Agricultural Air Emission Inventory for Alberta and Literature Review

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Acronyms

Government Agencies

AAFC. Agriculture and Agri-Food Canada

AAFRD: Alberta Agriculture, Food and Rural Development

EC: Environment Canada

US EPA: United States Environmental Protection Agency

USDA AAQT: United States Department of Agriculture, Agricultural Air Quality Task Force

Technical Terms

CWS: Canada Wide Standard

PM: Particulate Matter

PM2.5: Particulate matter with an average diameter less than 2.5 µm

PM10: Particulate matter with an average diameter less than 10 µm

TSP: Total Suspended Particles

Executive Summary

An initial Agricultural Emissions Inventory report for Alberta was complied in May 2000. This new updated report includes improvements in our understanding of particulate matter emissions factors, and more recent pesticide and fertilizer data. In addition, we developed better methods in using agricultural census data, thereby eliminating errors.

Increases in agricultural production in Alberta have raised public concern over agriculture's impact on air quality, health and the environment. This study establishes a preliminary agricultural air emissions inventory for 2000 for Alberta. The inventory was calculated by multiplying emission factors from the scientific literature with spatially distributed data. This emission inventory was compared to other established inventories, as a first step in assessing a potential link between agricultural emissions and its effects. Environment Canada's most recent Air Emissions Inventory for Alberta is for the year 1995. In order to compare agriculture emissions in Alberta with other sectors, we used the 1996 census to calculate a 1996 agricultural emissions inventory. Emissions were summarized for 11 Alberta Airsheds.

The agricultural industry in Alberta produced 430,633 tonnes of non-greenhouse gas pollutants in 2000. Particulate matter emissions of less than 10 μm in size (PM10) are the greatest emissions by tonnage and account for 59.8% of agricultural air emissions, but they only make up 16% of the total industrial PM10 emissions in Alberta. Ammonia is second largest agricultural air pollutant by tonnage accounting for 39.5% of agricultural air emissions. Agriculture is the primary source of man made ammonia in the atmosphere making up 90% of total industrial ammonia emissions in Alberta. Agriculture is also the primary source of pesticides in the atmosphere producing most of the 729 tonnes of airborne pesticides in Alberta.

This report has 14 recommendations to improve our understanding of the agricultural impact on air quality in Alberta. The area of highest priority is to confirm cattle emission factors, because cattle are a primary source of ammonia and PM emissions. Ammonia and PM emissions will come to the forefront in 2005 as Alberta implements the Canada Wide Standard for PM and Ozone.

Table E1: Summary of agricultural emission estimates compared to total emissions in Alberta

	Ammonia	Pesticides	PM 10	PM2.5	Sulphur Dioxide
Agricultural Emissions (2000)	169,913	729	257,552	6,617	73
Agricultural Emissions (1996) (tonnes yr^{-1})	133,989	n/a	256,124	6,473	68
Total Alberta Emissions (1995) (tonnes yr^{-1})	148,243	n/a	1,580,421	268,954	608,100
Agricultural/Total Alberta Emissions x 100 (1996/1995)	90.4%	n/a	16.2%	2.4%	0.01%

1 Background

Urban sprawl, combined with the intensification of agriculture land use in Alberta is increasing public concern over health and environmental impacts. The health and environmental impacts of short-term exposure to high concentrations of many of the individual compounds emitted by agriculture are well documented in the literature. The impacts of long term exposure to low concentrations of agriculturally emitted compounds are unknown. The knowledge basis of the impacts of these compounds in the atmosphere, on the environment and on human health of nearby residents is low. The development of an agricultural air emission inventory, designed to identify and quantify the compounds emitted to the atmosphere, is a first step to help assess the potential link between agricultural emissions and environmental and human health. This inventory also allows for a comparison of the agriculture's air emissions relative to other Alberta industries.

2 Objective

This study attempts to quantify the contribution of agriculture's emissions to air quality in Alberta. The project objectives are to: determine what agricultural operations emit pollutants into the atmosphere; estimate the mass of each pollutant emitted to the air, and compare these agricultural emissions with those from other Alberta industries. This study does not consider agricultural greenhouse gas emissions including carbon dioxide, methane, and nitrous oxide (AFRD Greenhouse Gas Team 1999).

3 Method

Agriculture air emissions research in Alberta has focused on monitoring, method, development, odour abatement, and emission rates and not on the development of emissions factors. The definitions of emission rates and emission factors are (Sweeten 2000):

- Emission rates are the mass of air contaminant released per unit time; i.e. kg of ammonia release per hour from a 1500 square meter hog lagoon. Emission rates are useful when comparing emission measurement techniques, but do not provide an easy method for calculating emissions from multiple sources.

- Emission factors are the mass of pollutant per throughput; i.e. kg of ammonia released per year per head of cattle. Emission factors are more useful for developing emission inventories, because they can be used to develop emission estimates using readily available, spatially defined agricultural census data.

Consequently, the emission factors taken from the literature and used to develop emission estimates:

Emission Estimate = Emission Factor x Functional Unit [EQ 1]

- Emission estimates are the total mass of the pollutant emitted for a given throughput (i.e. cow, grain) in a given area per year.
- Functional units are descriptions of the throughput. For example, the number of cows are the functional unit.

i.e.

Ammonia Emission Estimate = Ammonia Emission Factor (per head) x Number of Cows [EQ 2]

4 Source Data

4.1 Literature Search

Scientific literature and government documents were searched for agricultural air emissions. About 1100 references were compiled in a bibliographic database using ProCite®. A subset of about 350 articles were selected for review based on the following criteria:

1) the article listed agricultural emission factors or emission rates,
2) the article listed an agricultural activity that is relevant to Alberta, and
3) the article listed compounds that may have potential health impacts.

4.2 Emission Factors

For each aerial pollutant an emission factor was chosen. The criteria to choose emission factors were developed in consultation with expert opinions from Alberta Agriculture, Food and Rural Development (AAFRD), Alberta Environment, and Texas A&M and ranked in order of importance:

1) Emission factors developed by the Confined Livestock Air Quality Committee of the United States Department of Agriculture Agricultural Air Quality Task Force (USDA AAQTF). Emission factors were developed by an expert committee who reviewed the current state of knowledge and applied it to the United States agricultural operations.
    - The USDA report takes into account the North American based practices instead of relying on Europe emission factors.
    - The authors of this report conducted the research, which lead to the United States Environmental Protection Agency's (US EPA) emission factors.
2) Emission factors used by Environment Canada (EC). Environment Canada's emissions factors have been reviewed to meet quality standards.
3) Emission factors from studies on Alberta agricultural emissions.
4) Emission factors used by other agencies, such as the US EPA.
5) Select emission factors used in other emission inventory reports for Alberta, such as Golder Associates (1999).

The emission factors were then reviewed to determine if they were reasonable and take into account agricultural practices in Alberta. If none of the criteria were satisfied or clarity was needed on the use of emission factors, expert opinions were consulted.

In July 2000, the USDA recommended new cattle PM10 emission factors (Sweeten 2000). This study uses the recommended PM10 emission factor. The USDA did not recommend new cattle PM2.5 emission factors. Cattle PM2.5 emission factors, 20% of PM10, were used in this report. This method was based upon consultation with Auvermann (2001. *pers. comm.*)

4.3 Databases of Functional Units

The numerical databases used in this report were chosen to:

- give the most recently published data,
- give the highest spatial resolution available and
- minimize confidentiality conflicts.

4.3.1 Statistics Canada

Every five years Statistics Canada takes a population census. The last available census was performed May 14, 1996. A Census of Agriculture was conducted at the same time. The 1996 agricultural census collected information on farmland use, crops, livestock, and land management practices. In order to protect the confidentiality of its data providers, Statistics Canada reports data to the public by census divisions.

The 1996 Census of Agriculture defined at a municipal level was used to establish numerical values and distribution of functional units (AAFRD 1998). Data at the municipal level was chosen for this report to reduce errors produced in filling in data gaps. A higher resolution was not needed because the data was to be summarized and reported by Alberta airsheds (Section 5). Before the agriculture census data was redistributed into airsheds, data gaps created by confidentially issues were filled in for each census variable and municipal combination (Jaipaul 2001) (Appendix I). Only regional data protected by confidentiality was adjusted in order to add up to provincial totals (the sum of the regional totals are less than the provincial total for each category).

Statistics Canada collects detailed Canada census data every five years. Statistics Canada with AAFRD's Production, Economics and Statistics Branch conduct semi-annually and quarterly agricultural surveys to track census variables. These surveys were averaged for the year 2000 and compared with the 1996 census data to establish scaling factors. The scaling factors were then applied to census data for each census variable to establish airshed numbers in 2000. This method assumes the distribution of census variables around the province remained constant between 1996 and 2000.

During the process of updating the census values, heifers were subdivided into three categories: heifer-beef, heifer-dairy and heifer-slaughter. This was done by multiplying the 1996 census number by the average 1996 to 2000 ratio for the three categories of heifers.

4.3.2 Other Datasets

4.3.2.1 Fertilizer

Data used to calculate emissions from fertilizer application were derived from the Alberta Farm Fertilizer Price Protection Plan (Kryzanowski 1995). The plan administrators collected information from farmers on types of fertilizer purchased, farm location, and acreage of land to be fertilized. The 1991 fertilizer data set was adjusted to 2000 totals listed in Korol (2001). This approach assumes that distribution of fertilizer usage stayed the same between 1991 and 2000.

4.3.2.2 Pesticides

Data used to calculate emissions from pesticides were obtained from sales records for 1998 (Bytrus 2000). The quantity of pesticide active ingredients purchased was obtained under the authority of the Environmental Protection and Enhancement Act from various Alberta suppliers. Pesticide sales were reported by active ingredient for each rural municipality and airshed in Alberta.

5 Summarizing Emission Estimates

Emission estimates were calculated on a municipal scale (1991) and summarized by Alberta airsheds (Figure 5). Alberta Environment proposed 11 airshed in Alberta, three of which (West Central, Parkland and South Wood Buffalo) were defined previously by the Clean Air Strategic Alliance. Clean Air Strategic Alliance defined airsheds based on emission sources and volumes, dispersion characteristics, impacts, and administrative characteristics, such as who has jurisdiction over the land involved. Agricultural emission estimates are listed by Alberta airsheds and compared to total Alberta emissions as reported by Environment Canada. The Fort Saskatchewan airshed was established in 2001, but was not included in this report.

The area of each airshed and Statistics Canada livestock census values are presented in Appendix II. The Statistics Canada crop census values are presented in Appendix V.

Figure 5: Map of airsheds in Alberta (2000).

6 Emission Estimates

6.1 Ammonia

"Globally, agriculture is the main source of atmospheric ammonia (NH_3) from human activity" (Janzen 1998). Ammonia is a colourless gas with a sharp odour. It is associated with agricultural livestock operations and fertilizer applications (McGinn 1998). Unlike other pollutants, ammonia is highly reactive and remains in the atmosphere for only a short period of time (Janzen 1998). Ammonia is found in the environment as a primary pollutant, in combination with other compounds or as secondary pollutants, the product of atmospheric reactions.

As a primary pollutant, high concentrations of ammonia can irritate the eyes and nasal passages of animals and workers within intensive livestock facilities (Donham 1982). In combination with other airborne compounds, ammonia is an important component in odour issues (Section 6.4). Ammonia's impact as a secondary pollutant is dependent on its final product. Examples of atmospheric chemistry and atmospheric ammonia include (Janzen 1998):

i. the oxidation of ammonia leads to the formation of nitrous oxide (beyond the scope of this report):
    - a greenhouse gas, and
    - the formation of ground level ozone - a compound included in Canada Wide Standards,
ii. the reaction of ammonia to ammonium ion, a component of acid deposition (beyond the scope of this report),
iii. the acceleration of the reaction of sulphur dioxide to sulphuric acid, a component of acid rain (beyond the scope of this report), and
iv. the reaction of sulphates, nitrates, and chlorides with ammonia produce ammonium sulfate, ammonium sulphide, ammonium nitrate and ammonium chloride, respectively, which are associated with particulate material in the category of PM2.5 (Section 6.2)

6.1.1 Livestock

6.1.1.1 Emission Factors

Emission factors describing ammonia emitted from animal grazing, housing, spreading and storage of manure were taken from Asman (1992) (Table 6.1.1.1). These emission factors are used by the US EPA (Battye 1994). Livestock categories from Statistics Canada census data were matched with livestock categories in Asman (1992) in the same manner as in the US EPA report (Battye 1994), with one exception: "Beef cows" were assigned the emission factor for "Breeding bulls > 2 years" rather than the emission factor for "Dairy and calf cows". This is because beef cows are not fed as much as dairy cows and consequently should produce less ammonia (Milligan 2000). This method for classifying beef cows is consistent with the approach of Hartung (1994).

Table 6.1.1.1: Ammonia emission factors for livestock and conversions to Statistics Canada census data categories

Emission Factor Classifications (Asman, 1992)	Statistics Canada Census Data Category	Emission Factor (kg NH3/animal yr^{-1}) (Asman, 1992)
Breeding bulls > 2 yr	Beef cows	27.91
Dairy & calf cows	Milk cows	39.72
Young cattle for fattening	Heifer beef cow replacements – 1 year and over	15.19
Young cattle	Heifer milk cow replacements – 1 year and over	13.04
Young cattle	Heifers – others – 1 year and over	13.04
Fattening/grazing cattle> 2 yr	Steers – 1 year and over	8.22
Breeding bulls > 2 yr	Bulls – 1 year and older	27.91
Fattening Calves	Calves – under 1 year	5.23
Breeding sows > 50 kg	Sows and bred gilts	16.13
Fattening pigs	Other pigs under 20 kg	6.98
Fattening pigs	Other pigs 20 to 60 kg	6.98
Mature boars	Boars – 6 months and over	11.0
Mature boars	Other pigs over 60 kg	11.0
Poultry – Chickens – Composite	Total hens and chickens	0.1787
Poultry – Other	Ducks	0.117
Turkeys for slaughter	Turkeys	0.858
Ewes	Sheep and lambs	3.37
Horses and ponies	Horses	12.2
Milch Goats	Goats	6.4
Rabbit	Rabbit	2.8
Fox	Fox	2.25
Mink	Mink	0.58

6.1.1.2 Method

The 2000 ammonia emission estimates were calculated for livestock using the emission factors in (Table 6.1.1.1) and 2000 census livestock numbers. Ammonia emission estimates were not calculated for bison, deer, elk, llamas, alpacas, and other livestock because there are no published emission factors for these animals.

6.1.1.3 Emission Estimates

Ammonia emissions from livestock in Alberta in 2000 were 120,717 tonnes yr^{-1} (Figure 6.1.1.3; Appendix III, Table 1). Cattle emitted 95,722 tonnes yr^{-1}, which was the greatest amount of ammonia from an individual livestock class.

6.1.1.4 Potential Errors in Emission Estimates

Asman's (1992) emission factors are derived from research in the Netherlands. Climate, housing unit design, manure management and application techniques may be different in the Netherlands than in Alberta, introducing error into the estimates presented. Confirming Asman's estimate for Alberta would improve the estimates in this report. The excluded livestock is expected to produce an insignificant error due to the small number of animals involved.

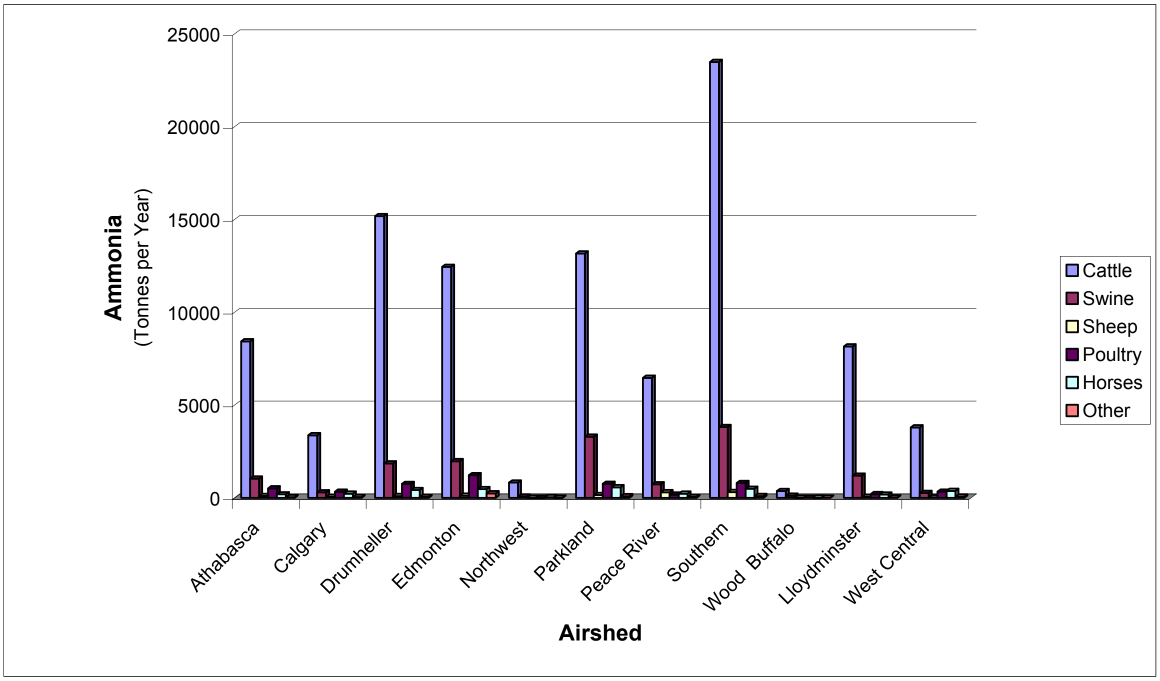

Figure 6.1.1.3: Ammonia emissions in Alberta from livestock for the year 2000 (Appendix III, Table 1)

6.1.2 Fertilizer Application

Synthetic fertilizers are extensively applied in the spring and fall in Alberta to supply essential plant nutrients to improve crop production. Fertilizer is either injected directly into the soil or applied to the soil surface, depending on form i.e. gaseous, fluid or solid form. Loss of ammonia to the atmosphere occurs during and after fertilizer application because of nitrogen mineralization. Nitrogen mineralization (i.e. hydrolization of urea) occurs within a few days of application under warm moist soil conditions (Kryzanowski 2001).

