Review of Documents Pertaining to the Alberta Environment Mobile Laboratory Lethbridge Area Livestock Operations Air Monitoring Survey and Response from the Chinook Health Region

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Executive Summary

Alberta Environment conducted a mobile air quality monitoring survey near livestock feeding operations in the Lethbridge area from September 1998 to July 1999. This initial monitoring survey was conducted in response to concerns voiced by local residents about odours from livestock feeding operations as well as a proposal for a hog processing plant in the Lethbridge area.

Following the public release of the Alberta Environment report and a critique by the Chinook Health Region, a request was made by Alberta Environment for this independent review of the Alberta Environment study and the Chinook Health Region critique. The terms of reference were to evaluate 5 specific issues itemized below. The review specifically did not address the larger question of whether health effects are associated with odours or other emissions from intensive livestock operations.

The monitoring survey generally used sampling sites located downwind of livestock operations where the operator of the mobile laboratory could perceive odours. The majority of sites surveyed had only 1 complete hour of monitoring data. Of 16 air quality parameters measured, only 3 would be expected to be contributors to odours from livestock operations. However, none of the parameters measured could be considered to be neither the sole nor even the primary cause of odours from livestock operations. Hydrogen sulphide (H_2S) was found to exceed 1 hour Alberta Ambient Air Quality Guidelines for two hog operation sites. Ammonia (NH_3) reached more than 25% of the 1 hour Alberta Ambient Air Quality Guidelines at 4 sites and was observed to be substantially higher for 10 of 14 sites when compared with air concentrations measured at control sites. Both of these air quality guideline levels used for comparison were based on odour detection. The third parameter monitored that might be expected to contribute to odours from livestock operations was total reduced sulphur (TRS) but the values reported for this parameter were no different than those reported for H_2S and the TRS results may be suspect.

1. <u>The ability of the monitoring survey design to address the objectives.</u>

The ability of this study to meet the stated objectives was limited because of the limited duration of data collected at most sites. The survey was able to characterize a few cases at one hog site and one case at another hog site when 1-hour ambient air quality guidelines for H_2S were exceeded. Obviously, having more data from more sites would provide a better basis for developing judgements about air quality at the other sites. To the extent that an evaluation of odour was the main underlying reason for this air quality survey, it had a limited ability to deal with identifying causes of odour problems.

2. <u>The validity of comparing air quality data collected in agricultural areas with data collected in urban and industrial areas.</u>

For those air quality parameters that are specific chemical substances, comparison between agricultural areas and urban or industrial areas could be interesting and informative. In this study, sampling was guided by the mobile laboratory operator's perception of odour and monitoring was done very close (as little as 15 m) to the detected odour source. Direct comparison of these targeted air pollutant concentration data with that measured elsewhere in the province at monitoring sites (agricultural, urban or industrial) that are chosen at random or typically known to be more than 100m from the nearest emission source would not be valid.

3. The interpretations and recommendations in the Chinook Health Region submission.

This commentary was rightfully critical of the news release that accompanied the Alberta Environment report because it does not accurately describe the results. The inaccuracy arises because the air quality monitoring reported deals with several specific air quality parameters, only some of which (H_2S and NH_3) may contribute to odours. But this report is not a comprehensive evaluation of odours from intensive livestock operations. The press release would have been accurate to state that "air quality measures taken near livestock operations were generally well below Alberta Ambient Air Quality Guidelines with two exceptions. These exceptions were H_2S levels that exceeded odour detection levels, but are well below levels known to cause human health effects."

The commentary compared 1 hour Alberta Ambient Air Quality Guidelines with a number of air quality guidelines from various U.S. agencies. These comparisons were not valid because the concentration levels for these comparisons corresponded to different averaging times. Concentration and averaging time for any air quality parameter are inextricably linked. Simple comparisons of air quality data from this survey with air quality data from elsewhere in the province is precluded by the targeted method of sampling site selection used in this survey.

The recommendations for event-based sampling and a more strategic approach to air quality monitoring deserve serious attention in order to address the issue of odours arising from livestock operations. Future collaborative efforts to address these issues will be in the best interests of all the stakeholders.

4. Improvements that could be made to the survey report format and presentation of data.

The report should have stated the objectives for the survey at the outset. The data for sites that had only one or two hours of monitoring data should have been displayed separately in the charts. Showing histograms with average and maximum values for sites with so few data points is too easily misinterpreted. Likewise, the sites with limited data should have been excluded from Table 1 that reports the overall average of air quality parameters measured.

5. Use of this air quality monitoring data for short and/or long-term health effect assessments.

These data are of limited value for short-term health effect assessments and of almost no value for long-term health effects assessments. There are not many cases in environmental health sciences where available evidence can be described as convincing that long term exposure to ambient levels of specific air pollutants has caused specific human health effects. These data are useful for short term health effects assessment to the extent that they could have shown if any concentrations of the air pollutants occurred at levels that are known to cause short term (acute) health effects. The results did not reveal such health concerns for those parameters monitored. The data reported are not particularly helpful for resolving the major underlying question about whether livestock operation odours cause health effects. The data in this report would only allow a conclusion that levels of two specific air pollutants (ammonia and H_2S) that may contribute to odour from livestock operations were found to be substantially below levels at which these pollutants are known to cause human health effects. The study does not address the intensity of odours or the likelihood of odours causing health effects.

Conclusions

The monitoring study has provided a preliminary perspective on conventional air quality measures for livestock operations in the Lethbridge region. Detectable odours were noted by the sampling staff at a number of sampling locations during the survey. Although the connection between odour perception and specific health effects is likely to remain uncertain for some time to come, the presence of readily detectable odours from some livestock operations is evident. The issues of annoyance and odour associated with livestock operations are likely to remain active as long as offensive odours can be readily detected in ambient air. Consequently, a collaborative approach by all of the interested parties to characterize these issues as fully as the available scientific methods will currently allow appears to be in the best interests of all the stakeholders. Recognizing the practical limits of available scientific tools for this purpose will be an important element of developing a consensus approach for dealing with these issues.

Review of Documents Pertaining to the Lethbridge Area Livestock Operations Air Monitoring Survey and Response from the Chinook Health Region

1. INTRODUCTION

1.1 Background

Alberta Environment conducted a mobile air quality monitoring survey near livestock feeding operations in the Lethbridge area from September 1998 to July 1999. The study objectives were presented for this review assignment as being to: (1) determine air quality measurements during the survey near livestock operations in the Lethbridge area; and (2) compare measured air quality levels to Alberta's air quality guidelines. One-hour time intervals were selected to allow direct comparison to Alberta's one-hour guidelines.

