include nausea, coughing, eye irritation, and headaches, which can happen within hours of exposure.[32,33] Other impacts include: chronic cough, chest tightness, wheeze, phlegm, increased cardiopulmonary risk (increased sympathetic tone in the cardiovascular system), as well as psychological symptoms, such as frequent depression, tension, and anger.[32-35] Aged farm workers, working on livestock farms for years, are more vulnerable to chronic diseases. Moreover, there are fatal asphyxiation accidents of farm workers

from exposure to gaseous emissions from manure lagoons.[36,37]

Unlike occupational health issues, the overall ambient air quality, rather than primary emissions in confined spaces, is more relevant for community health. However, there are few reports of ambient air quality investigations related to manure management operations. Accordingly, impacts on health of residents living in the vicinity of animal farms are not well studied.[38] While manure spreading causes substantial air emissions and therefore complaints from nearby communities, studies specifically on community health related to manure spreading are quite rare. Among the limited investigations are several epidemiologic studies in areas surrounding Concentrated Animal Feeding Operations (CAFO), in which the dominant sources of air emissions are those from manure management[38,39]; here the manure storage process is believed to be more involved than manure spreading. These studies are summarized in Table 2.

Table 2. *Summary of the peer reviewed literature for community health issues related to manure management*

Authors	Study Location and Period	Method	Sample Size	Health Outcomes	Results
Schiffman et al. (1995)[40]	North Carolina, USA; period n/a	Cross-sectional survey on: 1) residents living an average of 5.3 ± 6.5 years near hog operations; 2) control residents.	44 study and 44 control	Profile of Mood States (POMS) Total Mood Disturbance score (TMD)	More tension, more depression, more anger, less vigor, more fatigue, and more confusion reported among residents near intensive swine operations. The study group had significantly worse scores than the control group for every POMS factor and the TMD score ($p < 0.0001$).
Thu et al. (1997)[41]	N/A	1) Interviews on residents living within a 2-mile radius of a 4,000-sow swine production facility; 2) Data review on a random sample of demographically-comparable rural residents living near minimal livestock production.	18 study and 18 control	Respiratory	Significantly higher rates of four clusters of symptoms known to represent toxic or inflammatory effects on the respiratory tract reported among residents near large-scale swine operations.
Wing et al. (2000)[42]	North Carolina, USA; 1999	Cross-sectional interviews on: 1) residents living within a 2-mile radius of a 6,000-head hog operation; 2) living within 2-mile radius of two intensive cattle operations; 3) an agricultural area without livestock operations.	~50 in each area	Respiratory, gastrointestinal, skin/eye irritation, miscellaneous, Quality of life (QoL)	Increased occurrences of headaches, runny nose, sore throat, excessive coughing, diarrhea, and burning eyes among nearby residents. QoL was not significantly influenced in the vicinity of the cattle operation, but greatly reduced among residents near the hog operation.
Radon et al. (2004)[43]	Northern Germany; period n/a	Survey on all the residents living in a rural town with intensive animal production.	3112	Quality of Life (QoL)	Odour annoyance is a strong negative predictor of QoL among nearby residents. Sixty-one percent of the respondents complained about unpleasant odours and 91% of these accused livestock as source of these odours.

Table 2 (cont'd)

Authors	Study Location and Period	Method	Sample Size	Health Outcomes	Results
Avery et al. (2004)[44]	North Carolina, USA; period n/a	Survey and sIgA concentration test on residents living within 2.4 km of at least one hog operation.	15 study that serve as their control	Mucosal immune function	Immunosuppressive effect of malodour on mucosal immunity was observed.
Merchant et al. (2005)[45]	Iowa, USA; 1994-1998	Cross-sectional survey, clinical assessment, and serum analysis on: 1) residents living in farm; 2) town; 3) rural nonfarm locations.	341 farm households, 202 rural nonfarm households, and 461 town household	Asthma	High prevalence of asthma health outcomes observed among children living on farms.
Bullers. (2005)[46]	North Carolina, USA; 1998-1999	Cross-sectional interviews on: 1) residents living near industrial hog farms; 2) those in an area that had no industrial hog farm operations.	48 study and 34 control	Respiratory, Sinus, Nausea, Psychological	Increased respiratory, sinus, and nausea problems, increased psychological distress, and decreased perceptions of control were reported among nearby residents
Mirabelli et al. (2006)[47]	North Carolina, USA; 1999–2000	Data review on adolescents' respiratory health symptoms, school environments, and location of swine CAFOs.	58,169	Asthma	Adolescents' wheezing symptoms were observed; associated with exposure to airborne pollution from confined swine feeding operations. The prevalence of wheezing was 5% higher at schools that were located within 3 miles of an operation, relative to those beyond 3 miles and 24% higher at schools in which livestock odour was noticeable indoors twice per month, or more relative to those with no odour.
Sigurdarson et al. (2006)[48]	Iowa, USA; 2003	Cross-sectional survey on: 1) a study school located 1.5 mile from a CAFO, 2) a control school distant from any large-scale agricultural operation.	61 study and 248 control	Asthma	19.7% children from the study school and 7.3% children from the control school gave a history of physician-diagnosed asthma (Odds Ratio, 5.60; p=0.0085). When analysis included smoking status, pet ownership, age, and residence in a rural area or on a farm, the adjusted Odds Ratio is 5.719 (p=0.0035).
Radon et al. (2007)[49]	Lower Saxony, Germany; 2002–2004	Survey and clinical examinations on residents living in towns with high density of CAFOs.	6937	Respiratory	Adverse effect on respiratory health was shown among nearby residents.

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