6.1.2.1 Emission Factors

Emission factors from Asman (1992) were used to calculate ammonia emissions from fertilizer application (Table 6.1.2.1). The US EPA uses Asman's ammonia emission factors for their national ammonia inventory.

Table 6.1.2.1: Ammonia emission factors from fertilizer (Asman 1992)

Fertilizer Type	Anhydrous Ammonia	Urea	Ammonium Sulphate	Ammonium Nitrate	Nitrogen Solutions	Ammonium Phosphate	Other
kg NH3/Mg N	12	182	97	25	30	48	48

6.1.2.2 Method

The spatial distribution of fertilizer usage was obtained from the 1991 farm fertilizer price protection plan (Kryzanowski 1995). Using total provincial fertilizer sales (Korol 2001) the spatial distribution of fertilizer usage was estimated for 2000. This method assumes the spatial distribution pattern of fertilizer usage has remained constant over the past decade.

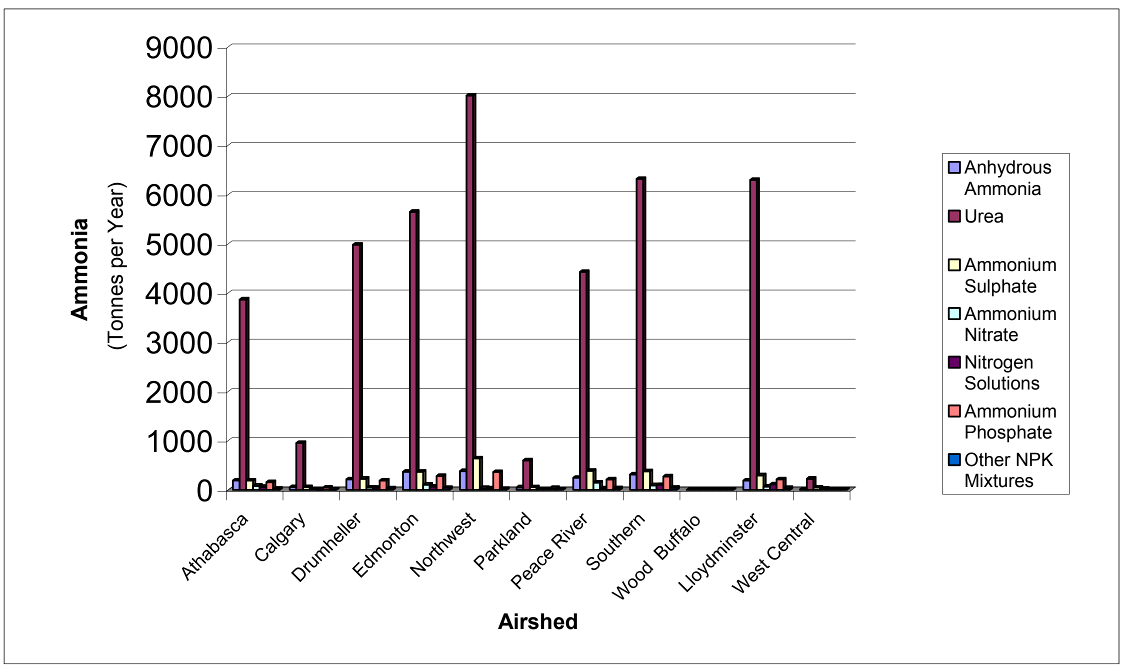

Figure 6.1.2.3: Ammonia emissions in Alberta from fertilizer for the year 2000 (Appendix III, Table 1)

6.1.2.3 Emission Estimates

In 2000, the estimated emission of total ammonia from fertilizer application in Alberta was 49,196 tonnes yr^{-1} (Figure 6.1.2.3; Appendix III Table 1). Urea fertilizer emitted the highest amount of ammonia (41,352 tonnes yr^{-1}).

6.1.2.4 Potential Errors in Emission Estimates

The Alberta Farm Fertilizer Price Protection Plan database has two limitations when used to estimate emissions of ammonia from fertilizer application (Kryzanowski 1995):

1) Location variables listed in the database describe the home quarter for the farm that purchased the fertilizer, and are not specific to the land receiving the fertilizer.
2) The database may contain non-agricultural entries such as golf courses, municipal parks and other landscape areas that may affect the summary.

The first limitation is not expected to be a source of error, because the airsheds are large relative to the size of an individual farm. The second limitation has a small impact on the total agricultural emissions from fertilizer use. For instance, in 1990, about 0.035% of total agricultural nitrogen use was attributed to golf courses (Alberta Environment 1990).

An updated spatial distribution of fertilizer usage in Alberta would improve these fertilizer emission estimates. On way would be to use the Soil Landscape Classification System to estimate fertilizer ammonia emission based on soil type and fertilizer usage.

6.1.3 Summary of Ammonia Emissions

In 2000, livestock accounted for 71% of the 169,913 tonnes of agriculturally produced ammonia emissions (Figure 6.1.3; Appendix III Table 1). Cattle operations were responsible for 79% of the livestock ammonia emissions or 95,722 tonnes of ammonia. Fertilizer application contributes 29% of ammonia emissions or 49,196 tonnes of ammonia. The mineralization of urea contributes 84% of the fertilizer ammonia emissions or 41,352 tonnes ammonia. Agriculture produces 90% of all ammonia emissions in Alberta.

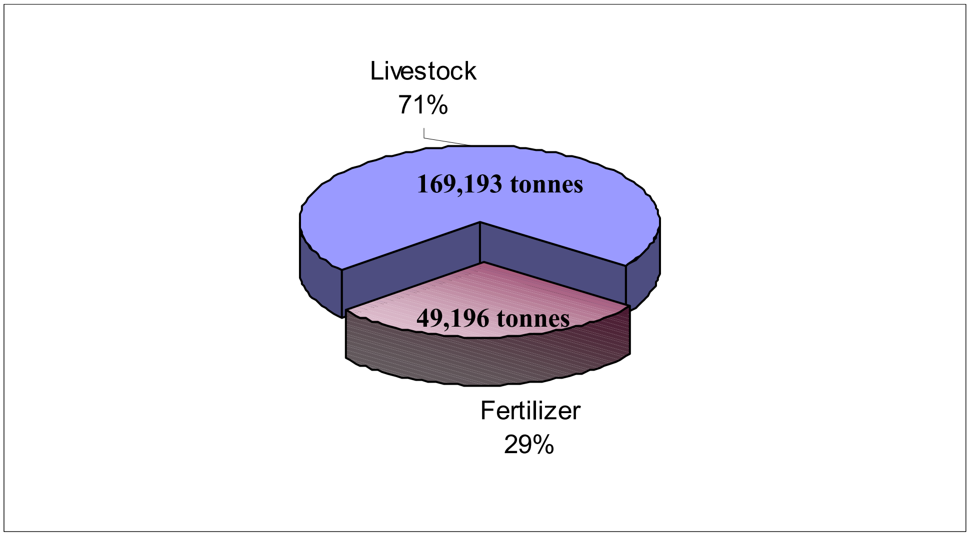

Figure 6.1.3: Comparison of Alberta's 2000 ammonia emissions

6.2 Particulate Matter

The Clean Air Strategic Alliance formed a Particulate Matter (PM) and Ozone project team in 2000 to reach consensus on recommendations for Alberta's implementation plan for achieving the provisions of the Canada-Wide Standard (CWS) for Particulate Matter and Ozone. The CWS sets ambient standards for particulate matter less than 2.5 micrometers (PM2.5) and ozone that are to be attained by 2010.

Particulate matter emissions are probably the most visible and identifiable aerial emissions of agriculture, whether from livestock, cropping or wind erosion. Particulate matter are airborne particles ranging in size from submicroscopic (0.005 μm) to coarse dust (100 μm) (Sweeten 2000). Agricultural PM is comprised of two types of particles: primary particles released intact into the air (i.e. soil, crop pollens, feedstuff, and feathers); and secondary particles formed in air through the reaction of gases (i.e. ammonium sulphate and ammonium nitrate). The distribution of the size profile is dependent on the source of emission.

Inhalation of PM has been linked to respiratory health problems in humans and animals (Popendorf 1985). Another health concern, which is beyond the scope of this report, is to address the microbial content (bacteria, bacterial cell walls, viruses, fungi and fungal spores) of PM (Muller 1987). Studies on the microbial content of cropping and livestock particulate emissions are in the initial stages (Pell 1997; Auvermann 2001). This literature review did not identify any emission factors for the microbial content of PM.

The environmental degradation effects of PM are:

i. reduced visibility (beyond the scope of this report), and
ii. the acceleration of the reaction of sulphur dioxide and nitrous oxides to sulphuric acid and nitric acid, respectively, components of acid rain (beyond the scope of this report).

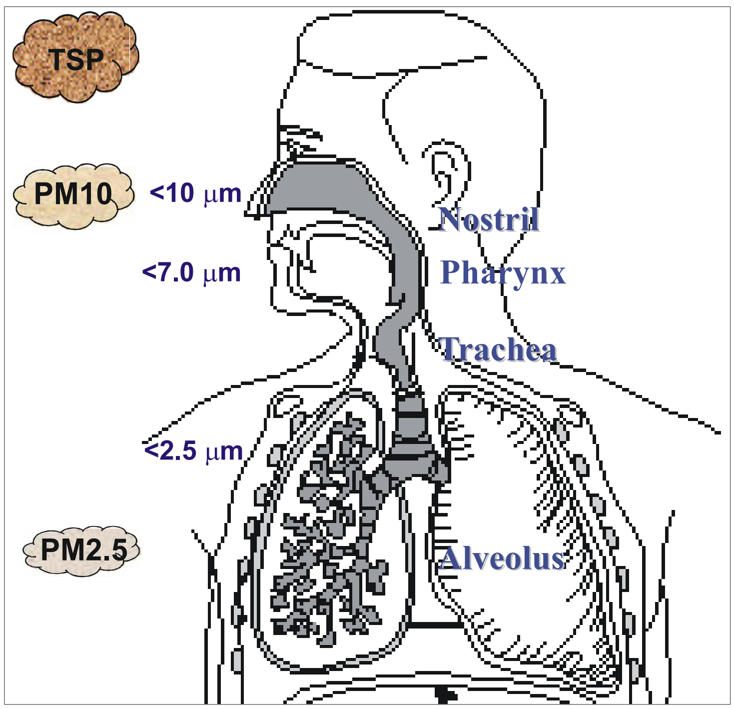

Figure 6.2: Deposition of particulate material in the respiratory tract

In an effort to better monitor and regulate emissions, PM is broken down into three size classifications (Figure 6.2):

i. Total Suspended Particles (TSP) - Airborne particles with a diameter of 0.005 to 100 μm. Particles greater than 10 μm in size are filtered in the nasal cavity.

ii. PM10 – A subcategory of TSP, PM10 particles have an average diameter less than 10μm. These particles are commonly referred to as inhalable particles because of their ability enter the upper respiratory tract.

iii. PM2.5 - A subcategory of PM10, PM2.5 particles have an average diameter less than 2.5μm. These particles are commonly referred to as respirable particles because they are small enough to enter the lower respiratory tract.

A category not formally recognized is PM7. This was established in research before the standardization of sizing. PM7 is a subcategory of PM10 and this sized of particle is capable of entering the pharynx (Figure 6.2).

6.2.1 Cattle

6.2.1.1 Emission Factors

The emission factors used for PM10 were obtained from USDA AAQTF (Sweeten 2000). The USDA AAQTF adopted a report by the Confined Livestock Air Quality Committee of the USDA AAQTF (Sweeten 2000). The USDA AAQFT report examined the state of knowledge for concentrated livestock air emissions. The report justified the cattle emissions factors by stating the research the standards were based on was:

- collected in California during the dry season, and
- not designed to produce the information necessary to develop standards.

Another reason for using the USDA AAQTF recommendations is that many of the authors involved in the development of the original emission factors, are involved in the current concentrated air quality emissions research. The PM10 emission factors proposed for cattle in feed yards are:

- 15 lbs PM10/1000 head/day or 2.48 kg PM10/head/year for beef cattle and
- 4 lbs PM10/1000 head/day or 0.66 kg PM10/head/year for dairy cattle.

PM2.5 is a fraction of PM10 and TSP. The USDA AAQTF report did not propose PM2.5 emission factors, therefore the ratio of 5:1, PM10 to PM2.5 was used to establish the PM2.5 emission factor from cattle (Auvermann 2001). The emission factors used in this report for PM2.5 for cattle in feed yards are:

- 3 lbs PM2.5/1000 head/day or 0.50 kg PM2.5/head/year for beef cattle and
- 0.8 lbs PM2.5/1000 head/day or 0.13 kg PM2.5/head/year for dairy cattle.

Cattle on managed pastures do not release PM and therefore have no PM emission factors (Milligan and Auvermann 2001). The emission factor for cattle in wintering sites is 50% of the standard emission factor (Golders 1999).

6.2.1.2 Method

The particulate emissions estimates for cattle were calculated using the above emissions factors combined with the census cattle numbers (2000) and cattle time management practices (Table 6.2.1.2). An example of cattle time management practices for dairy cows:

> The total available pasture season averages about 190 to 210 days per year (Engstrom; Milligan 2001). The number of days that would provide the quality of pasture necessary for lactating cows would be about 120 days or 32.9% of the year. The remainder of the year the cows would spend in dry lot feeding areas (feed yards).

To incorporate the cattle time management practices for Alberta, the cattle numbers were multiplied by the emission factor and time weighting for each category of cattle and management time [EQ 3]:

$$\text{Emission Estimate} = n_C * t_P * E_{FP} + n_C * t_W * E_{FW} + n_C * t_Y * E_{FY} \qquad \text{[EQ 3]}$$

where n_C = census value for the class
$t_{( )}$ = percent of time for class and management pratice
$E_{F( )}$ = emission factor for class and management practice
$_{( )}$ = $_P$ → pasture
= $_W$ → wintering site
= $_Y$ → livestock yard

Table 6.2.1.2: Cattle time management practices for Alberta (Milligan 2001)

Class	Pasture	Wintering Sites	Feed Yards
Beef Cows	50.0%	50.0%	0.0%
Dairy Cows	32.9%	0.0%	67.1%
Bulls	50.0%	50.0%	0.0%
Calves	50.0%	37.5%	12.5%
Steers	49.0%	5.0%	46.0%
Heifers-dairy	32.9%	67.1%	0.0%
Heifers-replacement	32.9%	67.1%	0.0%
Heifers-slaughter	0.0%	0.0%	100.0%

6.2.1.3 Emission Estimates

The estimated emissions of PM10 and PM2.5 from cattle in Alberta in 2000 were 4891 and 978 tonnes yr^{-1}, respectively (Figure 6.2.1.3; Appendix III Table 2). The beef cattle industry accounts for 98.8% of all particulate emissions from cattle.

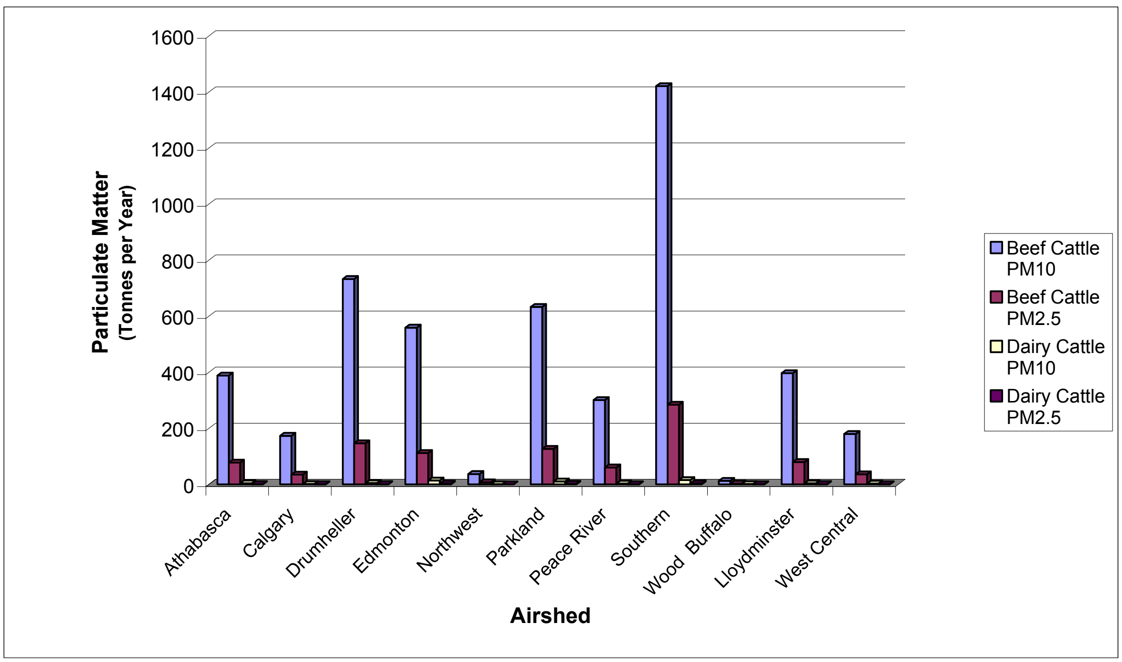

Figure 6.2.1.3: Particulate emission for cattle in Alberta for the year 2000 (Appendix III Table 2)

6.2.1.4 Potential Errors in Emission Estimates

Potential errors in PM emission estimates may result from using the USDA PM10 emission factors because they were developed to represent emission of cattle in the Great Southern Plains of the United States. The climate in Alberta is variable from north to south and east to west. Variations in moisture, growing seasons, and soils result in different livestock management systems across the province and therefore different emission factors around the province.

Confirmation of the USDA PM10 emission factors for Alberta, and developing PM2.5 emission factors for cattle operations would improve the emission estimates in this report.

The methods used in this report to estimate cattle PM emissions should be used by Environment Canada and Alberta Environment in future national air emissions inventories.

6.2.2 Other Livestock

6.2.2.1 Emission Factors

To compare emissions from livestock other than cattle with worker's health, most literature examines emissions within animal housing (Phillips 1998; Takai 1997). Emission factors from Takai (1998) were used to calculate emission totals because it listed emission factors for particulate matter discharged from animal housing. Takai (1998) listed measured PM10 and PM2.5 emissions from animal houses in four countries (England, The Netherlands, Denmark and Germany), differentiated by housing type (Table 6.2.2.1). An average of the four values was used to calculate emission estimates.