This initial monitoring survey was conducted in response to concerns voiced by local residents about odours from livestock feeding operations as well as a proposal for a hog processing plant in the Lethbridge area.

The results of this survey were made public in a report[1] entitled: *"Air Quality Monitoring Near Livestock Feeding Operations in the Lethbridge Area: September 1998 to July 1999"*. The Chinook Health Region responded to this survey in a letter[2] dated July 25, 2000 with an attached commentary[3] dated July 12, 2000. Alternate interpretations of the results were provided and recommendations were proposed.

Following the public release of the critique by the Chinook Health Region of the air quality monitoring report by Alberta Environment, a request was made for this review of both documents and related materials according to the following terms of reference.

1.2 Terms of Reference

A formal review of the following documents is requested:

1. *"Air Quality Monitoring Near Livestock Feeding Operations in the Lethbridge Area: September 1998 to July 1999"* dated June 26, 2000 prepared by Alberta Environment,

2. The letter from the Dr. Paul Hasselback, Medical Officer of Health for the Chinook Health Region to Doug Radke, Deputy Minister of Alberta Environment dated July 25, 2000, including the document *"Response to Alberta Environment Air Quality Report on Lethbridge area Livestock Operations: July 12, 2000"* prepared by the Chinook Health Region,

and an evaluation of the following:

1. The ability of the monitoring survey design to address the objectives.

2. The validity of comparing air quality data collected in agricultural areas with data collected in urban and industrial areas.

3. The interpretations and recommendations in the Chinook Health Region submission.

4. Improvements that could be made to the survey report format and presentation of data.

5. Use of this air quality monitoring data for short and/or long-term health effect assessments.

1.3 Limitations of Review

Given the controversy that has surrounded the issues of air quality related to intensive livestock operations, it is important to clarify what the foregoing terms of reference do not include. Specifically, this review does not seek to answer the larger issue of whether health effects are associated with odours or other air emissions from intensive livestock operations. That is clearly a much larger issue and is well beyond the scope of this review. Likewise, this review does not address any other environmental quality issues (water contamination, noise, etc.) that may be associated with intensive livestock operations. Finally, this review is limited to the documents provided, accessible scientific literature and the relevant experience and knowledge of the author. No original data collection, on-site investigations nor inspection of monitoring facilities or procedures was undertaken.

The scope of this review had to be limited if a timely response was going to be provided by this author because of other prior commitments. However, given the controversy that has been raised by these issues, some general advice for constructive investigation and improved understanding of odour-related air quality concerns from intensive livestock operations will be developed from the insights that are required to answer to the specific tasks in the Terms of Reference.

2. THE ALBERTA ENVIRONMENT STUDY AND REPORT

2.1 Results Reported

The air quality study was performed at 18 sites over a period of 10 individual days between September 1998 and July 1999. The Report[1] provided results for 17 of these sites, consisting of 3 controls and 14 source sites (Figure 1). Data from one site were excluded from the final report because monitoring was limited to 21 minutes of recorded data making these data insufficient to allow comparison with 1-hour guideline levels. Data were collected for the parameters listed in Table 1.

Table 1 Parameters Measured by the Mobile Air Monitoring Laboratory

Parameter Measured	**1 hour Ambient Air Quality Guideline**
Sulphur dioxide (SO_2)	0.172 ppm
Hydrogen sulphide (H_2S)	0.010 ppm
Total reduced sulphur (TRS)	no guideline
Total hydrocarbons (THC)	no guideline
Reactive hydrocarbons (RHC)	no guideline
Methane (CH_4)	no guideline
Polycyclic aromatic hydrocarbons (PAHs)	no guideline
Ozone (O_3)	0.082 ppm
Nitrogen dioxide (NO_2)	0.212 ppm
Nitric oxide (NO)	no guideline
Total oxides of nitrogen (NO_x)	no guideline
Total suspended particulates (TSP)	no 1 hr guideline
Inhalable particulates (PM_{10})	no 1 hr guideline
Respirable particulates ($PM_{2.5}$)	no 1 hr guideline
Carbon monoxide (CO)	13 ppm
Ammonia (NH_3)	2 ppm
Wind direction (WDR)	not applicable
Wind speed (WSP)	not applicable
Temperature (Temp)	not applicable
Relative Humidity (RH)	not applicable