Emission factors from Takai (1998) were reported by animal weight. Estimates of Alberta livestock weights were used to convert Statistics Canada animal inventory data into live weight basis. Proportions of various housing types used in Alberta were estimated based on consultation with AAFRD specialists (Appendix IV).

Table 6.2.2.1: PM10 and PM2.5 emission factors for animal housing (Takai 1998)

Type of Livestock	Average Weight	PM10	PM2.5
	kg	kg yr^{-1}	
Sows	200	1.987	0.207
Boars	300	2.980	0.310
Other Pigs	70	0.695	0.072
Poultry	1.9	0.105	0.167

Livestock on managed pastures do not release PM and therefore have no PM emission factors (Milligan; Auvermann 2001).

6.2.2.2 Method

The 2000 livestock housing emission estimates were calculated using livestock housing emission factors (Table 6.2.2.1) and 2000 census livestock numbers. The emission factors were converted from a kg per 500 kg of livestock per year using the weight factors estimated by AAFRD specialists.

6.2.2.3 Emission Estimates

The 2000 estimated emissions of PM10 and PM2.5 from animal housing were 4,069 and 561 tonnes yr^{-1}, respectively (Figure 6.2.2.3; Appendix III Table 2). The poultry industry accounts for 61% of the PM10 and 71% of the PM2.5 emissions from other livestock.

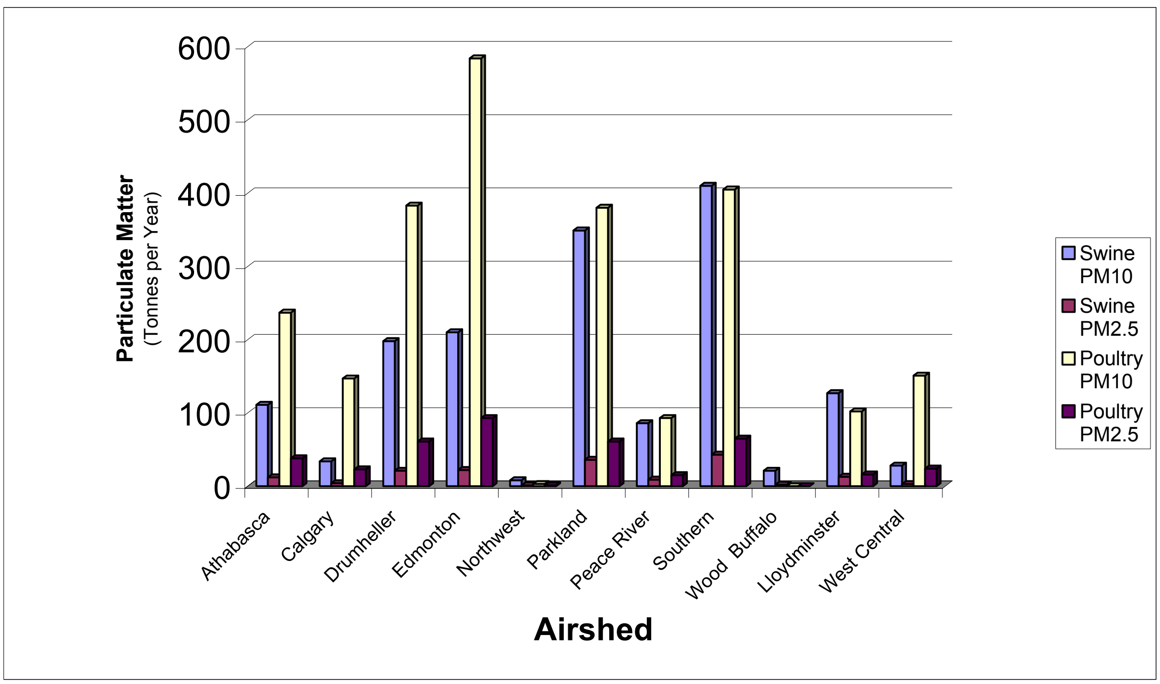

Figure 6.2.2.3: Particulate emission in Alberta for other livestock for the year 2000 (Appendix III Table 2)

6.2.2.4 Potential Errors in Emission Estimates

There are differences in environmental factors associated with animal houses used in Alberta and those used to derive emission factors used in Takai's study (1996).

Differences in building design (i.e. location of air outlets, animal densities), feeding practices and manure handling techniques result in different emissions.

Confirmation of Takai's emission factors for PM10 and PM2.5 from animal housing facilities for Alberta, as well as developing emission factors for manure storage would improve the estimates in this report.

6.2.3 Grain Harvesting and Handling

Grain harvesting refers to the process of obtaining cereal kernels from plants or the entire plant (i.e. forage, silage) and then loading the crop in trucks and transporting it out of the field (US EPA 1995). Grain handling refers to the process of receiving, internal handling and shipping of grain from elevators.

6.2.3.1 Emission Factors

The US EPA emission factors for grain harvesting were used to describe particulate emissions from wheat harvesting operations. These emission factors were developed for wheat in 1977 and were based on three field harvesting operations. They were developed for a mean particulate diameter of less than 7 μm as a function of the area of cropland harvested (Table 6.2.3.1a).

Table 6.2.3.1a: PM7 emissions factors for grain harvesting operations (US EPA 1998)

Operation	PM7 Emission Factor (g km^{-2})
Harvest machine	170
Truck loading	12
Field Transport	110

Table 6.2.3.1b: PM10 emissions factors for grain handling operations (US EPA 1998)

	Grain Receiving			Headhouse & Internal Handling	Grain Transporting	
	Straight Truck	Hopper Truck	Rail Car		Truck	Rail Car
lb/ton	0.059	0.0078	0.0078	0.034	0.029	0.0022
kg/Mg	0.0295	0.0039	0.0039	0.017	0.0145	0.0011

The US EPA emission factors for grain handling were used to describe particulate emissions from the receiving of incoming grain, the internal handling of grain and loading of out going grain (US EPA 1998). These emission factors were developed for PM10. It was assumed the incoming grain was delivered in straight trucks (i.e. traditional grain trucks vs. hopper trucks or railcars), the headhouse and internal handling systems fit the US EPA model and the grain was loaded into railcars instead of trucks (US EPA 1998) (Table .6.2.3.1b).

6.2.3.2 Method

The grain harvesting emission estimates were calculated by scaling the 1996 Statistics Canada grain acreage values, using the percent difference determined from the 2000 crop seeding acreage numbers (AFRD 2001a). The crops included in this calculation are listed in Appendix V.

The grain handling emission estimates were calculated using grain tonnage estimates (AFRD 2001a), which do not have spatial resolution. The crops included in this calculation: wheat, oats, barley, grains, buckwheat, rye, corn, alfalfa, hay, canola, flax, soybean, mustard, sunflower, safflower, potatoes, lentils, beans, canary seed, sugar, triticale, forage, and other (Appendix V).

6.2.3.3 Emission Estimates

Grain harvesting and handling represent 805 tonnes yr^{-1} or 0.3% of the overall agriculture PM10 emissions (Figure 6.2.3.3; Appendix III Table 2). Most of the particulate emissions (772 tonnes) are generated in the grain handling process.

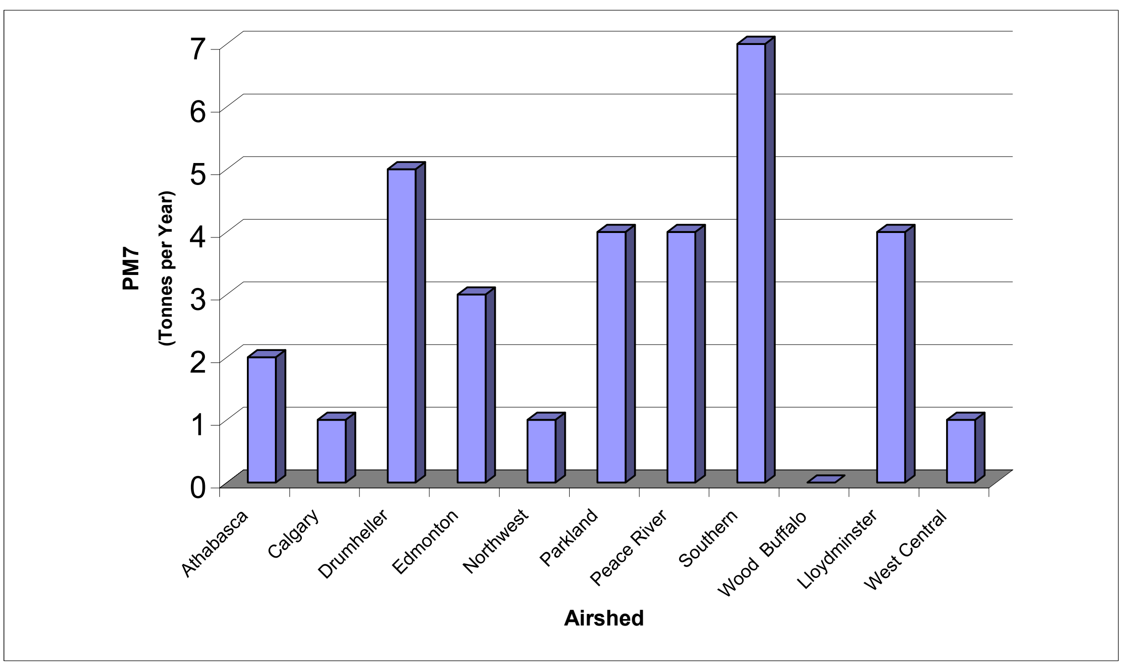

Figure 6.2.3.3: PM7 emissions from grain harvesting in Alberta for the year 2000 (Appendix III Table 2)

6.2.3.4 Potential Errors in Emission Estimates

Emissions of PM from grain harvesting depend on the speed of combine machines and field transport trucks, the width of the combine swath, and the time required to load a truck with grain (US EPA 1998). All of these factors vary with each operation, however it is not known to what extent these variations affect emission estimates.

Emissions of PM from grain handling are dependent on the type of delivery vehicle and receiving vehicle. The consolidation of grain elevators has allowed for the development and construction of cleaner facilities, thereby reducing the internal and external particulate emissions.

Developing PM10 and PM2.5 emission factors for grain harvesting and handling for Alberta would improve the estimates in this report.

6.2.4 Tilling and Wind Erosion of Agricultural Soils

Dry and windy conditions in Alberta, together with agricultural tillage practices, contribute to the loss of soil particles through wind erosion (Green 1990). Equations to estimate PM emissions from tillage and wind erosion depend upon soil and vegetation properties and meteorological conditions (Evans 1980). It is beyond the scope of this project to define these variables accurately for the entire province.

6.2.4.1 Method

Environment Canada estimated PM emissions from agricultural tillage and wind erosion (1995), and these estimates are reported here instead of calculated emissions (Figure 6.2.4; Appendix III; Table 2).

6.2.4.2 Potential Errors in Emission Estimates

The implementation of reduced tillage practices in the cropping sector over the past decade have decreased the PM emissions from tillage and wind erosions because:

- Increases in crop residue on fields and
- Increases in surface soil moisture.

The PM estimate presented in this report from tillage and wind erosion does not include this reduction in PM emission because they were not known at the time the estimate was made by EC. Therefore incorporating the reduced PM emission factor due to changes in tillage practices would improve the estimate in this report.

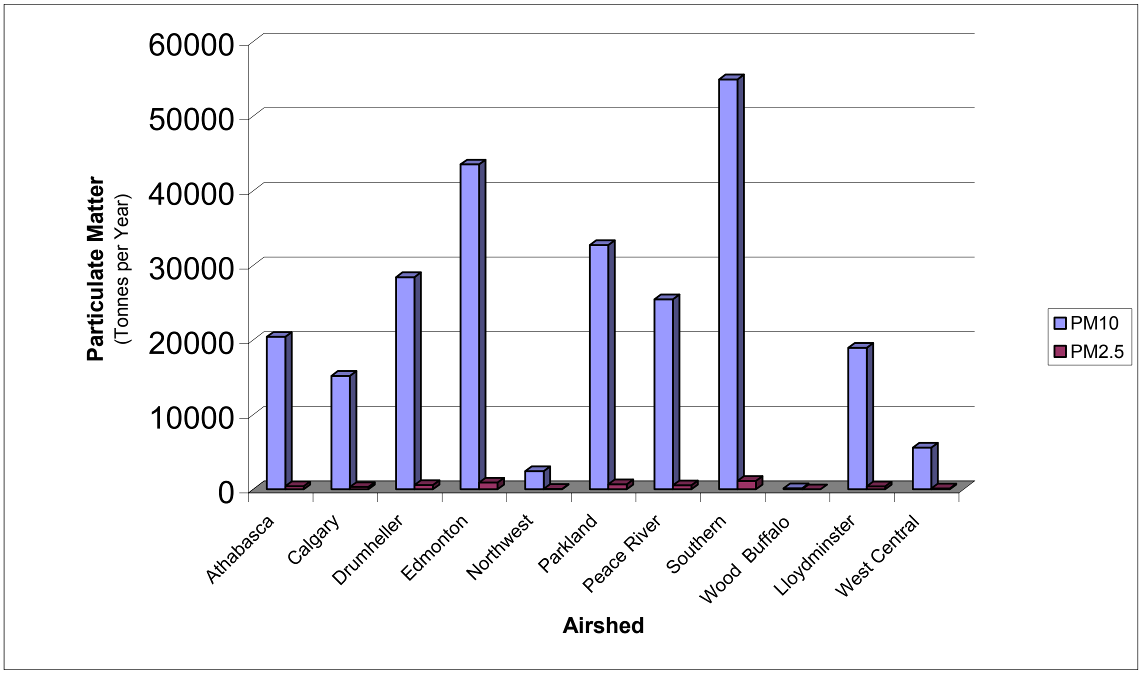

Figure 6.2.4: Particulate emissions from tilling and erosion for the year 2000 (Appendix III; Table 2)

6.2.5 Summary of Particulate Emissions

Tillage and wind erosion accounts for 247,788 tonnes yr^{-1} (96%) of PM 10 emissions and 5,104 tonnes yr^{-1} (77%) of PM2.5 emissions (Figure 6.2.5a and 6.2.5b; Appendix III Table 2). Livestock operations are the next largest source of PM emissions with beef cattle and poultry operations being the largest sources of particulates. Agriculture produces 16% PM10 and 2% of PM2.5 emissions in Alberta.

The PM estimates in this report do not include the microbial content of PM (bacteria, bacterial walls, viruses, fungi and fungal spores). To improve these estimates, characterization of microbial content of PM from cropping and livestock operations and the development of emission factors would be beneficial.

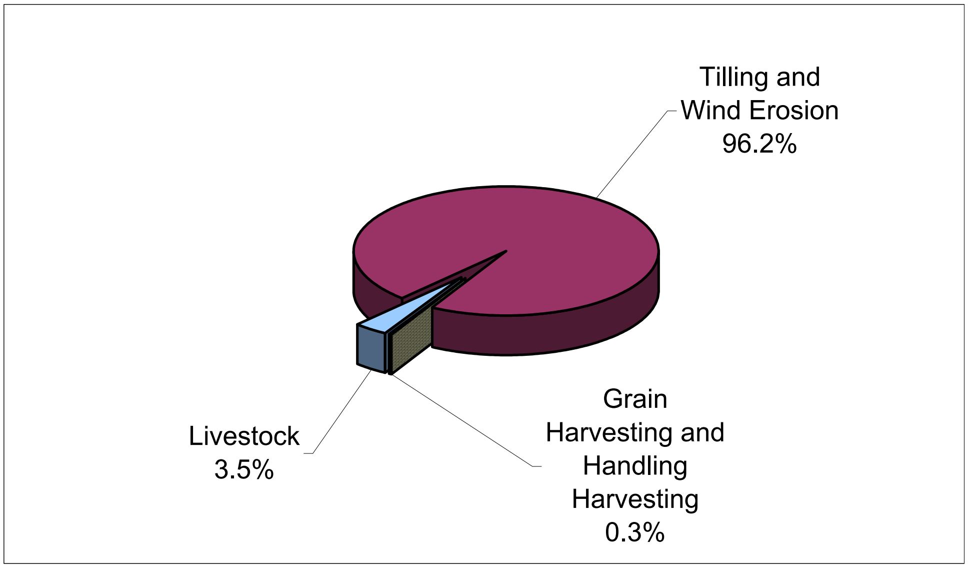

Figure 6.2.5a: Comparison of PM10 emissions in Alberta for the year 2000

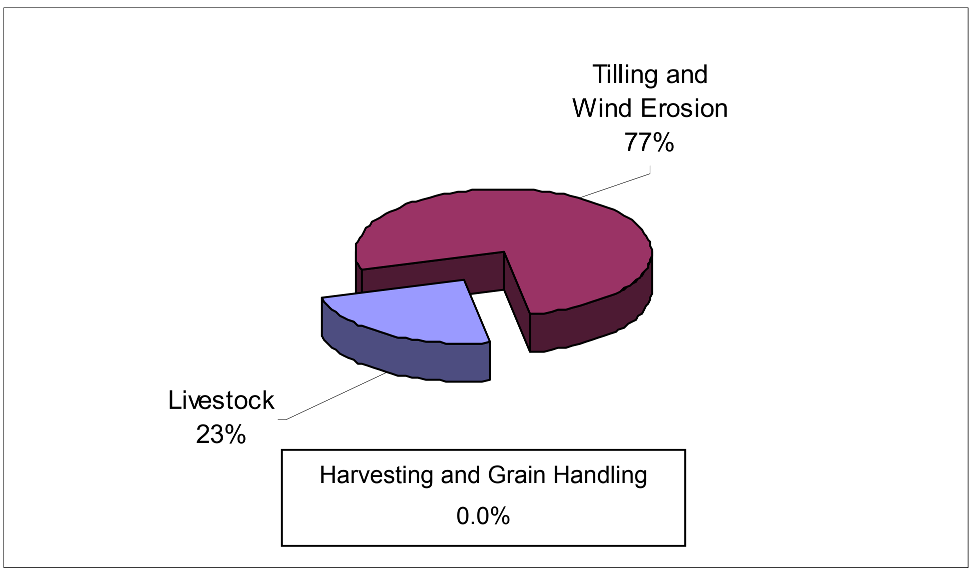

Figure 6.2.5b: Comparison of PM2.5 emissions in Alberta for the year 2000

6.3 Sulphur compounds

Agricultural release of sulphur compounds into the environment comes primarily from livestock and the incorporation of ammonium sulphate fertilizer into soil. Sulphur compounds are associated with odour (Section 6.4), the formation of secondary particulate material, acidification of precipitation and health effect. The sulphur compounds associated with odour are hydrogen sulphide and volatile organic sulphur compounds. Sulphur dioxide is associated with particulate material. Acidification of precipitation is linked to both hydrogen sulphide and sulphur dioxide. Health effects are associated with sulphur dioxide and hydrogen sulphide.