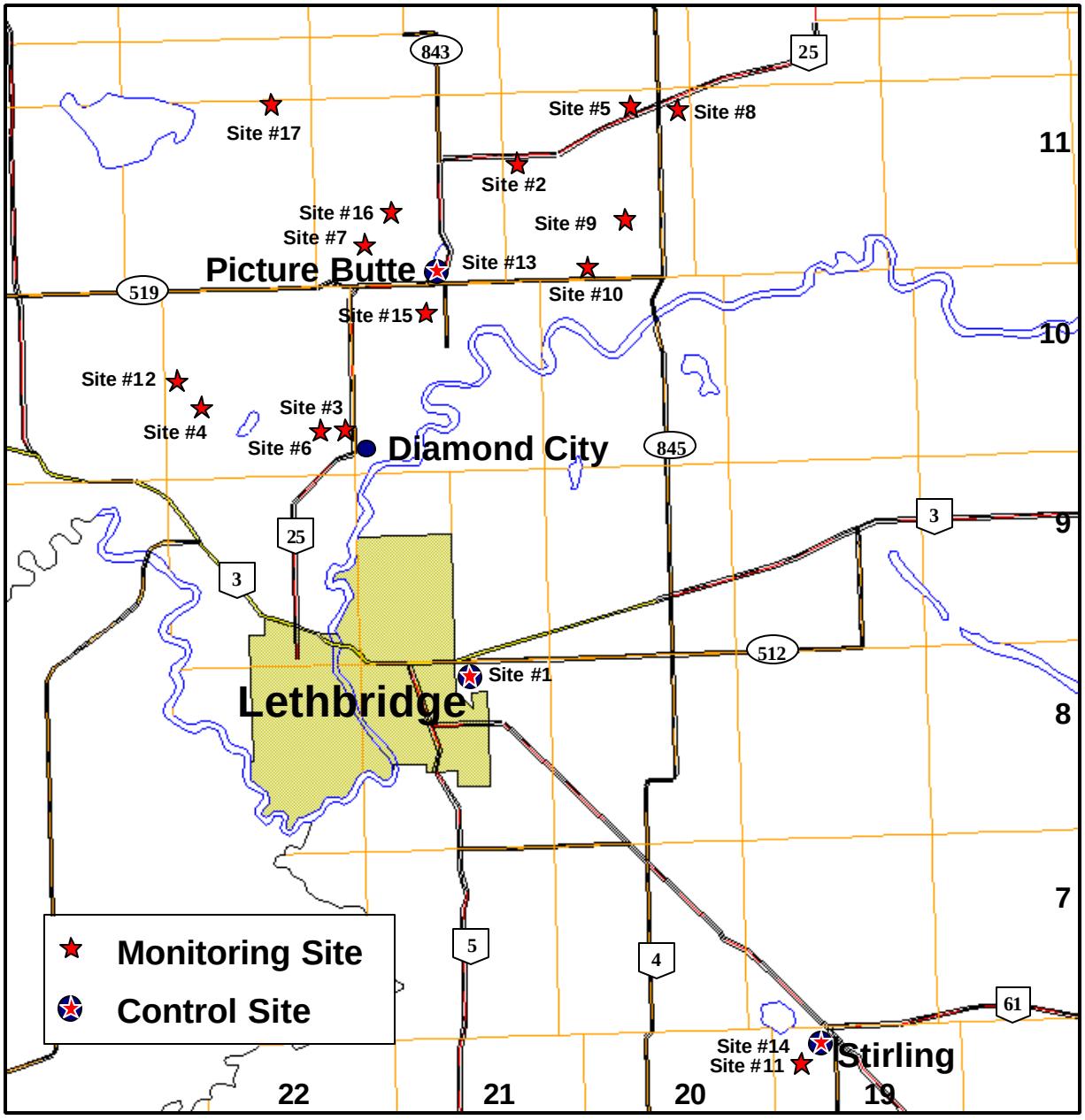

Figure 1 Location of Monitoring Sites in the Livestock Feeding Operations Survey (reprinted from Reference 1)

Sampling sites were chosen by Alberta Environment staff "*in the vicinity of livestock feeding operations based on the presence of odours in the area*." Almost 50 hours (17 hours at control sites, 30 hours at target sites) of air quality data were collected on these parameters during this survey. Of the target livestock sites, 9 had only 1 completed hour of data (8 cattle and 1 hog) and 2 others had only 2 completed hours of data (1 cattle, 1 hog). One cattle site (#3) had 5 completed hours of data on 5 separate days, and another cattle site (#4) had 4 completed hours of data on one day. Finally, one hog site (#16) had 8 completed hours of data on 7 separate days.

The report[1] states that: "*Staff conducted monitoring more often at sites where odour-causing compounds exceeded Alberta Environment guidelines than at sites where odour-causing compounds were lower than guidelines*." Because the only guideline levels that were exceeded in the study results were those for H_2S this comment was presumably directed at those cases. The cases of exceeding the H_2S guideline occurred at sites #12 (2 completed hours) and #16 (8 completed hours). Site #17 (4 complete hours) had a maximum 1-hour concentration at 80% of the guideline. On the basis of the foregoing rationale, the reason(s) for collecting 5 completed hours of data at site #3 is not obvious. Perhaps, the ammonia values at this site, which reached a 1 hr maximum of 0.6 ppm (the third highest observed 1 hr average concentration at any site), may have provided the grounds for the 5 hrs of monitoring at site #3.

Charts are presented for each air quality parameter measured showing average and maximum 1-hour concentrations for each site. Because sites #2, #4, #5, #6, #7, #8, #9, #10 and #15 had only 1 hour of completed monitoring data, showing an average and maximum for a single value is not meaningful. This display of average and maximum concentrations is also suspect for Sites #1, #11 and #12 that have only 2 completed hours of data.

For those sites with more data, rather than using the average (arithmetic mean), either the geometric mean or the median would be more meaningful. Air quality data are generally known to follow skewed distributions[4] with the log normal distribution being a commonly accepted approximation for the distribution of concentrations. A median will not be affected by skewed data while the geometric mean is the best indicator of central tendency if the data are distributed approximately log-normally.

2.2 Air Quality Results Related to Odour

As noted in Table 1, only 6 of the 16 air quality parameters that were monitored have 1 hr Alberta Ambient Air Quality Guideline values. Of these six ambient guideline parameters, only H_2S was exceeded on the basis of 1 hr average values at any site. Both maximum 1-hour values and the average of all 1-hour values at sites #12 and #16 exceeded the 1-hour ambient air quality guideline value of 0.010 ppm for H_2S. However, because only 2 samples were collected at Site #12, it would appear that one of the readings was non-detectable for the average to be exactly 50% of the maximum, as reported. The sampling notes about this site in Table 5 of the report[1] show that one of the two samples collected was 800 m from the hog feedlot while the other was 25m from the hog barns. The difference in sampling location for these two samples may explain the differences in air quality observed.

The maximum 1 hr average values for ammonia were 25% or more of the 1 hr guideline value at 4 sites (#3, #4, #16 and #17) and the average of 4 hours of sampling at site #17 was more than 60% of the 1 hr guideline value of 2 ppm. None of the samples exceeded the 1 hr guideline value but 10 of the 14 sites showed noticeably higher ammonia levels than the control sites. No statistical significance testing on most of these data are possible because of the limited number of hourly samples available for most sites. However, it would appear likely that ammonia concentrations were significantly higher than controls for sites #3, #16 and #17 where more data were collected.

The other four air quality parameters with 1 hr ambient guideline values (sulphur dioxide, ozone, nitrogen dioxide and carbon monoxide) are not characteristic of emissions from intensive livestock operations and would not necessarily be expected to show any difference from control sites. Nitrogen dioxide and carbon monoxide are primarily the result of combustion emissions and would be expected to be elevated in urban areas where traffic sources affect air quality. The finding that none of these parameters show excessive levels for the livestock operations is largely what would be expected.

Of the 10 reported air quality parameters that do not have 1 hr Alberta Ambient Air Quality Guidelines, only 6 might have some relevance to expected emissions from intensive livestock operations and only 2 (total reduced sulphur and reactive hydrocarbons) might have some relevance to odour problems from these operations.

Total reduced sulphur (TRS) is a combined measurement that attempts to measure all reduced (non-oxidized) sulphur compounds, most of which are very odorous. These include H_2S, various organic sulphides and various thiols (mercaptans), all of which are noted for their contribution to the noxious sulphur odour from anaerobic decay of organic matter (swamps, sludges and other decaying waste) and the characteristic odour from kraft pulp mills. Manure wastes from intensive livestock operations would be expected to produce a variety of TRS compounds in addition to H_2S.[5-8]

The TRS values reported were equal to the H_2S values at sites #16 and #17, two of the three sites reporting any notable H_2S. The third site (#12) that had notable hydrogen sulfide had no data for TRS because the instrument was not operational. The observation of identical values of TRS and H_2S at sites #16 and #17 is not reassuring about the performance of the TRS instrument during this study. Some additional reduced sulphur compounds other than H_2S would be expected for animal waste sources. The TRS values are generally higher than H_2S at most other sites (including the Picture Butte control site, #13), but the TRS and H_2S are barely above (3 to 5 times) the detection limit of 0.0006 ppm at these other sites. Further investigation into the validity of the reported TRS values cannot be performed with the reported summary data, but there appears to be some basis for concern about the validity of the TRS data for sites #16 and #17. These data would not change the overall report conclusions with regard to Alberta Ambient Air Quality Guidelines because there is no guideline for TRS.