Hydrogen sulphide, which smells like rotten eggs, is produced by microorganisms in an oxygen free (anaerobic) environment where sulphate is reduced to sulphide (Xue 1998). Anaerobic environments commonly occur in pig and other livestock slurries. High concentrations of hydrogen sulphide are toxic to humans and animals (Hartung 1988). Hydrogen sulphide is oxidized in the atmosphere to sulphur dioxide and reacts with moisture to produce sulphuric acid.

In the atmosphere, sulphur dioxide reacts with moisture to form sulphuric acid, which is directly linked to the acidification of precipitation. Sulphur containing particulate material forms through reactions such as sulphur dioxide and ammonia to form ammonium sulphate or ammonium sulphide (Section 6.2). The health effect of sulphur dioxide are primarily linked to the PM formation. High concentrations of sulphur dioxide act as an irritant to mucus membranes (eyes and respiratory system).

The volatile organic sulphur compounds (dimethyl sulphide, diethyl sulphide, methylmercaptan, disulphides, etc.)(Sweeten 1998) emitted by agriculture is beyond the scope of this report.

High emissions of sulphur compounds are associated with agitation of manure slurries. However, there is insufficient information to assess how frequently these high emission rates occur, and to estimate their contribution to an annual emission estimate.

6.3.1 Emission Factors

Alberta emission factors for sulphur compounds were not developed for Alberta because the concentration of sulphur compounds in barns in Alberta was found to be low enough not to warrant continuous monitoring (Clark 1987).

The emission factors for sulphur compounds from cattle were taken from US EPA (1998). The swine hydrogen sulphide emission factor was taken from Ni (1999), who examined hydrogen sulphide outputs of housing units with under floor liquid manure storage. The swine sulphur dioxide emission factor was obtained from the UDSA AAQTF report (2000).

Table 6.31: Sulphur compounds emission factors

Livestock Category	Hydrogen Sulfide	Sulphur Dioxide	Sulphur compounds
		(kg $animal^{-1}$ yr^{-1})	
Cattle	n/a	n/a	0.281
Sows (200 kg)	0.920	10% of hydrogen sulphide	n/a
Boars (300 kg)	1.380	10% of hydrogen sulphide	n/a
Other Pigs (70 kg)	0.322	10% of hydrogen sulphide	n/a

6.3.2 Method

The livestock housing emission estimates for sulphur compounds were calculated using the emission factors (Table 6.3.1) and the 2000 census livestock numbers. The swine emission factors were reported in units of kilograms of hydrogen sulphide per 500 kg of livestock per year. These emission factors were converted to kilograms of hydrogen sulphide per head per year by dividing the original emission factor with average weight estimates obtained from AAFRD specialists (Appendix IV). Only cattle and swine emissions were estimated due to availability of emission factors.

6.3.3 Emission Estimates

The emission estimates for sulphur compounds from cattle and swine in Alberta for the year 2000 totaled 2,440 tonnes yr^{-1} (Figure 6.3.3; Appendix III Table 3). Sulphur emission from cattle was 67% of the total livestock emissions.

6.3.4 Potential Errors in Emission Estimates

Errors in emission estimates for swine result from the limited number facilities examined by Ni (1999). This report assumed that all classes of swine produced the same amount of hydrogen sulphide and sulphur dioxide by weight.

6.3.5 Summary of Sulphur Compound Emissions

The emission estimates for sulphur compounds from cattle and swine in Alberta for the year 2000 totaled 2440 tonnes yr^{-1}. Cattle emissions represented 67% of the livestock sulphur emissions. Agriculture's contribution to the emission of sulphur compounds cannot be calculated because other industries report sulphur emissions on a compound by compound basis.

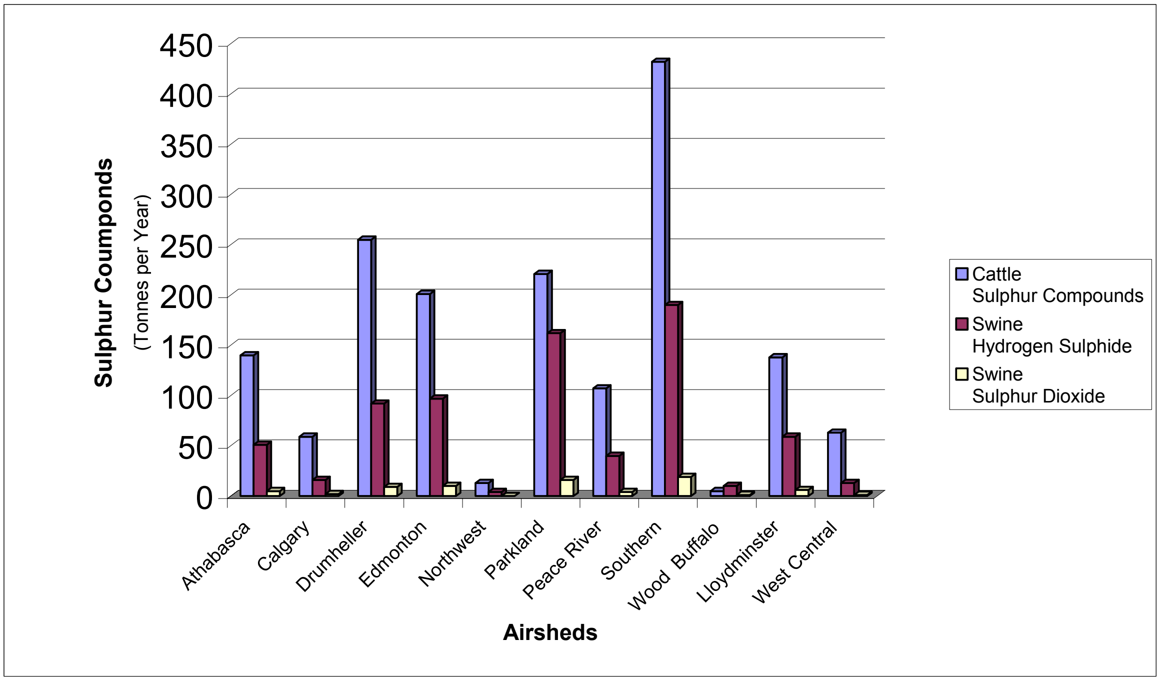

Figure 6.3.3: Sulphur compound emissions from Alberta livestock for the year 2000 (Appendix III Table 3)

Comparison of hydrogen sulphide emissions for swine in Alberta and other industries cannot be determined because the goal of other industries is to prevent the release of hydrogen sulphide. Other industries are required to report emissions greater than 10 tonnes of hydrogen sulphide on an individual release.

The 68 tonnes of sulphur dioxide emitted from swine operations accounted for 0.01% of Alberta's 1995 industrial sulphur dioxide emissions.

To improve estimates of sulphur compound emissions in Alberta, emission factors for hydrogen sulfide, sulphur dioxide and volatile organic compounds need to be developed. These estimates should encompass all industries in Alberta so agriculture's impact on the environment with respect to sulphur compounds relative to other industries can be made.

6.4 Odour

Odour is probably one of the most contentious air quality issues in agriculture since it is a perceptual issue and poorly understood. For example the smell of canola in bloom is the smell of money to some where it may one of the most offensive odours to others. Odour offensiveness is related to (Auvermann 2000; Sweeten 2000):

- F requency of exposure or number of times detected during a time period
- I ntensity , concentration or strength of the odour
- D uration of the period in which the odor remains detectable
- O ffensiveness and character or quality of odour

"These factors interrelate in causing nuisance conditions. Odor frequency and duration are partly dictated by climatic conditions, including wind-direction frequency, atmospheric stability, and moisture conditions"(Sweeten 2000).

In agriculture, odours originate from animal housing, manure storage, land application of manure and cropping. Livestock odours are generally chemically reduced gases associated with intermediate anaerobic conditions and include:

- Sulphur compounds - hydrogen sulphide, mercaptan, dimethyl sulphide, dimethyl disulphide
- Nitrogen compounds- ammonia, methyl amine, dimethyl amine, chloro-amine
- Volatile Organic compounds (VOC's) - fatty acids, phenols, ketones, aldhydes, alcohols, organic acids

Some studies have found up to 170 different compounds emitted from swine manure (Sweeten 1998). The complex composition of odorous air, together with the subjective nature of human response to odour, makes it difficult to measure and quantify.

Odour has been linked to complaints of headaches, drowsiness, and irritations to the eye, nose and throat (Schiffman 1998a and b). Other health problems are more subjective, and include stress and other psychological disorders.

6.4.1 Emission Factor

Odours are quantified by a variety of methods (St. Croix Sensory 2000):

- Character descriptors – medicinal, floral, fruity, vegetable, earthy, rotten/offensive, fishy, chemical
- Intensity – using n-Butanol as a reference scale – very faint, faint, noticeable, strong, very strong
- Hedonic tone – unpleasant (-10), neutral (0), pleasant (+10)
- Concentration of a compound – i.e. ammonia, hydrogen sulphide
- Persistence – very short, short, moderate, long, extremely long

Of these quantifiers, intensity and its subcategory of threshold dilution ratios are the two most often used indices to quantify odour concentrations. Odour intensity can be assessed by human odour panels at an olfactometer (Chen 1999) or by trained observers (Borg 2001), who categorize odour strength on a numeric scale using reference odours. Threshold dilution ratio describes the theoretical minimum concentration of the odour for detection in 50% of the population, and is commonly expressed as Odour Units (OU m^{-3}). Most studies measure threshold dilution ratio from ambient air surrounding livestock operations (Hobbs 1995; Liu 1994; De Bode 1991; Hobbs 1999). However, recent research suggests that odour intensities provide useful information in developing odour control measures (Chen 1999) and relate odour to human health impacts (Auvermann 2000).

There is no relationship between ammonia and sulphur compound concentrations and odour emissions (Sweeten 2000). Further research in this area may lead to more accurate techniques and protocol for estimating odour emissions.

At present, there are few studies reporting emission factors and odour emission estimates (Jacobson 1999; Guo 2001) listed odour emission factors/rates.

6.4.2 Emission Estimate

This report will not develop odour emission estimates for the following reasons:

1) There has been no protocol established by any government agency for the development of an odour emission inventory.
2) An attempt to apply emission rates from individual studies to all agricultural operations in Alberta would be inaccurate given the high variability in the composition of odorous air.
3) The literature suggests odour intensities are a more important measure of human health impacts: most emission factors are expressed as odour units (OU). A recent study (Jacobson 1999; Guo 2001) developed a relationship between odour intensity and OU.

6.5 Pesticides

"A pesticide is anything intended to prevent, destroy, repel, or manage a pest" (Health Canada 2001a). A pest is defined by human activity as a harmful, noxious or troublesome organism.

The most common method of classifying pesticides is based on the types organisms they are intended to control (Ali 2001):

- Herbicides: weeds i.e. 2,4-D and MCPA are used in conventional tillage prior to freeze up to control winter annuals such as flixweed, sheperd's-purse and stinkweed.
- Insecticide: damaging insects i.e. Chloropyrifos is used to control armyworm, cutworm, grasshopper, brown wheat mite, Russian what aphid and wheat midge in barley, oats and wheat in insect outbreak years.
- Fungidicide: fungi, bacteria, viruses, mycoplamas and nematodes i.e. Capatan is used to prevent seed decay, root rot, damping off, and seedling blight in beans, peas, soybeans, corn and sugar beets.
- Rodenticide (vertebrate): rodents i.e. Warfarin is used to control ground squirrels, pocket gophers, mice and voles.

"In agricultural production, pesticides are a regular component of most systems, and their development has given rise to entirely new ways of growing crops" (Pedigo 1989). For example, no-till cropping allows for the conservation of energy and soil but could not be considered without an integrated pest management system which includes the use of pesticides. The incorporation of integrated pest management systems has allowed the agriculture sector in Canada to be one of the lowest users of pesticides when compared to agricultural sectors in other developed nations. Canada uses one fifth of the pesticide used in France and less than half of pesticides used in the United States based on kilograms of active ingredient per square kilometre of agricultural land (Alberta Environment 2001).

"In 1998, a total of 9,300,497 kg of pesticide active ingredient was sold in, or shipped into, Alberta" (Byrtus 2000). The cropping sector accounted for 95.84% of Alberta total pesticide sales. The livestock sector was a minor consumer accounting for 0.07% of the total sales (Table 6.5 and Figure 6.5).

Table 6.5: Pesticide Sales by Sector (Byrtus 2000)

Sector	Active Ingredient (kg)	Percentage (%)
Agriculture (Cropping)	8,913,981.7	95.84
Domestic	72,024.4	0.77
Commercial/Industrial	304,881.6	3.28
Livestock	6,373.2	0.07
Structural	3236.8	0.03
Totals	**9,300497.7**	**100**

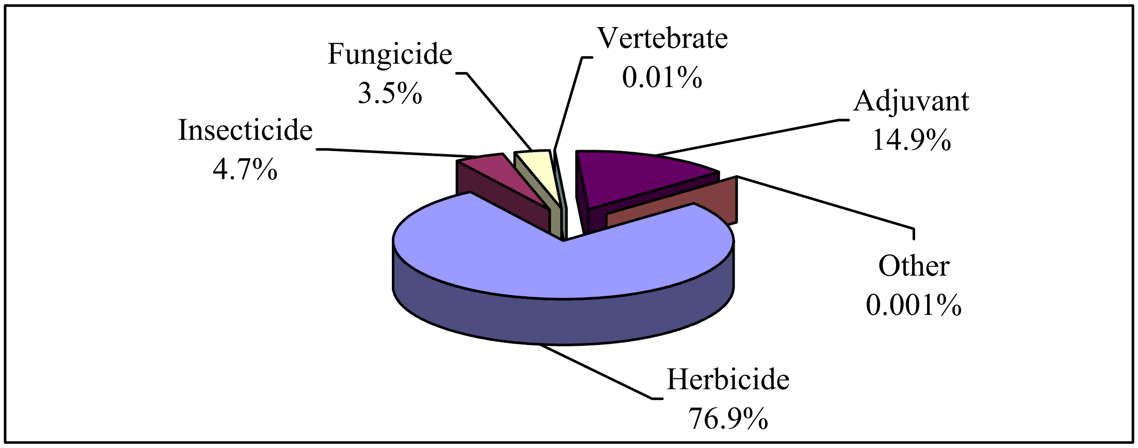

Figure 6.5: Breakdown of type of pesticide used by the agricultural cropping sector in Alberta (Byrtus 2000)

Aerial emissions from pesticides arise from the volatile nature of many active ingredients, solvents, and other additives used in product formulations (US EPA 1995). Emissions from pesticide use depend on formulation (dry or liquid) and method of application (soil incorporated or surface applied). Accidental exposure to pesticides is the largest cause of human health problems (World Health Organization 1992), however there is little published research to assess potential health impacts from pesticide releases to the atmosphere.

6.5.1 Emission Factors

Emission factors for pesticide active ingredients from the US EPA are categorized according to pesticide vapor pressure and method of application (Table 6.5.1). Pesticides with high vapor pressures are more volatile than those with low vapor pressures. Pesticides incorporated into the soil have a lower rate of volatilization than surface applied pesticides.

Table 6.5.1: Pesticide active ingredient emission factors (US EPA 1995)

Surface Application		Soil Incorporation	
Vapour Pressure Range (mm Hg at 20 to 25°C)	Emission Factor (10^{-3} tonnes Mg^{-1})	Vapour Pressure Range (mm Hg at 20 to 25°C)	Emission Factor (10^{-3} tonnes Mg^{-1})
1×10^{-4} to 1×10^{-6}	350	$<1 \times 10^{-6}$	2.7
$>1 \times 10^{-4}$	580	1×10^{-4} to 1×10^{-6}	21
		$>1 \times 10^{-4}$	52

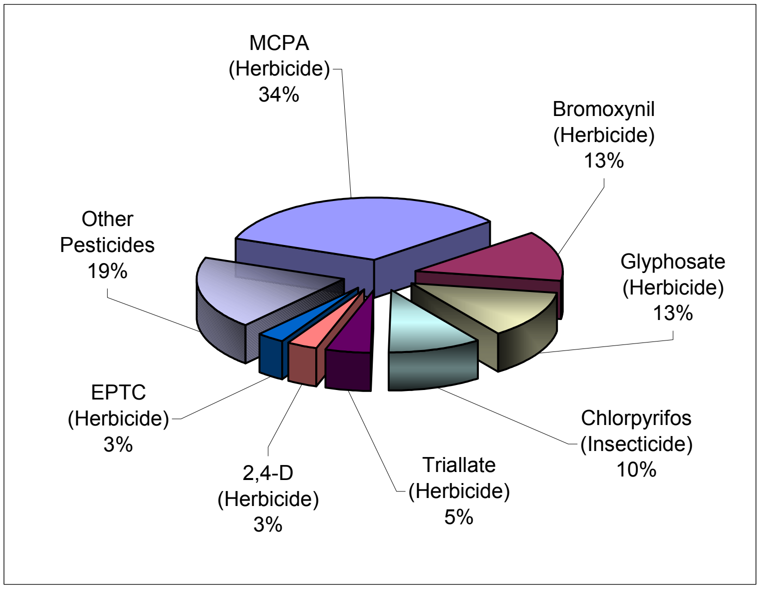

Figure 6.5.3: Breakdown of pesticide emissions in Alberta for the year 1998 (Appendix VI)

6.5.2 Method

Byrtus (2001) calculated emission estimates using tonnage of active ingredient applied, vapour pressure of pesticide application method and US EPA emission factors. Bytrus's survey results account for approximately 97% of the total pesticide sales in Alberta (2000). The emissions estimates were assembled in spatial distribution tables by pesticide emission and municipality or airshed.