The report provides results on total hydrocarbons, reactive hydrocarbons and methane. Total hydrocarbons is an overall measure of atmospheric hydrocarbons including methane. Although methane is certainly emitted from intensive livestock operations, methane makes no contribution to odour because it is odourless. Reactive hydrocarbons may include volatile organic compounds, some of which may be odorous. In particular, volatile fatty acids may contribute to foul odours. However, because some of the more odorous individual compounds have very low odour thresholds they could be contributing to an odour problem without noticeably influencing the overall reactive hydrocarbon concentration. The latter is the sum of many compounds that are not very odorous. For example, butyric acid has an odour detection threshold[9,10] as low as 0.001 to 0.0001 ppm. For such odorous compounds, concentrations 10 or more times above their odour threshold could be present while still contributing only a small fraction of a combined reactive hydrocarbon sum around 1 ppm. If any of these very odorous individual compounds were present at high concentrations, the reactive hydrocarbon parameter may include them in the overall sum, but finding the overall reactive hydrocarbon concentrations around 1 ppm does not tell us whether very odorous individual compounds were present or absent in this summed concentration.

2.3 Air Quality Results Unrelated to Odour

The air quality parameters for total suspended particulates, inhalable particulates, respirable particulates, polycyclic aromatic hydrocarbons, ozone, sulphur dioxide, nitrogen dioxide and carbon monoxide are unrelated to odour, at least with regard to emissions expected from intensive livestock operations. Nitrogen dioxide and sulphur dioxide can be odorous at sufficient concentration, but neither are expected as major emissions from intensive livestock operations and they are unlikely to contribute to any odour problems that may arise from such operations.

Of these remaining air quality parameters reported, only the particulate parameters might be considered relevant to emissions from intensive livestock operations because these can be a substantial source of dust emissions. However, dust emissions will be primarily evident in the Total Suspended Particulate measure, with a contribution also plausible for the Inhalable Particulate (PM_{10}) parameter. Elevated levels were observed for these parameters at sites #12 and #16 for both average and maximum 1 hr values. The Respirable Particulate ($PM_{2.5}$) is the parameter drawing the greatest attention with regard to health concerns such as indications of premature mortality. [11] However, the source of this finer particulate is generally attributed to combustion emissions rather than dust, which tends to be comprised of particulates larger than $PM_{2.5}$. This makes the maximum 1 hr concentration at site #16 of 32 $\mu g/m^3$ rather interesting and not entirely expected. This one observation, which was from 14:18 to 15:25 on 22 September 1998 occurred during a very dusty episode because Total Suspended Particulate for this hour was 442 $\mu g/m^3$ and PM_{10} was 298 $\mu g/m^3$, both relatively extreme values. However, if there are important, non-combustion sources of respirable particulate emissions associated with intensive livestock operations, this would certainly be of great interest from a health perspective.

3. THE CHINOOK HEALTH REGION RESPONSE AND CRITIQUE

The Chinook Health Region responded to the release of the Alberta Environment report[1] with a letter[2] from Dr. Paul Hasselback to Mr. Doug Radke dated July 25 and an accompanying response commentary[3] dated July 12, 2000.

The response commentary[3] opened with a discussion of the Alberta Environment news release. The response continued discussing the Alberta Environment report[1] with respect to hydrogen sulphide, particulate matter, ammonia, methane / total hydrocarbons, overall quality of the air, omissions from the final report, methodology issues, putting the study in context and conclusions.

3.1 News Release

The commentary reports the news release[12] as stating *"Our air quality of monitoring of livestock operations near Lethbridge indicates that odours are well below levels that may affect public health.*" This statement, as cited, does not accurately describe the results in the Alberta Environment report.[1] The inaccuracy arises because the air quality monitoring reported deals with several specific air quality parameters, only some of which (H_2S and NH_3) may contribute to odours. But this report is not a comprehensive evaluation of odours from intensive livestock operations as will be elaborated in Section 4.2. It would be accurate to state that "air quality measures taken near livestock operations were generally well below Alberta Ambient Air Quality Guidelines with two exceptions. These exceptions were H_2S levels that exceeded odour detection levels, but are well below levels known to cause human health effects."

The Alberta Environment monitoring survey was not designed and was certainly not capable of determining what levels of odours might affect public health. This survey was only capable of determining whether specific parameters, some of which are odorous, were present at levels that are known to have adverse health effects. The question of what levels of odours may cause public health effects is contentious and could not be resolved by this kind of monitoring survey. This survey would have been able to show that emissions of parameters known to cause odours were present at levels that were also expected to cause health effects. The finding that these specific parameters were not present at levels high enough to cause health effects does not assure the absence of odours. If, as seems likely, odour is caused by agents that were not directly monitored, any inference about the health implications of such odorous agents is not possible. The data in this report would only allow a conclusion that levels of two air pollutants (ammonia and H_2S) that may contribute to odour from livestock operations were found to be below levels that are known to cause human health effects.

Consequently, the short version quoted from the press release states a conclusion that could not be reached with the type of data that was collected in this air quality monitoring survey. Inevitable pressures from the media for short, easily quoted statements, may have contributed to producing a statement that is not accurate. However, Alberta Environment staff must insure that their public summaries accurately represent what their scientific staff have actually found and reported.

3.2 Hydrogen Sulphide

The commentary referred to a number of U.S. criteria for H_2S, specifically the U.S. EPA reference concentration (RfC) of 1 $\mu g/m^3$ (0.00077 ppm or about 0.001 ppm), ATSDR guidelines of 0.07 ppm for acute exposure and 0.030 ppm for intermediate exposure and Minnesota Department of Health 30 minute average, enforcement levels of 0.03 and 0.05 ppm.

The RfC value was mentioned along with the quote that this value "*is below the reported odor threshold in humans*." This point was presumably made to contrast with the statement from the Alberta Environment report that the Alberta ambient air quality guideline of 0.010 ppm for a one-hour average "*is based on odour perception.*" Given that there is a range of individual human sensitivity to odour perception for any chemical, including H_2S, that the U.S. EPA RfC value is intended to be without an appreciable risk of deleterious effects during a lifetime and that the RfC was derived using an uncertainty factor of 1000 to reduce from a no observed adverse effect level in mice, the two statements quoted are not in conflict nor even inconsistent with one another.

The ATSDR values quoted are 3 to 7 times less stringent than the Alberta 1 hr guideline. More important, the ATSDR acute guideline level (0.07 ppm) is intended to cause no adverse health effects in the most sensitive individuals for 1 to 14 days of exposure and the intermediate guideline level (0.03 ppm) is intended to cause no adverse health effects in the most sensitive individuals for 15 to 364 days of exposure. The ATSDR values do not conflict with the Alberta guideline of 0.01 ppm for 1-hr being based on odour perception.

The Minnesota standards of 0.03 and 0.05 ppm are also not in conflict with the Alberta guideline of 0.01 ppm for 1-hr being based on odour perception. The Minnesota standards are stated as being based on "*not to be exceeded over two times per year*" or "*not be to be exceeded over two in any five consecutive days*". It is not clear from the information provided, but the second quote implies that these standards may be enforced as daily average values. If these are daily average values, then the Minnesota standards should be compared with the Alberta ambient air quality guideline of 0.003 ppm for a 24-hr average.

3.3 Particulate Matter

The commentary provides some background discussion on the Canada Wide standards development for particulate matter and then made a number of comparisons as follows: "*Alberta's Ambient air quality guideline for Total Suspended Particulates is a 24 hour average of 100 mg/m^3.*

- *Only one of the sites had single one-hour exceedances of the 24 hour average guidelines of 30 mg/m^3 for $PM_{2.5}$ and this site had an overall average of 7 mg/m^3.*
- *8 of 17 sites had average air quality exceedances of the PM_{10} 24-hour average guideline of 50 mg/m^3, while 10 of the sites had maximum one-hour concentrations in exceedance of this level.*
- *6 of 17 sites had average air quality in excess of the Alberta 24-hour TSP guideline, while 8 sites were in excess of this level for maximum one-hour measures.*
- *In the City of Lethbridge, the Fire Hall site evaluated during a smoke related event, but on two other occasions was also noted to have higher TSP levels and PM_{10} levels. Two other sites had maximum one-hour measures in excess of PM_{10} levels of 50 mg/m^3.*"

The quoted comparison mixes together a number of items and some of these comparisons are not valid. In particular, lower concentrations are specified for longer averaging times in air quality guidelines and standards because there is a relationship between both exposure time and concentration such that longer exposure time to a low concentration may be as harmful as a shorter time of exposure to a high concentration. This will be discussed further in Section 4.2 of this report. However, for the purposes of this discussion it can be stated that comparing hourly average concentration levels with criteria for other averaging times (e.g. daily average guidelines) is not valid. Likewise, comparing averages of 1-hour average values with the daily average guideline is not valid unless the 1-hour values that were being averaged covered most of a 24-hour period. This was not the case for these data, 3 of the 6 sites referred to had only 1 hr of data collected, and the other sites mentioned were 2, 4 and 8 hours of data across different days.

These data do show that some samples were collected during some very dusty periods at some sites, particularly sites #16 and #17. Dust, as represented by TSP may not have anything to do with odour nuisance, but high dust levels can certainly be a nuisance in their own right.

3.4 Ammonia

Mention was made of ATSDR minimal risk exposure guidelines for ammonia being 0.5 ppm for acute exposure and 0.3 ppm for chronic exposure in contrast to the 1 hour Alberta Ambient Air Quality Guideline of 2 ppm for ammonia. These levels are set to be below levels that might cause health effects in the most sensitive individuals for exposures from 1 to 14 days for the acute guidelines and for more than 1 year for the chronic guidelines. Finding 1-hour maximum ammonia concentrations that are in excess of the much longer term ATSDR exposure guidelines does not support any expectations of health effects.

Comparisons of the highest concentrations observed with other sampling sites in the province does suggest that localized emissions of ammonia are evident at the livestock sites but the targeted nature of the ample sites may be an important factor in the levels observed.

3.5 Methane / Total Hydrocarbons

The interpretation of total hydrocarbons data in the Alberta Environment report was described as "*certainly open to challenge*." Concerns were expressed about "*what to make of such high methane levels*." The commentary is likely correct in noting that the elevated methane is related to manure at the sites, but beyond being a gas that can be measured and that likely comes from these sources, methane itself does not contribute to odour or any possible health effects. Because there are so many sources of methane in the environment, methane would not be very useful as a general tracer for emissions from livestock operations.

3.6 Quality of the Air

This section of the report presents some comparisons of air quality measures from the livestock site survey with air quality data from other sites in Alberta. The comparisons must be interpreted with consideration of the sampling strategy that was followed in the Alberta Environment survey of the livestock sites. In this case, the monitoring crews located the monitoring laboratory close to the prospective emission source, particularly in the case of the highest concentration values recorded (with 15-20 m for site #16, 25 m for site#12, 30-35 m for site #17).

Concentrations of air pollutants can be expected to decrease in proportion with approximately the square of the distance from the source (i.e. doubling the distance from the source would generally decrease concentrations by at least a factor of four).

Although emitters of air pollutants must be responsible for their emissions any distance from their property, the dilution effect must be considered when comparing air quality data from different locations. In this case, it would not be possible to draw a conclusion that air quality in the entire vicinity of the emission sources was being characterized. The sampling strategy used was clearly targeted on identifying whether these livestock operations were emitting measurable levels of odorous air pollutants.

3.7 Omissions from the Final Report

Several items were noted that had were not included in the Alberta Environment report. These included the provincial comparisons noted above, 5 minute peak values which apparently had been available earlier and data from an 18th site that was not included in the final report.

The issue of comparisons with other sites in Alberta has been addressed in the previous section 3.6 above. Comparisons can be useful but they must be made for data obtained with similar sampling strategies if the comparisons are to be meaningful.

The argument for not including the 5 minute peak values in the report is that there are no ambient air quality guidelines for 5 minute peak values and therefore nothing to compare these measures with. Given the comparisons that have been made between data for one sampling period with guidelines for a different time period, concerns about possible misinterpretation and inappropriate comparisons seem justified. On the other hand, for the purposes of judging whether emissions would give rise to detectable odour values, 5 minute peak values that exceed odour detection thresholds would be capable of producing detectable odours. At high enough levels, such peak values could cause odour complaints. The challenge in this case is how such data can be accurately used to evaluate the odour problem without being made available for inappropriate comparisons with 1-hour guideline values. Given the level of public concern and resulting media coverage of these issues, invalid comparisons will not help clarify these issues.