6.5.3 Emission Estimates

The total emission estimates of pesticides active ingredients in Alberta for the year 1998 totaled 729 tonnes yr^{-1} (Appendix VI). The emissions of active ingredients ranged from <0.01 to 245 tonnes yr^{-1} (Appendix VI). Seven pesticide account for 81% of total pesticide emissions for Alberta (Figure 6.5.3).

6.5.4 Potential Errors in Emission Estimates

The pesticide sales record data set contains annual product sales, not pesticide use. There probably is carry over of products by farmers from year to year. In addition, pesticide use outside the agricultural sector is not accounted for.

6.5.5 Summary of Pesticides Emissions

In 1998, of the 9,300 tonnes of pesticide active ingredient sold or shipped into Alberta about, 729 tonnes were emitted to the atmosphere (Bytrus 2001). Agricultural sales accounted for 96% of all pesticide active ingredients sold in Alberta for the year 1998. The commercial/industrial, domestic and structural sectors account for the remainder of Alberta pesticide sales (Table 6.5). Consequentially, agriculture is primary source of pesticide emissions. Herbicides accounted for the largest percentage of emissions. Based on a kilogram of active ingredient per hectare, the agriculture sector in Alberta is one of the smaller consumers of pesticide use. Whereas the home and garden sector is one of the largest users, using four times the amount of pesticide per hectare as the agricultural sector (Alberta Environment 2001).

7 Comparison with Other Estimates

To assess a potential link between agricultural emissions and its impact, this emissions inventory was compared to other established inventories. Environment Canada's most recent Air Emissions Inventory for Alberta is for the year 1995. In order to compare agriculture emissions in Alberta with other sectors we used the 1996 census to calculate a 1996 agricultural emissions inventory.

7.1 Ammonia

To compare ammonia provincial emissions from EC and this report the 1996 livestock and 1995 fertilizer emission estimates were calculated. The ratio of Alberta ammonia emission estimates in this report and Environment Canada's 1995 estimates (Cosham 2000) was 149% for livestock, 44% for fertilizer and 107% overall (Table 7.1).

Table 7.1: Comparison of AAFRD 1996 and Environment Canada 1995 Alberta ammonia emission estimates

Category/Sector	EC (Alberta)	AAFRD	AAFRD / EC (Alberta)
		(tonnes yr^{-1})	
Animal Husbandry	**1995 Inventory**	**1996 Inventory**	
Cattle	52270	92101	176%
Swine	16257	13616	84%
Sheep	442	1136	257%
Poultry	4234	2402	57%
Horses	1326	1828	138%
Other livestock	304	497	163%
Animal Husbandry Total	**74832**	**111581**	**149%**
Fertilizer Application	**1995 Inventory**	**1995 Inventory**	
Urea	36043	14527	40%
Ammonium sulphate	2028	1234	61%
Ammonium nitrate	481	73	15%
Anhydrous ammonia	8527	1627	19%
Nitrogen solutions	1058	101	9%
Ammonium phosphate	2001	954	48%
Other fertilizer materials	304	3875	13%
Fertilizer Application Total	**50443**	**22408**	**44%**
Agricultural Total	**125275**	**133989**	**107%**
Total All Other Sources	**14254**		
Provincial Total	**139529**		
Agricultural Total / Provincial Total	**90%**	**90%**	

Differences in the livestock ammonia emission estimates are due to the use of different emission factors and inventory sample years. The increase in livestock emissions calculated by AFRD in 1996, compared to the 1995 emissions calculated by Environment Canada was expected because of growth in livestock operations. Agricultural emission factors from livestock depend on environmental conditions and animal husbandry practices. As a result, reported emission rates range between 50 and 80% of the excreted nitrogen. This produces a large difference in some of the categories, but still fall within an acceptable margin of error (Milligan 2000).

Differences in the fertilizer ammonia emissions are due to the source of the fertilizer data and method of calculating ammonia emissions. Environment Canada used total provincial fertilizer data from the Canadian Fertilizer Institute (Korol 1999). This report used higher resolution data from the Farm Fertilizer Price Protection Plan. The Farm Fertilizer Price Protection Plan data may have underestimated the total amount of urea fertilizer used in the province. Estimates for this report are based on fertilizer type and usage, where Environment Canada's estimates are based on fertilizer type, soil type, soil pH, and organic content.

Agriculture is the primary source of man made ammonia in the atmosphere making up 90% of total industrial ammonia emissions in Alberta (Figure 7.0).

7.2 Particulate Matter

7.2.1 PM10

Table 7.2.1: Comparison of AAFRD 1996 and Environment Canada 1995 PM10 emission estimates

	Livestock			Agricultural	All Industries	
Airshed Name	**AAFRD**	**EC**	**AAFRD / EC**	**AAFRD**	**EC**	**AAFRD / EC**
	(tonnes yr^{-1})			(tonnes yr^{-1})		
Athabasca/Cold Lake Region	740	4979	15%	21188	137634	15%
Calgary Region	355	3701	10%	15551	100764	15%
Drumheller Region	1318	6928	19%	29766	149627	20%
Edmonton Region	1367	10606	13%	44916	188918	24%
Northwest Region	49	594	8%	25527	52034	49%
Parkland Zone	1372	7973	17%	3816	97011	4%
Grande Prairie/Peace River Region	483	6205	8%	33222	126108	26%
Southern Alberta Region	2252	13384	17%	57209	176951	32%
South Wood Buffalo Region	35	35	100%	35	14088	0%
Wainwright/ Lloydminster Region	629	4621	14%	19605	114168	17%
West Central Zone	361	1360	27%	5945	423118	1%
Provincial Total	**8960**	**60386**	**15%**	**257552**	**1580421**	**16%**

To compare PM10 emissions estimates with EC, this report calculated the 1996 PM10 emission estimates. The provincial estimates of PM10 emissions from this report for livestock were 15% of Environment Canada's 1995 estimates (Table 7.2.1). This highlights the difference in emission factors and the effect they have on inventories. The growth in the livestock sector between 1995 and 1996 has little effect on the overall picture of agriculture PM10 emissions impact because the majority of particulate emissions are produce by tillage and wind erosion.

Provincially agriculture produces 16% of PM10 emissions when compared to other industries (Figure 7.0). Using Environment Canada agricultural PM10 emission estimates, agriculture in Alberta contributes 19% of provincial PM10 emissions.

7.2.2 PM2.5

To compare PM2.5 emissions estimates with EC, this report calculated 1996 PM2.5 emissions estimates. The provincial estimates for PM2.5 emissions from livestock were 15% of Environment Canada's 1995 estimates (Table 7.2.2). This again highlights the differences in emission factors and the effect they have on inventories. The growth in the livestock sector between 1995 and 1996 has little effect on the overall picture of agriculture with regards to PM2.5 emissions because the majority of particulate emissions are produce by tillage and wind erosion.

Table 7.2.2: Comparison of AAFRD 1996 and Environment Canada 1995 PM2.5 estimates emissions

	Livestock			Agricultural	All Industries	
Airshed Name	**AAFRD**	**EC**	**AAFRD / EC**	**AAFRD**	**EC**	**AAFRD / EC**
	(tonnes yr^{-1})			(tonnes yr^{-1})		
Athabasca/Cold Lake Region	102	782	13%	523	34092	2%
Calgary Region	47	581	8%	360	12644	3%
Drumheller Region	194	1007	19%	780	20335	4%
Edmonton Region	195	1665	12%	1092	29361	4%
Northwest Region	9	93	10%	534	29339	2%
Parkland Zone	190	1251	15%	240	11049	2%
Grande Prairie/Peace River Region	80	974	8%	754	23312	3%
Southern Alberta Region	416	2101	20%	1548	20986	7%
South Wood Buffalo Region	5	5	100%	5	5782	0%
Wainwright/ Lloydminster Region	107	725	15%	498	15118	3%
West Central Zone	45	213	21%	160	66936	0%
Provincial Total	**1390**	**9397**	**15%**	**6494**	**268954**	**2%**

Provincially agriculture produces 2% of the PM2.5 emissions when compared to other industries (Figure 7.0). Using EC agricultural PM2.5 emission estimates, agriculture in Alberta contributes 5% of provincial PM2.5 emissions.

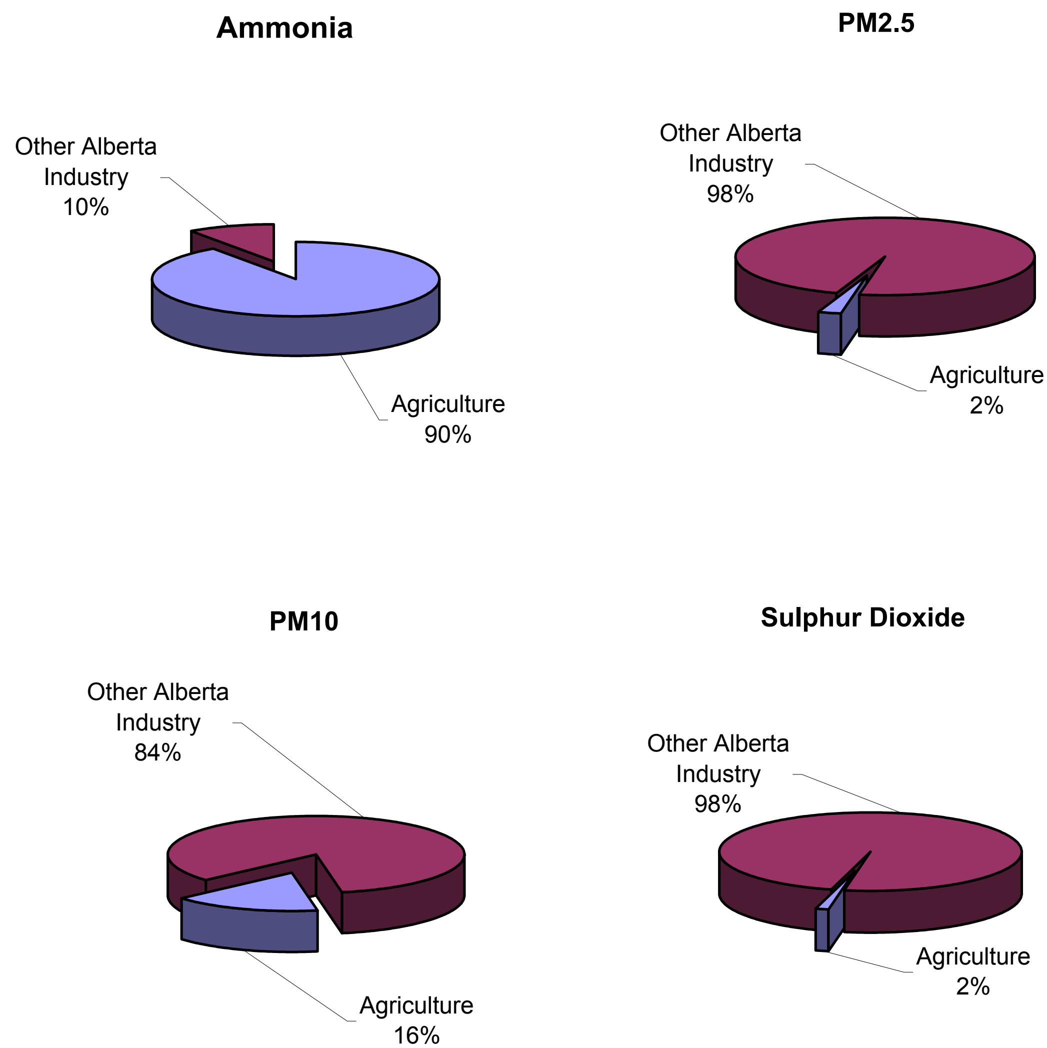

Figure 7.0: Comparison of the agricultural emission in Alberta to other industries for the year 1996/1995

7.3 Sulphur compounds

Sulphur compounds are generally not examined as a group and cannot be compared to other emissions inventory estimates.

Hydrogen sulphide is toxic. The oil and gas industry is required to recover hydrogen sulphide to prevent its release into the atmosphere (Slubik 2001). Hydrogen sulphide emissions are reported when emissions are over 10 tonnes. There is no standing inventory of hydrogen sulphide emissions.

Swine operation emitted 68 tonnes of sulphur dioxide in Alberta or 0.01% of the total Alberta industrial emissions (608,100 tonnes) in 1996 (Environment Canada 1998) (Figure 7.0). Environment Canada reports no agricultural emissions of sulphur dioxide.

7.4 Pesticides

Agricultural sales accounted for 96% of all pesticide active ingredient sold in Alberta, consequently agriculture is the primary source of pesticide emissions. Based on a kilogram of active ingredient per hectare, the agriculture sector in Alberta is one of the smaller consumers of pesticide use. Whereas the home and garden sector is one of the largest users, using four times the amount of pesticide per hectare as the agricultural sector (Alberta Environment 2001).

8 Conclusions

Agriculture is a major industry in Alberta. Its activities have the potential to impact our health and the environment. In 2000, agriculture produced 430,633 tonnes of emissions into the atmosphere (Appendix III). Although, PM10 emissions were the largest total emission by tonnage (60% of agricultural air emissions), agricultural PM10 emissions only make up 16% of the total industrial PM10 emissions in Alberta. Agriculture emits 169,913 tonnes of ammonia or 90% of industrial ammonia emissions in Alberta, which makes agriculture Alberta's primary source of man made ammonia in the environment. The other major aerial emissions from agriculture are pesticides. Agricultural emissions account for the majority of the 729 tonnes of pesticides emitted to the atmosphere in the year 1998.

9 Recommendations for Enhancing Alberta Agricultural Air Emissions Estimates

To improve the accuracy of estimating agricultural air emissions, the following recommendation can be made:

a) Confirm Asman's ammonia emission factors for livestock operations for Alberta.
b) Update the spatial distribution of fertilizer usage estimates for Alberta.
c) Use the provincial Soils Landscape Classification system to produce a fertilizer ammonia emission based on soil type and fertilizer usage.

d) Characterize microbial content (bacteria, bacteria cell walls, viruses, fungi and fungal spores) of PM associated with cropping and livestock operations.
e) Develop emission factors for the microbial content of PM.
f) Confirm USDA's PM10 emission factors for cattle operations for Alberta.
g) Develop PM2.5 emission factors for cattle operations in Alberta.
h) Environment Canada and Alberta Environment adopt the cattle PM estimate methods used in this report for national air emissions inventories.
i) Confirm Takai's (1998) emission factors for PM10 and PM2.5 from animal housing facilities for Alberta.
j) Develop PM10 and PM2.5 emission factors for manure storage for Alberta.
k) Develop PM10 and PM2.5 emission factors for grain harvesting and handling for Alberta.
l) Update the tilling and wind erosion of agricultural soils emissions for Alberta incorporating reduced tillage practices.
m) Develop emission factors for hydrogen sulphide, sulphur dioxide, and volatile organic sulphur compounds for agriculture in order to develop emission estimates for sulphur compounds for Alberta.
n) Develop an Alberta sulphur emission estimate that encompasses all of Alberta's industries. This would allow a comparison of agriculture's impact on the environment with respect to hydrogen sulphide relative to other industries.

10 Bibliography

Cited Literature

Alberta Agriculture, Food and Rural Development. 2001a. *Field crop statistics for Alberta*. <<http://www.agric.gov.ab.ca/economic/stats/crpsum00.html>> Alberta Agriculture, Food and Rural Development. Accessed October, 2001.

Alberta Agriculture, Food and Rural Development. 2001b. *Livestock statistics for Alberta*. <<http://www.agric.gov.ab.ca/navigation/economics/livestock/index.html >> Alberta Agriculture, Food and Rural Development. Accessed October, 2001.

Alberta Agriculture, Food and Rural Development, Greenhouse Gas Team. 1999. *Agriculture and Agri-Food Industry Greenhouse gas emissions in Alberta - Summary statement.* Edmonton: Alberta Agriculture, Food and Rural Development.

Alberta Agriculture, Food and Rural Development, Production Economics and Statistics Branch. 1998. *1996 Census of agriculture for Alberta: I.D., M.D., and County data by region.* Edmonton: Alberta Agriculture, Food and Rural Development.

Alberta Environment. 1990. Unpublished Alberta Environment survey of provincal golf courses.

Alberta Environment. 2001. Pesticide Management; Protection and Enforcement. <<http://www3.gov.ab.ca/env/protenf/pesticide/>> Alberta Environment. Accessed October 2001.

Ali S., Dosdall L., Harrison L., and Bourne J. 2001. *Crop protection 2001*, S. Ali, editor, "in co-operation with the agro-chemical industry". Edmonton, AB: Alberta Agriculture, Food and Rural Development.

Asman W.A.H. 1992. *Ammonia emissions in Europe: Updated emissions and emission variations*. Bilthoven, Netherlands: National Institute of Public Health and Environmental Protection.

Auvermann B. 2001. *Personal communication*. [Texas]: Texas A and M University.

Battye R., Battye W., Overcash C. and Fudge S. 1994. *Development and selection of ammonia emission factors: Final Report*. Washington, DC: U.S. Environmental Protection Agency.

Borg R. 2001. *Personal communication*. Red Deer, AB: Alberta Agriculture, Food and Rural Development.

Byrtus G. 2000. *Overview of 1998 pesticide sales in Alberta*. Edmonton, AB: Alberta Environment, Environmental Sciences Division.

Byrtus G. 2001. *Personal communication*. Edmonton, AB: Alberta Environment, Environmental Sciences Division.

Chen Y., Bundy D.S.,and Hoff S.J. 1999. Using olfactometry to measure intensity and threshold dilution ratio for evaluating swine odor. *Journal of the Air and Waste Management Association,* 49: 847-853.

Chetner S., Dzikowski P., Arendt A. and Hoskinson G. 2001. Literature review and intensive livestock emission inventory for Alberta. Edmonton, AB: Alberta Agriculture, Food and Rural Development, Conservation and Development Branch.

Clark P.C. and McQuitty J.B. 1987. Air quality in six Alberta commercial free-stall dairy barns. *Canadian Agricultural Engineering,* 29(1): 77-80.

Cosham S. 2000. 1995. Ammonia Emissions Inventory Guidebook. [draft] Hull, PQ: Environment Canada, Pollution Control Branch: iv-271.

De Bode M.J.C. 1990. Odour and ammonia emissions from manure storage. In *Odour and ammonia emissions from livestock farming*, V. C. Nielsen, J. H. Voorburg, P. Pierre L'Hermite, editors, and Commission of the European Communities, Expert Odours Group; pp.59-66. London & New York: Elsevier Applied Science.