The exclusion of the data for the one site that had only 21 minutes of data is justified from the perspective of comparisons with 1-hour guideline values. However, if some of the highest values were being recorded at this site, the overall objectives of this study suggested that more monitoring should have been done at this site, as was done at other sites where high concentrations were observed. Some explanation is warranted about why additional sampling was not pursued at this site if high short-term peak values were being observed.

3.8 Methodology Issues

Limitations of this study design were raised to note that this report provides only a series of spot checks. Because manure spreading was not targeted, there is no insight provided about odours from this activity. The observation that this survey only provides a sense of emissions from feedlots, hog barns and lagoons is fair comment. The results and the operator comments in Table 5 do show that there are some grounds for odour concern at specific sites.

3.9 Putting the Study in Context – Is Health Affected by Livestock Odours?

A correlation analyses is presented to suggest that methane, total hydrocarbon, ammonia and PM_{10} may be used as surrogate measures for odour. I would be cautious in pursuing this approach to data interpretation because correlations, particularly with small data sets like these, can be strongly influenced by a few extreme values. This can be best evaluated by looking at scatter plots to determine if a few extreme values are possibly driving the correlation coefficient calculation. For highly skewed data like these, log transformations should also be performed before comparing correlation coefficients. But the largest concern is that correlation among the parameters mentioned does not provide any assurance that any of these parameters are correlated with odour intensity. The suggestion of pursuing odour sniffing to better understand this problem is excellent and will be elaborated further in Section 4.2. This discussion will also address the role of H_2S and other compounds in contributing to odour problems from livestock operations.

3.10 Conclusions

The commentary introduces references to a few studies that suggest that health problems may be associated with odours from livestock operations. Addressing the merits of these studies and the issue of whether livestock operations can cause health effects is beyond the scope of this review. However, the health concerns are clearly an issue that is not likely to disappear, particularly if odours are readily detected in the region. That livestock operations can produce noxious odours is a fact. Some of the mobile laboratory operator's notes in Table 5 of the report[1] document that strong odours were evident in some cases. (e.g. Site #5, "*picking up feedlot odours all down hwy 845*", Site #16, "*Downwind of hog feedlot lagoon. Very strong odour*"). The suggestion that all the parties should "*work together for collective solutions*" seems eminently reasonable and will be addressed further in my conclusions.

3.11 Cover Letter from Dr. Hasselback to Mr. Radke (July 25, 2000

The letter makes five recommendations for consideration by Alberta Environment. Three of these that relate to the findings of the report are addressed in the following comments.

A "*strategic approach to monitoring*" is encouraged. As a preliminary survey on this issue, the Alberta Environment report[1] was strategic in the sense that detection of odours influenced where sampling was performed. To the extent that odours from livestock operations is the core issue that must be addressed before any relationships between odour and health effects could be seriously evaluated, there is considerable scope for designing future monitoring surveys more strategically to deal with the question of odours.

A request for extending the period of air quality monitoring "*to better reflect long term average emissions*" perhaps by use of "*a series of passive monitoring stations for hydrogen sulphide and ammonia*" would allow air quality data for these parameters to be compared with other locations in Alberta, if comparable data were collected. However, a longer term monitoring approach for integrated measurement of ammonia or hydrogen sulphide will not be very useful for better characterizing odour problems.

A suggestion that " *'event' based monitoring to determine the impact of manure spreading practices on air quality*" be pursued is certainly relevant to charactering the extent of odour problems from intermittent activities. In some cases, such intermittent activities may pose the greatest odour insult so that the odour issue cannot be fully characterized without some evaluation of such activities. On the other hand, event-based monitoring is logistically challenging and cannot be done without a substantial commitment of resources.

The letter also states: *"The release of the document further highlighted the discrepancy which exists between the current Alberta Ambient Air Quality Guidelines and those guidelines now being used in other jurisdictions in order to protect public health – most notably in relation to ammonia*." I would disagree with this statement to the extent that it implies that Alberta's Ambient Air Quality Guidelines are less stringent than those being used in other jurisdictions. No examples have been presented of 1-hour guidelines for any air quality parameter are lower for another jurisdiction. The reference to ammonia is not a valid comparison if it is based on the ATSDR minimal risk levels cited because those levels are based on 1 to 14 day exposures and longer than 1 year exposures, not 1 hour levels.

This letter does commend Alberta Environment for doing this survey and it encourages future collaborative efforts towards better understanding of these air quality issues.

4. ASSESSMENT AND REVIEW

4.1 Specific Questions from the Terms of Reference

1. The ability of the monitoring survey design to address the objectives.

The objectives of the study as provided in the Terms of Reference for this review were to:
(1) determine air quality during the survey near livestock operations in the Lethbridge area; and
(2) compare measured air quality levels to Alberta's air quality guidelines.

The survey measured one so-called "*air toxic substance*" and all of the "*common air pollutants*" for which there are current Alberta Ambient Air Quality Guidelines. Ammonia, is the only "*air toxic substance*" among these guidelines that is relevant to livestock operation emissions. Accordingly, the focus of the parameters selected for monitoring with the mobile laboratory was directed at the two objectives stated above. The major limitation of the survey design relative to these objectives was the collection of only 1 hour of data at 9 of the 17 sites. On one hand, the ability to conduct such mobile surveys at all is a credit to Alberta Environment, because this kind of mobile monitoring capability is sophisticated, technically demanding and not widely available. However, the value of having only a single hour of air quality data at more than half the sites evaluated undermines our ability to conclude that there are no air quality problems at these sites. There is clearly a tradeoff between the number of sites to monitor and the amount of data to collect at each site. Unfortunately, there is no right answer for how to balance this tradeoff.

Sufficient data (3 or more hours of data) were collected to allow at least preliminary judgements about air quality for the days sampled for at least 5 sites (3 livestock, 2 control). The survey was able to characterize a few cases at one hog site and one case at another hog site when 1-hour ambient air quality guidelines for H_2S were exceeded. Obviously, having more data from more sites would provide a better basis for developing judgements about air quality at the other sites.

The report[1] stated that the "*survey was in response to public complaints about odours in the area from livestock feeding operations*." Although evaluating odour is not explicitly stated as an objective in the Terms of Reference for this review, the report itself and the responses it has engendered indicate that an evaluation of odour was the main underlying reason for this survey. To the extent that my inference is correct, the study had a limited ability to deal with identifying causes of odour problems. That concern will be elaborated more fully in Section 4.2 below.

2. The validity of comparing air quality data collected in agricultural areas with data collected in urban and industrial areas.

Some air quality parameters correspond to specific chemical substances (H_2S, ammonia) while others represent groups of chemicals (THC) and others represent pollutants with similar physical properties (TSP, PM_{10}, $PM_{2.5}$). We can be reasonably confident that particulate matter can have substantially different chemical composition in rural agricultural areas compared with urban and industrial areas. We can also be reasonably confident that group parameters like total hydrocarbons can have substantially different chemical composition in rural agricultural areas compared with urban and industrial areas. In such cases where chemical composition is likely to be different, simple comparison of these parameters between different regions for interpreting air quality must be done with caution and will have limited value.

For air quality parameters that are specific chemical substances, comparison between agricultural areas and urban or industrial areas could be interesting and informative. The main caution for doing this type of comparison would be to insure that the sampling strategies for the sites are comparable. In this report[1] sampling was guided by the operator's perception of odour and monitoring was done very close (as little as 15 m) to the detected odour source. Direct comparison of these targeted air pollutant concentration data with that measured at monitoring sites (agricultural, urban or industrial) elsewhere in the province that are chosen at random or typically known to be more than 100m from the nearest emission source would not be valid.

3. <u>The interpretations and recommendations in the Chinook Health Region submission.</u>
These have been discussed in detail in Section 3 of this report. This commentary was rightfully critical of the news release that accompanied the Alberta Environment report because it does not accurately describe the results. The inaccuracy arises because the air quality monitoring reported deals with several specific air quality parameters, only some of which (H_2S and NH_3) may contribute to odours. But this report is not a comprehensive evaluation of odours from intensive livestock operations. The press release would have been accurate to state that "air quality measures taken near livestock operations were generally well below Alberta Ambient Air Quality Guidelines with two exceptions. These exceptions were H_2S levels that exceeded odour detection levels, but are well below levels known to cause human health effects."

The commentary compared 1 hour Alberta Ambient Air Quality Guidelines with a number of air quality guidelines from various U.S. agencies. These comparisons were not valid because the concentration levels for these comparisons corresponded to different averaging times. Concentration and averaging time for any air quality parameter are inextricably linked as outlined in Section 4.2. Simple comparisons of air quality data from this survey with air quality data from elsewhere in the province is precluded by the targeted method of sampling site selection used in this survey.

The recommendations for event-based sampling and a more strategic approach to air quality monitoring deserve serious attention in order to address the issue of odours arising from livestock operations. Future collaborative efforts to address these issues will be in the best interests of all the stakeholders.

4. <u>Improvements that could be made to the survey report format and presentation of data.</u>
The report does provide an impressive amount of information about this survey in a relatively concise manner. A reader can determine, without a lot of difficulty, what was done and what was found.

The report should have stated the objectives for the survey at the outset. This would provide a better basis for interpreting what can and cannot be concluded from the data presented.

The data for sites that had only one or two hours of monitoring data should have been displayed separately in the charts. Showing histograms with average and maximum values for sites with so few data points is too easily misinterpreted. The report does provide the tabulated information on page 5 that allows a reader to recognize these data limitations, but the 14 histograms, each showing 17 sites, are likely to catch the attention of readers more easily than the detailed text tabulated on page 5 of the report. Likewise, the sites with limited data should have been excluded from Table 1 that reports the overall average of air quality parameters measured.

5. Use of this air quality monitoring data for short and/or long-term health effect assessments. These data are of limited value for short-term health effect assessments and of almost no value for long-term health effects assessments. In rendering such an apparently negative judgement, it should be noted that meaningful data for long term health effects assessments are extremely difficult to acquire because causation of health effects by air pollutants requires the combination of both a sufficient human exposure to a pollutant and an operative mechanism for that pollutant to produce chronic effects from long term, low level exposures. There are not many cases in environmental health sciences where available evidence can be described as convincing that long term exposure to ambient levels of specific air pollutants has caused specific human health effects. Consequently, the data in this report[1] have much company in not being very useful for the purpose of assessing long-term health effects.

These data are useful for short term health effects assessment to the extent that they could have shown if any concentrations of the air pollutants occurred at levels that are known to cause short term (acute) health effects. The results did not reveal such health concerns for those parameters monitored. We can be more confident about what levels of pollutant exposure can cause acute health effects than we can be for chronic effects. This higher confidence arises because accidental and past occupational exposures to many air pollutants have provided us with the direct evidence for acute effects arising from short-term exposure. Of course, because this evidence is not gathered experimentally nor by design, for obvious ethical reasons, we cannot know in direct evidentiary terms how far below the observed acute effect exposure levels there will be no acute health effects. Such assessments for developing air quality guidelines must make use of uncertainty factors that are applied with considerable "judgement".

The data reported are not particularly helpful for resolving the major underlying question about whether livestock operation odours cause health effects. In this regard, the press release for the report has not accurately represented the findings by stating: *"Our air quality monitoring of livestock operations near Lethbridge indicates that odours are well below the levels that may affect public health*". The data in this report would only allow a conclusion that levels of two specific air pollutants (ammonia and H_2S) that may contribute to odour from livestock operations were found to be substantially below levels at which these pollutants are known to cause human health effects. The study does not address the intensity of odours or the likelihood of odours causing health effects.

4.2 General Comments Relevant to the Terms of Reference

A consistent theme in the commentary about the Alberta Environment report was a comparison of the 1 hour monitoring data with guidelines for the same parameters, but for different averaging times. Concern was also expressed about removal of 5-minute maximum values from the final report.

A fundamental reality associated with air quality data and biological responses is that these depend on both the concentration of pollutant and the duration of exposure. As an example, acutely toxic gases the fatality risk has come to modeled according to a concept described as the toxic load.[13] This concept expresses the parameter that drives the biological response as a product of concentration and time, with the former raised to a power "n"

$$\text{biological response (toxic load)} = C^n\, t$$

A key premise imbedded in this concept, which has been widely adopted for the risk management of industrial releases of acutely toxic gases like H_2S, ammonia and chlorine, is that time and concentration are inextricably linked. This means that, in principle, the same level of response in a population may arise for a combination of a low concentration with a long exposure time as would occur for a higher concentration with a shorter exposure time.