Donham K.J., Knapp L.W., Monson R., and Gustafson K. 1982. Acute toxicity exposure to gases from liquid manure. *Journal of Occupational Medicine,* 24(2): 142-145.

Engstrom D. 2000, 2001. *Personal communication*. Edmonton, AB: Alberta Agriculture, Food and Rural Development.

Environment Canada. 1991. *Methods manual for estimating emissions of common air contaminants from Canadian sources*. Ottawa, ON: Environment Canada, Conservation and Protection.

Environment Canada. 1998. National Pollutant Release Inventory; National Overview 1998. Ottawa, ON: Environment Canada.

Evans J.S., and Cooper D.W. 1980. An inventory of particulate emissions from open sources. *Journal of the Air Pollution Control Association,* 30(12): 1298-1303.

Golder Associates. 1999. *Report on assessment of potential environmental effects of livestock expansion in Alberta*. Calgary, AB: Golder Associates.

Green F.H.Y., Yoshida K., Fick G., Paul J., Hugh A., and Green W.F. 1990. Characterization of airborne mineral dusts associated with farming activities in rural Alberta, Canada. *Int. Arch. Occup. Environ. Health,* 62: 423-430.

Guo H. 2001. *Personal communication*. Edmonton, AB: Alberta Agriculture, Food and Rural Development.

Hartung J. 1988. Tentative calculations of gaseous emissions from pig houses by way of the exhaust air. In *Volatile emissions from livestock farming and sewage operation* / V. C. Nielsen, J. Voorburg, and P. L'Hermite, editors. London: Elsevier Applied Science, pp.54-58.

Hartung J., and Phillips V.R. 1994. Control of gaseous emissions from livestock buildings and manure stores. *Journal of Agricultural Engineering Research,* 57(3): 173-189.

Health Canada. 2001a. Applicator Core; basic knowledge requirements for pesticide education in Canada. <<http://www.hc-sc.gc.ca/pmra-arla/english/pdf/edu/edu_applicat-e.pdf>> Health Canada. Accessed October 2001.

Hobbs P.J., Misselbrook T.H., and Cumby T.R. 1999. Production and emission of odours and gases from ageing pig waste. *Journal of Agricultural Engineering Research,* 72(3): 291-298.

Hobbs P.J., Misselbrook T.H., and Pain B.F. 1995. Assessment of odours from livestock wastes by a photoionization detector, an electronic nose, olfactometry and gas chromatography-mass spectrometry. *Journal of Agricultural Engineering Research,* 60(2): 137-144.

Janzen H.H, Desjardins R.L., Asselin J.M.R., and Grace B. 1998. *The Health of our air: toward sustainable agriculture in Canada.* Ottawa, ON: Agriculture and Agri-Food Canada.

Korol M. and Rattray G. 2001. *Canadian fertilizer consumption, shipments and trade - 1999/2000*, prepared by [Ottawa, ON]: Agriculture and Agri-Food Canada.

Kryzanowski L.M. 1995. Impact of fertilizer use intensity on surface water quality. In *Impacts of agriculture on surface waters in Alberta phase 2 selection of soil landscape units and study design considerations for the surface water quality monitoring program.* Edmonton, AB: Canada-Alberta Environmentally Sustainable Agriculture Agreement, Alberta, and Alberta Environmental Protection.

Kryzanowski L.M. 2001. *Personal communication*. Edmonton, AB: Alberta Agriculture, Food and Rural Development.

Liu, Q. and Hoff S.J. 1994. Odor concentration and emission rate from a swine facility. *Papers of the American Society of Agricultural Engineers.* St. Joseph, MI: American Society of Agricultural Engineers: 94-4545.

Milligan D. 2000, 2001. *Personal communication*. Edmonton, AB: Alberta Agriculture, Food and Rural Development.

Muller W. and Wieser P. 1987. Dust and microbial emissions from animal production. In Strauch, D., ed. *Animal Production and Environmental Health* 6: 47-89.

Ni J.Q., Heber A.J., Lim T.T., Diehl C.A., Agricultural & Biological Engineering Dept Purdue University, and Monsanto EnviroChem Systems. 1999. Continuous measurement of hydrogen sulfide emission from two large swine finishing buildings. Written for presentation at the 1999 *ASAE/CSAE-SCGR Annual International Meeting*, sponsored by ASAE/CSAE-SCGR, Toronto, Ontario, Canada, July 18-22, 1999. St. Joseph, MI: American Society of Agricultural Engineers.

Pedigo L.P. 1989. *Entomology and Pest Management.* New York. MacMillan Pubishing Comapany. xxii-646

Pell A.N. 1997. Manure and microbes: Public and animal health problem? *Journal of Dairy Science,* 80(10): 2673-2681.

Phillips V.R., Holden M.R., Sneath R.W., Short J.L., White R.P., Hartung J., Seedorf J., Schroder M., Linkert K.H., and Pedersen S. 1998. The development of robust methods for measuring concentrations and emission rates of gaseous and particulate air pollutants in livestock buildings. *Journal of Agricultural Engineering Research,* 70(1):11-24.

Popendorf W., Donham K.J., Easton D.N., and Silk J. 1985. A synopsis of agricultural respiratory hazards. *American Industrial Hygiene Association Journal* 46: 154-161.

Reynold J. 2001. *Personal communication*. Edmonton, AB: Alberta Agriculture, Food and Rural Development.

St. Croix Sensory, Inc. 2001. "Odour School®" / Nasal Ranger® workshop. Red Deer, Alberta, May 1-4, 2001. [*Workbook* and exercises.] St. Croix Sensory, Inc.

Schiffman S.S. 1998a. Livestock odors: implications for human health and well-being. *Journal of Animal Science,* 76(5): 1343-1355.

Schiffman S.S., Walker J.M., Small R. and Millner P.D. 1998b. Workshop on health effects of odors. In *Animal Production Systems and the Environment: An International Conference on Odor, Water Quality, Nutrient Management and Socioeconomic Issues*: pp.407-412. Iowa State University.

Sweeten J.M., Parnell C.B. Jr., Shaw B.W., and Auvermann B.W. 1998. Particle size distribution of cattle feedlot dust emission. *Transactions of the American Society of Agricultural Engineers, 41*(5): 1477-1481.

Sweeten J.M., Erickson L., Woodford P., Parnell C.B., Thu K., Coleman T., Flocchini R. Reeder C., Master J.R., Hambleton W., Bluhm G., and Tristao D. 2000. *Air Quality Research and Technology Transfer White Paper and recommendations for concentrated animal feeding operations.* United States Department of Agriculture, Agricultural Air Quality Task Force (AAQTF), Confined Livestock Air Quality Subcommittee. <<http://www.nrc.nrsc.usda.gov/faca/Archives/2000/Policy/CAPO.htm>> Accessed October 2001.

Takai H., Jacobson L.D. and Morsing S. 1996. Airborne dust concentration variation in pig buildings. In *International Conference on Air Pollution from Agricultural Operations*, pp.309-315. Ames, Iowa: Midwest Plan Service.

Takai H., Pedersen S., Johnsen J.O., Metz J.H.M., Koerkamp P.W.G.G., Uenk G.H., Phillips V.R., Holden M.R., Sneath R.W. and Short J.L. 1998. Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research,* 70(1): 59-77.

Takai, H., Pedersen S. and White R. 1997. Dust concentrations in livestock buildings in Northern Europe. In *Livestock Environment V: Proceedings of the Fifth International Symposium of the ASAE*, pp.504-511. Robert W. Bottcher, and Steven J. Hoff, eds. Michigan: American Society of Agricultural Engineers.

United States Environmental Protection Agency, Office of Air Quality Planning and Standards. 1995. *Compilation of air pollutant emission factors*. 5th ed. Research Triangle Park, NC: USEPA.

United States Environmental Protection Agency. 1998. *Compilation of air pollutant emission factors AP-42*. 5th ed. <<http://www.epa.gov/ttn/chief/ap42/index.html>> Washington, DC: US EPA. Office of Mobile Services. Accessed October 2001.

World Health Organization, WHO Commission on Health and Environment. 1992. Occupational diseases related to food and agriculture. In *Report of the Panel on Food and Agriculture*, pp.135-143. Geneva: World Health Organization.

Xue S.K., Chen S., and Hermanson R.E. 1998. Measuring ammonia and hydrogen sulfide emitted from manure storage facilities. *Tranactions of the American Society of Agricultural Engineers, 41*(4): 1125-1130.

NonCited Literature

Alberta Agriculture, Food and Rural Development. 2001c. *Overview of the Alberta poultry industry*; prepared for the Agricultural Lenders Workshop, Olds, AB. Revised ed. (July 13, 2001). Edmonton, AB: Alberta Agriculture, Food and Rural Development.

Chetner S., Arendt A. and Hoskinson G. 2001. Annotated literature review of greenhouse gas emissions from composted agricultural products; Developed for the Alberta Environmentally Sustainable Agriculture (AESA) Council. (July 19, 2000) Edmonton, AB: Alberta Agriculture, Food and Rural Development.

Chicken Farmers of Canada. 2001. *Chicken data handbook / Manuel de données sur le poulet.* Ottawa, ON: Chicken Farmers of Canada.

Cotton M.M. 1995. Pesticide characteristics and a preliminary assessment of the potential environmental significance of pesticides to surface water. In *Impacts of* *agriculture on surface waters in Alberta phase 2 selection of soil landscape units and study design considerations for the surface water quality monitoring program.* Edmonton, AB: Canada--Alberta Environmentally Sustainable Agriculture Agreement, Alberta, and Alberta Environmental Protection Vol. Appendix A1.

Cotton, M.M., and Bytrus G. 1995. Pesticide sales trends in Alberta. In Impacts *of agriculture on surface waters in Alberta. Phase 2 selection of soil landscape units and study design considerations for the surface water quality monitoring program.* Edmonton, AB: Canada-Alberta Environmentally Sustainable Agriculture Agreement, Alberta, and Alberta Environmental Protection Vol. Appendix A2.

Dzikowski P., Bertram H., Flesch T., McGinn S., Arendt A. and Coates T. 1999. *Measuring ammonia emissions from liquid hog manure storage lagoons and land application*. Edmonton, AB: Alberta Agriculture, Food and Rural Development.

Grelinger M.A. and Lapp, T. 1996. An evaluation of published emission factors for cattle feedlots. In *International Conference on Air Pollution from Agricultural Operations*, pp.9-15. Ames, Iowa: MidWest Plan Service.

Health Canada. 2001b. Report of the House of Commons Standing Committee on the Environment and Sustainable Development, entitled *Pesticides: Making the Right Choice For the Protection of Health and the Environmen*t. <<http://www.hc-sc.gc.ca/pmra-arla/english/pdf/hlawns/hl-GovtResp-e.pdf>> Health Canada. Accessed October 2001.

Hesketh H.E., and Cross F.L. 1983. *Fugitive emissions and controls*. Ann Arbor, MI: Ann Arbor Science.

Jacobson L.D., Moon R.D., Bicudo J., and et al. 1999. "A summary of the literature related to air quality and odor." *Generic environmental impact statement on animal agriculture*, (H). University of Minnesota.

Kurvits T. and Marta T. 1998. Agricultural NH_3 and NO_x emissions in Canada. In

[Proceedings of] "Nitrogen, the confer-N-s" (Nitrogen Conference), March 23-27, 1998, Noordwijkerhout, The Netherlands. Draft 19pp. [Ottawa, ON: Agriculture and Agri-Food Canada.]

McGinn S.M., and Janzen H.H. 1998. Ammonia sources in agriculture and their measurement. *Canadian Journal of Soil Science,* 78(1): 139-148.

McQuitty J.B. 1985. Air quality in confinement animal housing - is there a cause for concern? *Agriculture and Forestry Bulletin,* 8(1): 32-38.

Pain B.F., Phillips V.R., Clarkson C.R., Misselbrook T.H., Rees Y.J., and Farrent J.W. 1990. Odour and ammonia emissions following the spreading of aerobically-treated pig slurry on grassland. *Biological Wastes* 34(2): 149-160.

Toma and Bouma. 1997. Environmental Issues Document: A Background Document on the Alberta Agri-food Growth Strategy: 23. Edmonton, AB: Alberta Agriculture, Food and Rural Development.

United States Department of Agriculture, Agricultural Research Service. [2001]. USDA-ARS national programs: *Air quality -- Action Plan*. 45pp. <http://www.nps.ars.usda.gov/…/…number=203&docid=320g_id=8>

United States Environmental Protection Agency. 1985. *Compilation of air pollutant emission factors*. 4th ed. Toronto, ON: Micromedia Ltd.

United States Environmental Protection Agency. 1997. *National ambient air quality standards for particulate matter, final rule*. Washington, DC: USEPA.

Zahn J.A., DiSpirito A.A., Do Y.S., Brooks B.E., Cooper E.E. and Hatfield J.L. 2001. Correlation of human olfactory responses to airborne concentrations of malodorous volatile organic compounds emitted from swine effluent. *Journal of Environmental Quality*, 30: 624-634.

Appendix I: Data Gap Filling

G_i = Data gap caused by the confidentially (municipals reporting farms with variable but no census numbers reported).
C_n = The next larger summary of data (i.e. agricultural region for municipality, total cows for beef and dairy cows or Alberta in the case of some census variables).
F_n = Farms in the sub-field (number of farms was never confidential).
F_i = Farms in the municipality data gap.

Example:

		Total Other Pigs				
Peace Region	**Municipality**		**# Farms**		**Head**	**Adjusted Values**
Region Total		F_n =	**373**	C_n =	46,212	46,212
Grande Prairie County No. 1	CO 1		61		11,110	11,110
East Peace M.D. No. 131	ID 17		8		53	53
M.D. of Big Lakes	ID 17		26		1,845	1,845
Clear Hills No. 21	ID 21		37		3,130	3,130
Northern Lights No. 22	ID 22		36		981	981
Mackenzie No. 23	ID 23		89		6,310	6,310
Greenview No. 16	CO 16		44		5,451	5,451
Smoky River No. 130	MD 130	F_{MD130} =	6	G_{MD130} =	x	743
Birch Hills No. 19	ID 19		10		4,111	1,405
Spirit River No. 133	MD 133	F_{MD133} =	3	G_{MD133} =	x	372
Saddle Hills No. 20	ID 20		31		6,509	6,509
Fairview No. 136	MD 136		15		3,458	3,458
Peace No. 135	MD 135		7		1,214	1,214

$G_i = Cn / F_n$
$= 46212 / 373$
$= 5.47$

$G_{MD130} = F_{MD130} * G_i$
$= 6 * 123.89$
$= 743$

$G_{MD133} = F_{MD133} * G_i$
$= 3 * 123.89$
$= 372$

Appendix II: Airshed Areas and Statistics Canada Livestock Variable List for Alberta

Table AII-1: Total airshed area (km^2) and census values of each livestock variable for the year 2000 (refer to Table AII-2 for livestock categories associated with each column name).

Airshed Name	AREA (km^2)	BULLS	MLKCOW	BFCOWS	HFBCR	HFDCR	HFOTH	STEERS	CALFU1	BOARS
Athabasca/ Cold Lake	155372241	11637	6557	211042	2899	31726	18847	25419	188412	1501
Calgary	22203726	5570	2183	77137	1656	18120	10765	18233	74688	1335
Drumheller	166833991	22784	6891	374286	5809	63571	37765	73056	323625	2041
Edmonton	69731889	16230	28519	281354	5203	56938	33824	37191	254999	2384
Grande Prairie/Peace River	462732201	1294	628	20856	293	3201	1902	1452	17811	167
Northwest	117612030	17501	20188	301647	5570	60950	36208	64665	278321	3232
Parkland	330850438	9305	4184	161467	2429	26577	15789	21520	138147	4764
South Alberta	251681963	27353	23926	435080	21015	229968	136615	209508	451762	6798
South Wood Buffalo	12	3260	2971	3186	155	1696	1007	1724	3179	4278
Wainwright/Lloydminster	71217707	12370	5331	197985	2930	32060	19046	47178	174349	1346
West Central	104490794	4759	4765	89422	1743	19073	11330	12896	79155	374
PROVINCIAL TOTAL	1752726991	**132063**	**2264087**	**106142**	**49701**	**543880**	**323099**	**512841**	**1984451**	**28219**

Airshed Name	SOWS	OPIGS	TSHEEP	TCHICK	TURKEY	OTHPLT	HORSES	GOATS	RABBITS	MINK	FOX
Athabasca/ Cold Lake	12934	116387	30555	2075878	161126	16674	15923	5549	1706	0	144
Calgary	3627	32623	17552	1251898	119449	19533	18831	6212	1187	8014	134
Drumheller	23546	208418	28930	3377440	161803	98814	34680	7365	2243	0	0
Edmonton	22517	227651	33998	5155430	346658	38906	39045	32729	11222	5342	590
Grande Prairie/Peace River	846	8748	3359	29096	2114	630	3161	1013	339	0	0
Northwest	36992	382233	46047	3381224	173185	52844	47088	10962	4251	13356	536
Parkland	10589	73324	89496	842576	31483	12829	18578	5931	6751	0	40
South Alberta	45234	431750	93344	3565956	180013	100767	40160	14031	1669	0	32
South Wood Buffalo	2833	3203	3227	3862	134	170	1140	198	83	0	0
Wainwright/Lloydminster	13579	138318	15954	901631	46112	22800	14894	3146	1253	0	64
West Central	3254	29222	10905	1302230	114710	16503	30759	6204	8902	5342	348
PROVINCIAL TOTAL	**175951**	**1651876**	**373367**	**21887221**	**1336788**	**380470**	**264259**	**93340**	**39606**	**32054**	**1888**

Table AII-2 List of all variables from Statistics Canada 1996 Census database related to livestock populations in Alberta

Variable Name	Label
BULLS	Bulls – 1 year and over
MLKCOW	Milk cows
BFCOWS	beef cows
HFBCR	heifer beef cow replacements – 1 year and over
HFDCR	heifer dairy cow replacements – 1 year and over
HFOTH	heifers – others – 1 year and over
STEERS	steers – 1 year and over
CALFU1	calves –under 1 year
BOARS	boars – 6 months and over
SOWS	sows and bred gilts
OPIGS	Other pigs
TSHEEP	total sheep and lambs
TCHICK	total hens and chickens
TURKEY	turkeys
OTHPLT	total other poultry
HORSES	horses and ponies
GOATS	goats
RABBITS	rabbits
MINK	mink
FOX	fox

Appendix III: Summary of Agricultural Emissions Estimates in Alberta for the year 2000.

Table AIII-1: Summary of Alberta agricultural 2000 ammonia emissions in tonnes per year

	Livestock							Fertilizer								
Airshed Name	**Cattle**	**Swine**	**Sheep**	**Poultry**	**Horses**	**Other**	**Total**	**Anhydrous Ammonia**	**Urea**	**Ammonium Sulphate**	**Ammonium Nitrate**	**Nitrogen Solutions**	**Ammonium Phosphate**	**Other NPK Mixtures**	**Total**	**Provincial Total**
								(tonnes yr^{-1})								
Athabasca/Cold Lake Region	8435	1038	103	511	194	41	10322	193	3870	190	84	62	159	28	4585	14907
Calgary Region	3373	301	59	328	230	48	4339	56	956	58	17	7	48	8	1150	5489
Drumheller Region	15183	1857	97	754	423	53	18367	217	4982	228	47	45	192	30	5742	24109
Edmonton Region	12452	1978	115	1223	476	245	16489	372	5651	372	107	66	283	41	6890	23379
Northwest Region	825	77	11	7	39	7	966	385	8014	639	40	31	363	22	9493	10459
Parkland Zone	13167	3300	155	759	574	91	18047	53	600	55	1	0	38	3	751	18798
Grande Prairie/Peace River Region	6473	735	302	179	227	57	7972	249	4430	388	151	32	213	34	5496	13468
Southern Alberta Region	23490	3818	315	803	490	95	29011	316	6321	381	94	100	275	45	7532	36543
South Wood Buffalo Region	370	115	11	1	14	1	512	0	0	0	0	0	0	0	0	512
Wainwright/Lloydminster Region	8156	1199	54	203	182	24	9818	192	6300	298	67	115	217	38	7228	17046
West Central Zone	3798	261	37	333	375	69	4872	12	229	51	25	2	10	2	329	5201
																0
Provincial Total	**95722**	**14679**	**1258**	**5103**	**3224**	**731**	**120717**	**2045**	**41352**	**2661**	**633**	**458**	**1797**	**250**	**49196**	**169913**

Appendix III continued.

Table AIII-2a: Summary of Alberta 2000 particulate material emissions in tonnes per year

	Beef Cattle		Dairy Cattle		Cattle		Swine		Poultry		Provincial Livestock Total	
Airshed	**PM10**	**PM2.5**	**PM10**	**PM2.5**	**PM10**	**PM2.5**	**PM10**	**PM2.5**	**PM10**	**PM2.5**	**PM10**	**PM2.5**
	(tonnes yr^{-1})											
Athabasca Cold Lake Region	388	78	4	1	392	78	111	12	237	38	740	128
Calgary Region	173	35	1	0	174	35	34	4	147	23	355	62
Drumheller Region	732	146	4	1	737	147	198	21	383	61	1318	229
Edmonton Region	559	112	14	3	573	115	210	22	584	93	1367	229
Northwest Region	37	7	0	0	37	7	8	1	3	1	49	9
Parkland Zone	633	127	10	2	643	129	349	36	380	61	1372	225
Grande Prairie Peace River Region	301	60	2	0	303	61	86	9	93	15	483	84
Southern Alberta Region	1421	284	15	3	1436	287	410	43	405	65	2252	394
South Wood Buffalo Region	12	2	1	0	14	3	21	2	0	0	35	5
Wainwright Lloydminster Region	397	79	3	1	400	80	127	13	102	16	629	109
West Central Zone	179	36	3	1	182	36	28	3	151	24	361	63
PROVINCIAL TOTAL	**4832**	**966**	**58**	**12**	**4891**	**978**	**1582**	**165**	**2487**	**396**	**8960**	**1539**

Appendix III continued.

Table AIII-2a continued: Summary of Alberta 2000 particulate material emissions in tonnes per year

	Tillage and Wind Erosion			Grain Harvesting	Grain Handling	Grain Total	Provincial Total	
Airshed	**TSP**	**PM10**	**PM2.5**	**PM7**	**PM10**	**PM10**	**PM10**	**PM2.5**
	(tonnes yr^{-1})							
Athabasca Cold Lake Region	42116	20445	421	2	n/a	n/a	21180	547
Calgary Region	31301	15195	313	1	n/a	n/a	15547	374
Drumheller Region	58593	28443	586	5	n/a	n/a	29752	812
Edmonton Region	89705	43546	897	3	n/a	n/a	44901	1123
Northwest Region	5026	2440	50	1	n/a	n/a	25526	534
Parkland Zone	67434	32735	674	4	n/a	n/a	3800	272
Grande Prairie Peace River Region	52482	25477	525	4	n/a	n/a	33216	757
Southern Alberta Region	113196	54950	1132	7	n/a	n/a	57156	1516
South Wood Buffalo Region	292	142	3	0	n/a	n/a	34	5
Wainwright Lloydminster Region	39082	18972	391	4	n/a	n/a	19598	499
West Central Zone	11504	5584	115	1	n/a	n/a	5941	177
PROVINCIAL TOTAL	**510439**	**247788**	**5104**	**33**	**772**	**805**	**257552**	**6617**

Appendix III continued.

Table AIII-3 continued: Summary of Alberta 2000 sulphur emissions in tonnes per year

Airshed Name	Cattle	Swine		Total
	Sulphur Compounds	Hydrogen Sulphide	Sulphur Dioxide	Sulphur Compounds
	(tonnes yr^{-1})			
Athabasca/Cold Lake Region	140	51	5	196
Calgary Region	59	16	2	76
Drumheller Region	255	92	9	356
Edmonton Region	201	97	10	308
Northwest Region	13	4	0	18
Parkland Zone	221	162	16	399
Grande Prairie/Peace River Region	107	40	4	151
Southern Alberta Region	432	190	19	641
South Wood Buffalo Region	5	10	1	15
Wainwright/ Lloydminster Region	138	59	6	203
West Central Zone	63	13	1	77
PROVINCIAL TOTAL	**1634**	**733**	**73**	**2440**

Table AIII-4 continued: Summary of Alberta 2000 total agricultural air emissions in tonnes per year

Airshed Name	Total Agricultural Air Emissions Estimate
	(tonnes yr^{-1})
Athabasca/Cold Lake Region	36327
Calgary Region	21126
Drumheller Region	54355
Edmonton Region	68680
Northwest Region	36061
Parkland Zone	23020
Grande Prairie/Peace River Region	46920
Southern Alberta Region	94654
South Wood Buffalo Region	562
Wainwright/ Lloydminster Region	36931
West Central Zone	11224
PROVINCIAL TOTAL	**430633**

Appendix IV: Alberta Livestock Weights and Assumptions for Animal Housing.

Table AIV-1: Average Alberta livestock weights used to calculate emissions from animal housing (AAFRD Specialist 2001)

Livestock Category	Average Weight (kg)
Dairy Cows	635
Sows	200
Boars	300
Other Pigs	70
Poultry	1.9

Appendix V: Airsheds and Statistics Canada Crops Variable List for Alberta

Table AV-1: Airsheds and census values in km^2 for each crop variable for the year 2000

Airshed	Wheat	Oats	Barley	Grains	Buckwheat	Rye	Corn	Alfalfa	Hay	Canola	Flax	Soybean
Athabasca	0.228022	0.204581	0.577002	0.029623	0.000555	0.003572	0.000337	0.741229	0.266172	0.225855	0.07408	0.000209
Calgary	0.225944	0.026441	0.274007	0.016064	0	0.012567	0.000361	0.098865	0.058097	0.099361	0.057742	0
Drumheller	1.82083	0.304491	0.771085	0.102366	0.000466	0.034571	0.002963	0.608748	0.241154	0.61554	0.660703	0.000165
Edmonton	0.615928	0.237989	0.809503	0.036606	0.000555	0.006791	0.001577	0.703992	0.302426	0.465716	0.277041	0.000161
Northwestern	0.20221	0.045043	0.12589	0.001963	0.000932	0.001141	4.07E-05	0.132248	0.055956	0.292619	0.091435	0
Parkland	0.607056	0.121073	1.108738	0.053329	0.000932	0.011465	0.000639	0.660213	0.33521	0.553535	0.215023	0.000321
Peace	1.056144	0.189533	0.46738	0.013783	0.000466	0.003493	0.000262	0.588888	0.313719	0.91533	0.661332	0
Southern Alberta	2.724524	0.091733	1.402478	0.026087	0.000466	0.01913	0.011188	0.616042	0.177254	0.575187	1.295646	0.00035
S Wood Bu	9.39E-05	6.89E-05	0.000107	1.22E-06	0	5.49E-05	0	0.000186	0.000195	7.65E-05	0	0
Wainwright	1.10459	0.254622	0.748939	0.063264	8.86E-05	0.012334	0.000193	0.296747	0.116902	0.661837	0.7578	0
West Central	0.026529	0.060613	0.095956	0.011418	0	0.001234	0.000164	0.134135	0.170207	0.026255	0.045088	4.84E-05
Alberta	**8.611868**	**1.536188**	**6.381087**	**0.354505**	**0.004461**	**0.106351**	**0.017725**	**4.581292**	**2.037292**	**4.431311**	**4.13589**	**0.001255**

Airshed	Mustard	Sunflower	Safflower	Potatoes	Peas	Lentils	Beans	Canary	Sugar	Triticale	Forage	Other
Athabasca	6.88E-06	1E-07	0	0.000552	0.063008	0.000306	1.51E-06	0.000893	6.83E-06	0.000689	0.00705	0.001475
Calgary	0.000927	0.000129	0.000119	0.000447	0.009136	0.000252	1.42E-05	0.0005	1.38E-06	0.00023	0.00183	0.000139
Drumheller	0.011639	0.000286	0.00023	0.001266	0.090206	0.001027	0.000492	0.011895	0.000267	0.009426	0.022161	0.000256
Edmonton	0.000131	1.02E-05	0	0.00427	0.126265	0.000251	7.81E-05	0.001295	1.76E-08	0.00138	0.003629	0.000617
Northwestern	0	0	0	2.48E-05	0.02397	0	1.28E-06	0	0	2.27E-05	0.025886	0.000321
Parkland	0.000216	0.000226	9.77E-05	0.002219	0.083835	3.13E-05	1.29E-06	0.000352	0	0.001322	0.029221	0.000808
Peace	0	0.00017	0	0.000811	0.160539	0.000309	1.58E-05	0.003083	0	0.000154	0.185124	0.00049
Southern Alberta	0.045954	0.001113	0.001474	0.025579	0.057098	0.034883	0.032767	0.007385	0.049356	0.013453	0.026537	0.004404
S Wood Bu	0	0	0	4.57E-07	2.7E-05	0	1.79E-08	4.79E-07	0	1.52E-07	1.62E-05	0
Wainwright	0.000185	7.03E-05	0	0.000779	0.16112	0.000755	0.000125	0.001589	0	0.003026	0.003845	0.000361
West Central	2.64E-05	3.1E-06	0	0.000714	0.004706	0	3.46E-05	0.000154	0	0.000422	0.00135	1.48E-05
Alberta	**0.059084**	**0.002008**	**0.00192**	**0.036661**	**0.779911**	**0.037814**	**0.03353**	**0.027146**	**0.049631**	**0.030125**	**0.306649**	**0.008885**

Appendix V continued.

Table AV-1 continued: Airsheds and census values in km^2 for each crop variable for the year 2000

Airshed	Mustard	Sunflower	Safflower	Potatoes	Peas	Lentils	Beans	Canary	Sugar	Triticale	Forage	Other
Athabasca	6.88E-06	1E-07	0	0.000552	0.063008	0.000306	1.51E-06	0.000893	6.83E-06	0.000689	0.00705	0.001475
Calgary	0.000927	0.000129	0.000119	0.000447	0.009136	0.000252	1.42E-05	0.0005	1.38E-06	0.00023	0.00183	0.000139
Drumheller	0.011639	0.000286	0.00023	0.001266	0.090206	0.001027	0.000492	0.011895	0.000267	0.009426	0.022161	0.000256
Edmonton	0.000131	1.02E-05	0	0.00427	0.126265	0.000251	7.81E-05	0.001295	1.76E-08	0.00138	0.003629	0.000617
Northwestern	0	0	0	2.48E-05	0.02397	0	1.28E-06	0	0	2.27E-05	0.025886	0.000321
Parkland	0.000216	0.000226	9.77E-05	0.002219	0.083835	3.13E-05	1.29E-06	0.000352	0	0.001322	0.029221	0.000808
Peace	0	0.00017	0	0.000811	0.160539	0.000309	1.58E-05	0.003083	0	0.000154	0.185124	0.00049
Southern Alberta	0.045954	0.001113	0.001474	0.025579	0.057098	0.034883	0.032767	0.007385	0.049356	0.013453	0.026537	0.004404
S Wood Bu	0	0	0	4.57E-07	2.7E-05	0	1.79E-08	4.79E-07	0	1.52E-07	1.62E-05	0
Wainwright	0.000185	7.03E-05	0	0.000779	0.16112	0.000755	0.000125	0.001589	0	0.003026	0.003845	0.000361
West Central	2.64E-05	3.1E-06	0	0.000714	0.004706	0	3.46E-05	0.000154	0	0.000422	0.00135	1.48E-05
Alberta	**0.059084**	**0.002008**	**0.00192**	**0.036661**	**0.779911**	**0.037814**	**0.03353**	**0.027146**	**0.049631**	**0.030125**	**0.306649**	**0.008885**

Appendix VI: Summary of 1998 Pesticide Emissions in Alberta

Table AVI-1: Summary of Alberta's pesticide emissions by active ingredient in kg per year for the year 1998 (Bytrus 2001, *pers. comm.*).

Pesticide	Total Emissions of Active Ingredient (kg)	Non-spatial Allocated Pesticide Emissions*	Athabasca Cold Lake	Calgary	Drumheller	Edmonton	Grande Prairie Peace River	Northwest	Parkland	Southern Alberta	Southern Wood Buffalo	Wainwright Lloydminster	West Central
2,4-D acid	341.38	23.90	21.36	19.33	32.44	63.67	24.57	4.01	18.07	113.09	0.00	20.95	0.00
2,4-D amine salts	4860.07	0.00	108.44	68.12	852.22	345.56	781.94	98.11	180.31	2196.77	0.00	228.60	0.00
2,4-D esters	18727.39	4.43	479.51	154.36	3574.41	1068.77	704.78	154.79	1041.06	10021.31	0.00	1523.96	0.00
2,4-DB	733.26	0.00	87.38	3.39	27.57	109.04	244.42	3.70	58.40	180.83	0.00	18.53	0.00
Acephate	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.39	0.00
Aluminum Phosphide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amitrole	697.62	0.00	0.70	20.30	74.20	18.90	2.10	0.00	59.50	521.22	0.00	0.70	0.00
Ammonium Sulphate	2488.66	3.47	51.75	2.08	132.57	0.97	98.06	111.92	1439.83	573.17	0.00	74.84	0.00
Arsenic (monosodium methane arsonate-MSMA)	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00
Atrazine	157.27	2.39	0.20	0.46	0.21	7.01	0.39	0.02	0.17	146.36	0.00	0.08	0.00
Azinphos-methyl	9.12	0.00	0.00	0.00	0.04	4.28	0.17	0.00	0.00	4.64	0.00	0.00	0.00
Bacillus Thuringiensis ssp Kurtaki	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bacillus Thuringiensis, Serotype H-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benomyl	495.67	4.90	19.63	3.57	10.57	233.73	11.38	15.30	13.65	165.42	0.00	17.52	0.00
Bentazon	422.32	0.00	1.36	0.00	0.30	26.54	7.56	0.00	13.19	369.80	0.00	3.56	0.00
Boracic Acid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brodifacoum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bromacil	40.45	0.00	1.80	0.99	3.30	4.94	3.56	0.48	5.10	17.24	0.00	3.04	0.00

Pesticide	Total Of Total Active	Non-spatial Allocated Pesticide Emissions*	Athabasca Cold Lake	Calgary	Drumheller	Edmonton	Grande Prairie Peace River	Northwest	Parkland	Southern Alberta	Southern Wood Buffalo	Wainwright Lloydminster	West Central
Bromodiolone	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bromoxynil	93836.85	238.43	1259.83	1816.58	23389.97	4105.22	2122.79	327.68	4667.62	47461.05	0.00	8447.67	0.00
Butoxypolypropylene GlycolL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butylate	102.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	102.08	0.00	0.00	0.00
Captan	5.62	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	5.56	0.00	0.00	0.00
Carbaryl	520.11	0.33	31.29	2.56	91.68	68.55	14.14	0.00	29.58	169.34	0.00	111.97	0.68
Carbathiin	328.52	0.35	15.90	25.98	37.96	39.20	34.32	1.63	39.72	99.82	0.00	33.64	0.00
Carbofuran	224.47	0.00	0.27	0.00	30.78	10.87	0.27	0.00	0.57	179.43	0.00	2.28	0.00
Chlorine Dioxide from Sodium Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorophacinone	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorothalonil	17645.89	14.06	46.86	18.75	119.50	2916.50	0.00	0.00	506.13	13991.28	0.00	32.80	0.00
Chlorpropham	237.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	237.94	0.00	0.00	0.00
Chlorpyrifos	75523.46	0.00	7117.77	892.08	8944.61	7120.01	15906.17	3538.21	6211.60	23258.26	0.00	2534.74	0.00
Chlorsulfuron	3.91	0.00	0.00	0.00	0.26	0.32	0.00	0.00	1.05	1.58	0.00	0.71	0.00
Clethodim	87.17	0.00	1.61	0.91	7.82	4.52	31.20	3.63	8.51	16.07	0.00	12.92	0.00
Clodinafop-Propargyl	1204.31	1.97	37.96	7.30	168.46	156.05	158.49	20.28	65.64	367.18	0.00	220.99	0.00
Clopyralid	2021.78	0.84	137.42	17.26	180.89	405.66	418.93	44.56	187.14	384.74	0.00	244.33	0.00
Coal Tar Acids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal Tar Oils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Copper 8-Quinolinolate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Copper Oxychloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Copper Triethanolamine complex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Pesticide	Total Of Total Active	Non-spatial Allocated Pesticide Emissions*	Athabasca Cold Lake	Calgary	Drumheller	Edmonton	Grande Prairie Peace River	Northwest	Parkland	Southern Alberta	Southern Wood Buffalo	Wainwright Lloydminster	West Central
Coumaphos	1.60	0.01	0.01	0.37	0.08	0.44	0.13	0.00	0.42	0.05	0.00	0.08	0.01
Cupric Hydroxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyanazine	136.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	136.21	0.00	0.00	0.00
Cycloate	1327.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.35	1319.62	0.00	0.00	0.00
Cyfluthrin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyhalothrin-Lambda	38.43	0.00	1.01	0.00	6.64	0.00	14.37	0.42	1.36	14.38	0.00	0.24	0.00
Cypermethrin	15.08	0.00	0.00	0.00	0.01	0.41	0.00	0.00	0.05	14.60	0.00	0.01	0.00
D-Trans Allethrin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deet	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deltamethrin	27.10	0.00	1.87	0.36	5.34	0.84	3.71	0.47	0.53	12.43	0.00	1.55	0.00
Desmedipham	81.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	81.72	0.00	0.00	0.00
Di-n-propyl isocinchomeronate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diazinon	534.01	2.00	15.91	25.17	23.14	215.02	13.50	0.00	24.67	179.98	0.00	27.09	7.54
Dicamba	4155.89	3.37	94.78	33.63	715.89	216.69	310.95	31.67	112.47	2400.97	0.00	235.47	0.00
Dichlobenil	334.86	0.72	13.35	0.84	46.52	53.52	38.38	0.00	12.23	154.79	0.00	14.52	0.00
Dichlorprop present as butoxyethyl ester or as isooctyl ester	13898.29	0.00	8.40	200.55	2278.76	270.75	17.64	44.10	1946.49	6359.25	0.00	2772.35	0.00
Dichlorvos	2.08	0.00	0.10	0.06	0.25	0.87	0.09	0.06	0.50	0.12	0.00	0.00	0.04
Diclofop-methyl	1133.97	0.00	106.60	13.35	149.36	192.63	68.45	0.00	98.46	408.89	0.00	96.24	0.00
Dicofol	11.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.91	0.00	0.05	0.00
Didecyl dimethyl ammonium chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Difenzoquat	335.49	0.00	54.83	2.24	40.74	56.96	26.88	0.56	53.12	82.80	0.00	17.36	0.00

Pesticide	Total Of Total Active	Non-spatial Allocated Pesticide Emissions*	Athabasca Cold Lake	Calgary	Drumheller	Edmonton	Grande Prairie Peace River	Northwest	Parkland	Southern Alberta	Southern Wood Buffalo	Wainwright Lloydminster	West Central
Dimethoate	1013.07	0.00	2.02	5.04	73.86	61.49	21.84	0.00	7.31	804.75	0.00	36.76	0.00
Dimethomorph	25.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.52	0.00	0.00	0.00
Diphacinone	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diquat	759.06	0.00	29.76	5.15	33.96	98.70	73.25	6.41	32.39	440.76	0.00	38.69	0.00
Diuron	9.70	0.00	0.00	0.00	0.20	0.00	0.01	0.00	0.07	8.46	0.00	0.95	0.00
Endosulfan	2.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.94	0.00	0.00	0.00
Endothall	17.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.88	0.00	0.00	0.00
EPTC	22373.05	0.00	4.64	88.16	134.56	941.92	92.80	0.00	176.32	20934.65	0.00	0.00	0.00
Ethalfluralin	9498.18	1.31	674.21	56.40	1489.96	1576.81	919.69	60.91	513.58	2794.73	0.00	1410.58	0.00
Ethametsulfuron-methyl	162.27	0.00	15.17	2.75	20.84	33.74	22.27	5.60	16.03	25.42	0.00	20.46	0.00
Ethephon	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00
Ethofumesate	4395.79	0.00	0.00	0.00	0.00	0.00	1.68	0.00	0.00	4394.11	0.00	0.00	0.00
Fenoxaprop-ethyl	4.12	0.00	0.00	0.00	3.64	0.00	0.00	0.00	0.06	0.34	0.00	0.08	0.00
Fenoxaprop-p-ethyl	2097.17	0.00	114.25	44.19	395.98	332.45	138.58	19.88	287.50	538.04	0.00	226.31	0.00
Fenthion	102.77	10.92	9.77	1.33	5.32	7.80	15.25	0.84	27.41	3.60	0.00	15.81	4.73
Fenvalerate	0.14	0.00	0.01	0.00	0.01	0.02	0.01	0.00	0.04	0.02	0.00	0.04	0.00
Flamprop-m-methyl	38.20	2.68	0.48	0.00	8.10	1.69	8.23	0.00	4.72	12.20	0.00	0.09	0.00
Fluazifop-butyl	0.42	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.35	0.00	0.00	0.00
Fluazifop-p-butyl	451.99	0.00	15.34	2.17	75.91	62.33	81.97	2.13	38.38	101.70	0.00	72.06	0.00
Fluroxypyr	829.53	0.00	79.45	4.86	51.14	262.20	91.59	15.99	174.34	39.47	0.00	110.51	0.00
Fonofos	17.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.33	0.00	0.83	0.00
Formaldehyde	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gibberellic Acid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glufosinate Ammonium	2219.03	0.00	132.37	17.25	354.07	396.23	330.80	29.49	280.35	251.24	0.00	427.24	0.00

Pesticide	Total Of Total Active	Non-spatial Allocated Pesticide Emissions*	Athabasca Cold Lake	Calgary	Drumheller	Edmonton	Grande Prairie Peace River	Northwest	Parkland	Southern Alberta	Southern Wood Buffalo	Wainwright Lloydminster	West Central
Glyphosate isopropylamine salt	83861.01	261.57	5345.95	1394.06	15863.77	11937.95	8729.67	924.14	8174.16	17831.24	0.00	13398.50	0.00
Glyphosate mono-ammonium salt	1548.39	0.00	6.73	0.75	375.67	41.37	80.98	15.46	11.85	724.68	0.00	290.90	0.00
Glyphosate trimethylsulfonium salt	6556.58	3.47	264.71	33.65	1244.22	430.13	844.95	243.10	350.41	2922.78	0.00	219.15	0.00
Hexazinone	84.98	0.00	5.25	0.05	0.00	0.42	1.42	0.00	0.16	72.02	0.00	5.67	0.00
Imazamethabenz	6078.77	0.00	551.92	194.48	684.21	903.95	919.29	68.72	1220.77	1056.10	0.00	479.34	0.00
Imazamox	148.11	0.00	6.30	1.33	22.33	18.36	26.14	2.21	12.74	21.07	0.00	37.64	0.00
Imazethapyr	368.50	2.77	15.77	1.50	34.27	46.23	84.05	8.19	27.82	28.70	0.00	119.19	0.00
Iprodione	172.96	0.00	0.14	0.59	6.69	52.48	18.30	0.00	69.91	5.01	0.00	19.85	0.00
Lindane (gamma BHC)	1191.60	0.08	8.48	22.24	36.37	116.54	439.93	3.21	131.14	249.26	0.00	184.34	0.00
Linuron	3057.16	0.00	33.32	52.68	229.32	312.94	37.87	0.00	403.94	1471.77	0.00	515.34	0.00
Malathion	6801.68	831.25	194.76	65.45	645.21	585.47	144.03	35.63	302.96	3778.36	0.00	205.09	13.48
Maleic Hydrazide	19.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.31	0.00	0.00	0.00
Mancozeb	1598.04	0.00	3.23	0.00	0.53	67.34	0.00	0.00	4.83	1520.49	0.00	1.64	0.00
Maneb	22.85	0.00	0.37	0.15	3.60	1.02	0.62	0.06	0.39	15.22	0.00	1.41	0.00
MCPA amine	4987.63	0.18	567.18	125.56	552.30	721.98	1041.16	100.63	734.63	344.76	0.00	799.26	0.00
MCPA ester	240741.09	378.22	14126.81	4379.11	46132.45	32254.73	18206.19	1599.79	32463.68	58702.38	0.00	32497.72	0.00
MCPA potassium or sodium salts	1911.07	5.85	110.39	31.68	345.98	132.24	214.70	4.42	129.75	656.09	0.00	279.97	0.00
MCPB sodium salt	114.50	0.00	7.04	0.00	0.63	20.24	41.50	0.11	1.10	38.64	0.00	5.25	0.00
Mecoprop amine salt	188.73	0.00	0.13	0.31	21.14	1.39	0.00	0.00	0.78	164.99	0.00	0.00	0.00
Mecoprop potassium salt	54.85	1.37	1.28	0.00	0.57	12.19	0.32	0.00	32.68	6.45	0.00	0.00	0.00
Metalaxyl	78.69	0.00	0.56	0.00	0.06	12.85	0.58	0.00	0.51	63.55	0.00	0.58	0.00

Pesticide	Total Of Total Active	Non-spatial Allocated Pesticide Emissions*	Athabasca Cold Lake	Calgary	Drumheller	Edmonton	Grande Prairie Peace River	Northwest	Parkland	Southern Alberta	Southern Wood Buffalo	Wainwright Lloydminster	West Central
Methamidophos	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Methidathion	203.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	203.28	0.00	0.00	0.00
Methomyl	127.85	2.05	0.31	0.48	0.40	1.66	0.71	0.00	2.25	119.34	0.00	0.49	0.15
Methoxychlor	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00
Metiram	40.13	0.00	0.00	0.00	0.16	1.16	0.00	0.00	0.11	38.70	0.00	0.00	0.00
Metolachlor	1504.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1504.25	0.00	0.00	0.00
Metribuzin	2660.47	0.00	132.91	0.66	171.46	649.52	63.70	1.75	506.47	978.13	0.00	155.87	0.00
Metsulfuron-methyl	31.60	0.00	0.73	0.57	3.75	4.71	7.37	0.08	3.19	5.50	0.00	5.70	0.00
Mineral Oil (Insecticidal or adjuvant)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscalure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-alkyl (40% C12, 50% C14, 10% C16) dimethyl benzyl ammonium chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-alkyl (5% C12, 60% C14, 30% C16, 5% C18) dimethyl benzyl ammonium chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-Alkyl Diethanolamine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-alkyl Polyethoxyethanol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-Octyl bicycloheptene dicarboximide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naled	389.44	0.00	0.00	0.00	0.00	0.00	4.57	0.00	0.00	384.85	0.00	0.02	0.00
Napropamide	5.39	0.03	0.00	0.00	0.00	0.06	0.38	0.00	0.00	4.92	0.00	0.00	0.00
Naptalam	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00

Pesticide	Total Of Total Active	Non-spatial Allocated Pesticide Emissions*	Athabasca Cold Lake	Calgary	Drumheller	Edmonton	Grande Prairie Peace River	Northwest	Parkland	Southern Alberta	Southern Wood Buffalo	Wainwright Lloydminster	West Central
Nicosulfuron	5.83	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.15	5.54	0.00	0.00	0.00
Nonylphenoxypolyethoxyethanol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Octylphenoxypolyethoxyethanol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oxadiazon	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oxyfluorfen	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.64	0.00	0.00	0.00
Paraffin Base Mineral Oil (Adjuvant)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Paraffin Base Petroleum Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Paraquat	167.61	0.00	0.14	0.14	5.04	16.07	3.18	1.61	0.83	131.80	0.00	8.80	0.00
Parathion	3.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.36	0.00	0.00	0.00
Pendimethalin	371.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.19	368.19	0.00	0.00	0.00
Permethrin	10.64	0.12	0.14	0.53	0.79	4.71	0.53	0.02	0.40	3.18	0.00	0.21	0.00
Petroleum Hydrocarbon Blend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phenmedipham	81.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	81.56	0.00	0.00	0.00
Phorate	998.87	0.00	0.00	1.56	6.44	3.59	0.00	0.00	1.56	985.73	0.00	0.00	0.00
Phosmet	12.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.95	0.00	0.00	0.00
Picloram (acid, isooctyl ester or potassium salt)	15.00	0.00	0.00	0.44	0.00	0.69	0.40	0.00	11.61	1.61	0.00	0.25	0.00
Picloram (amine salts)	1.65	0.00	0.00	0.00	0.00	0.09	0.02	0.00	1.15	0.38	0.00	0.01	0.00
Piperonyl Butoxide	4.64	0.55	0.21	0.05	0.24	0.56	0.31	0.45	1.75	0.29	0.01	0.18	0.06
Pirimicarb	37.63	0.00	0.00	0.00	0.00	22.75	0.00	0.00	0.00	14.88	0.00	0.00	0.00

Pesticide	Total Of Total Active	Non-spatial Allocated Pesticide Emissions*	Athabasca	Calgary	Drumheller	Edmonton	Grande Prairie Peace River	Northwest	Parkland	Southern Alberta	Southern Wood Buffalo	Wainwright Lloydminster	West Central
Polyoxyalkylated Alkyl Phosphate Ester	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Propamocarb Hydrochloride	44.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.49	0.00	0.00	0.00
Propanil	565.60	0.00	0.00	0.00	229.60	30.80	0.00	0.00	14.00	19.60	0.00	271.60	0.00
Propiconazole	194.24	0.35	0.61	1.84	9.14	14.04	1.01	0.00	83.65	79.58	0.00	4.03	0.00
Propoxur	1.08	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Propyzamide	9.03	0.00	0.00	0.00	2.17	0.04	0.84	0.00	1.61	4.34	0.00	0.04	0.00
Putrescent whole egg solids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrazon	698.82	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	698.07	0.00	0.00	0.00
Pyrethrins	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyridate	17.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.01	0.00	0.00	0.00
Quinclorac	51.08	0.00	1.18	0.00	0.29	3.32	30.61	8.72	0.43	3.18	0.00	3.35	0.00
Quizalafop-p-ethyl	93.44	0.00	4.57	0.32	5.56	11.71	31.83	2.02	9.88	16.91	0.00	10.64	0.00
Quizalofop-ethyl	808.54	0.00	85.56	15.43	107.79	160.80	114.05	28.04	78.01	128.69	0.00	90.17	0.00
Resmethrin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rimsulfuron	2.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.21	0.00	0.00	0.00
Rotenone	4.17	0.35	0.17	0.14	0.31	0.42	0.16	0.00	0.21	2.19	0.00	0.12	0.08
Safer's Insecticidal Soap	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sethoxydim	2053.75	0.00	123.08	12.05	92.17	256.89	530.99	82.48	54.35	449.62	0.00	452.11	0.00
Silica Aerogel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silicon Dioxide Salt Water Fossils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Simazine	23.93	0.00	0.00	0.62	0.78	0.00	0.22	0.00	1.27	21.03	0.00	0.00	0.00

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Sodium Chlorate	11.76	0.00	0.00	0.00	4.72	0.00	0.25	0.00	1.79	5.00	0.00	0.00	0.00
Sodium Metaborate Tetrahydrate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Strychnine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfaquinoxaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulphur (Fungicide)	2047.50	0.00	406.00	0.00	0.00	14.00	35.00	0.00	0.00	49.00	0.00	1543.50	0.00
Sulphur (Insecticide)	98.26	23.44	5.46	2.40	2.05	25.87	10.93	0.00	6.12	8.38	0.00	8.06	5.55
Sulphur (Vertebrate Control)	204.57	144.30	3.23	0.33	0.11	22.37	0.00	0.00	5.09	26.87	0.00	2.27	0.00
Surfactant Blend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall Oil Fatty Acids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tallow Fatty Acid Amine Ethoxylate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tebuthiuron	1.10	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.25	0.37	0.00	0.00	0.00
Terbacil	30.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.63	0.00	0.00	0.00
Terbufos	348.29	0.00	0.00	0.00	4.99	2.60	5.98	0.00	0.05	334.61	0.00	0.05	0.00
Tetrachlorvinphos	1.82	0.00	0.28	0.00	0.00	0.00	0.00	0.00	1.54	0.00	0.00	0.00	0.00
Thiabendazole	8.61	0.00	0.00	0.00	0.00	0.07	0.81	0.00	0.00	7.67	0.00	0.05	0.00
Thifensulfuron-methyl	479.41	0.00	38.74	11.19	70.47	77.06	51.88	5.53	72.76	87.24	0.00	64.54	0.00
Thiophanate-methyl	1.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.98	0.00	0.00	0.00
Thiram	443.01	0.00	24.32	7.05	37.21	69.70	71.88	1.98	57.04	120.21	0.00	53.61	0.00
Tralkoxydim	4421.32	7.06	205.11	81.90	771.82	414.71	209.93	18.59	461.48	1875.50	0.00	375.21	0.00
Triadimenol	62.31	0.00	4.44	3.11	0.00	0.89	0.00	0.00	13.20	36.81	0.00	3.88	0.00
Triallate	36009.87	0.00	1983.07	457.24	3818.62	3419.15	986.02	0.00	7379.03	15381.74	0.00	2585.00	0.00
Triasulfuron	17.67	0.00	0.10	0.27	3.92	2.21	2.46	0.03	3.35	4.44	0.00	0.89	0.00

Pesticide	Total Of Total Active	Non-spatial Allocated Pesticide Emissions*	Athabasca Cold Lake	Calgary	Drumheller	Edmonton	Grande Prairie Peace River	Northwest	Parkland	Southern Alberta	Southern Wood Buffalo	Wainwright Lloydminster	West Central
Tribenuron Methyl	2367.26	0.00	144.08	43.52	280.66	301.51	226.31	25.83	347.31	720.62	0.00	277.42	0.00
Trichlorfon	12013.22	23.30	72.97	1.12	4183.17	191.59	132.57	0.45	6329.31	1029.70	0.00	42.78	6.27
Triclopyr	141.05	0.00	28.22	4.03	3.36	38.98	29.90	0.00	11.36	20.83	0.00	4.37	0.00
Trifluralin	11961.40	0.00	548.79	149.55	3141.15	942.59	461.27	132.32	1062.54	2702.84	0.00	2820.34	0.00
Vegetable Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vinclozolin	903.81	0.00	3.57	0.00	3.99	461.20	4.41	0.63	5.04	420.98	0.00	3.99	0.00
Warfarin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Soluble Dyes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zinc Phosphide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	**729173.74**	**2002.55**	**35863.74**	**10659.00**	**122755.64**	**76332.68**	**56709.98**	**7859.02**	**78971.80**	**261070.72**	**0.01**	**76910.01**	**38.60**

* The non-spatially allocated pesticide emissions were the result of non-spatially allocated sales. The total of this column is represented in the provincial emission totals but has not been apportioned to airsheds.