Another theme that is evident with air pollutants in the environment is that their concentration at some point in space where we may be sampling will fluctuate as the wind carries the pollutant past our sampling point. An emission source of pollutants is diluted with cleaner air as a pollutant disperses downwind from the source. Those pollutant concentration fluctuations may be, and often are, extreme.[13] Dispersion in the atmosphere progresses as the small volume of air from the emission source that is carrying the air pollutant is mixed with turbulent eddies of cleaner surrounding air. Even if the emission rate is constant, at any point downstream of the emission, there will be major fluctuations observed in the pollutant concentration because eddies will bring in volumes of air mixed with varying proportions of the pollutant emission as the wind passes a fixed sampling point in space. If the emission source itself has a variable rate of pollutant release, even greater fluctuations will be observed.[13] If sampling occurs for a very short time, extremes between non-detectable and very high peak concentrations are likely to be observed. As the averaging time for monitoring is increased, the extremes from high to low concentration will be smoothed out.

Because both of these concentration-time interactions are important, when air quality guidelines are set for longer averaging times, lower levels will be specified. This trend is demonstrated in Table 2 which summarizes the different concentration levels for different averaging times for the common air pollutants that are covered by the Alberta Ambient Air Quality Guidelines. The guideline values summarized in Table 2 show that without exception, lower concentration values are specified for longer averaging times. This trend is not arbitrary, it is fundamentally based on the realities of how they cause biological effects and how air pollutants disperse in the atmosphere.

Table 2 Alberta Ambient Air Quality Guidelines

Air Quality Parameter	**Averaging Time**	**Guideline Value**
Sulphur Dioxide	1 hour	0.172 ppm
	24 hours	0.057 ppm
	1 year (arithmetic mean)	0.011 ppm
Hydrogen Sulphide	1 hour	0.010 ppm
	24 hour	0.003 ppm
Nitrogen Dioxide	1 hour	0.212 ppm
	24 hour	0.106 ppm
	1 year (arithmetic mean)	0.032 ppm
Carbon Monoxide	1 hour	13 ppm
	8 hour	5 ppm
Total Suspended Particulate	24 hour	100 $\mu g/m^3$
	1 year (geometric mean)	60 $\mu g/m^3$

As noted in Section 4.1, the underlying rationale for this study was to address concerns about odours from livestock operations. The study that was done with the available mobile monitoring laboratory attempted to address that issue by measuring some parameters that are relevant to odours from livestock operations (ammonia, H_2S and TRS) and by guiding the sampling locations and periods by odour perception. However, the parameters that were measured with the possible exception of TRS, are may not be the greatest contributors to odours from livestock operations. This point is illustrated with a summary in Table 3 of agents that have been reported to be important components of livestock odours along with their respective odour threshold concentrations. TRS should include many compounds that could be important odour contributors, but, as noted in Section 2.2, the TRS values reported in this study[1] should be subject to scrutiny because they were found to be mostly identical with the H_2S levels. These TRS results may be valid, but the absence of any non-H_2S component of TRS is a concern for samples from these emission sources.

The values in Table 3 have been adapted from a summary [8] of compounds with low odour thresholds that are found in animal wastes. The lowest reported odor detection level in Table 3 is reported from the most comprehensive available compilation[10] of odor thresholds in air. The reported values[10] are of variable quality because some are from very old original references and no standard methods were used among all the reported values. For some of these substances, validated geometric mean odour detection thresholds have been reported by the American Industrial Hygiene Association. [14] These suggest, for example, that methyl mercaptan, ethyl mercaptan and phenyl mercaptan have geometric mean odour detection thresholds as little as 1/10 of that for H_2S. Some individuals find the mercaptan odours to be more objectionable than H_2S odour. The mercaptans and sulphides listed in Table 3, if present in the air samples for this survey, should have reported as TRS.

The odour from livestock wastes will be comprised of a complex mixture of a number of these extremely odorous compounds. Yasuhara[15] attempted to develop a recipe for the odour of solid swine manure by preparing defined mixtures of individual compounds and evaluating these mixtures for their similarity with solid swine manure by means of a sensory panel. He found that a synthetic solution comprised of the following mass fractions of odorous compounds produced the best agreement with the authentic solid swine manure (note that H_2S was not included):

- isobutyric acid 13%,
- butyric acid 26%,
- isovaleric acid 13%,
- valeric acid 13%,
- p-cresol 26%,
- indole 2.6%,
- skatole 2.6%,
- dimethyl sulphide 0.13%,
- dimethyl disulphide 0.13%,
- butanol 2.6%
- isoamyl alcohol 2.6%

Table 3 Agents Reported to Contribute Substantially to Odours from Livestock Operations (adapted from reference 8)

Range of detection threshold ppm	Common name	Alternate names	Lowest reported detection threshold[10] ppm	Geometric mean odour threshold[14] ppm
< 0.000 001				
	methyl mercaptan	methanethiol	0.000 000 15	0.000 54
	n-propyl mercaptan	2-propanethiol	0.000 000 8	
0.000 0011 – 0.000 01				
	allyl mercaptan	2-propene-1-thiol	0.000 0017	
	diacetyl	dimethyl glyoxal 2,3-butanedione	0.000 002	
	phenylacetic acid	phenylethanoic acid	0.000 005	
0.000 011 – 0.000 1				
	p-cresol	4-methylphenol	0.000 01	
	ethyl mercaptan	ethanethiol	0.000 017	0.000 35
	amylvinyl ketone	1-octene-3-one	0.000 02	
	thiophenol	phenylmercaptan benzenethiol	0.000 03	0.000 3
	2,4-decadienal		0.000 03	
	2,6-dimethylphenol		0.000 04	
	2,4-nonadienal		0.000 04	
	decanal		0.000 04	
	m-cresol	3-methylphenol	0.000 05	0.006
	caprylic acid	octanoic acid	0.000 05	
	pelargonaldehyde	nonanal	0.000 05	
	isovaleric acid	3-methyl butanoic acid	0.000 05	
	diethyldisulphide	ethyldithioethane	0.000 06	
	hydrogen sulphide		0.000 07	0.0045
	2-phenylethanol		0.000 07	
	skatole	3-methylindole	0.000 07	
	o-cresol	2-methylphenol	0.000 09	
	2-nonenal		0.000 09	
	trimethylamine		0.000 1	
	dimethylsulphide	methylthiomethane	0.000 1	
	n-butyric acid	butanoic acid	0.000 1	
	indole		0.000 1	
	crotylmercaptan	2-butene-1-thiol	0.000 1	
0.000 11 – 0.001				
	n-valeric acid	pentanoic acid	0.000 2	
	butyraldehyde	butanal	0.000 3	

In addition to the complexity of the mixture of components that make up the odour, there will be a distribution of sensitivity for response to the odour produced by any substance or mixture. This has been illustrated by Shusterman[16] who estimated that odour detection and recognition for H_2S arise at about 0.001 ppm for the most sensitive individuals with a median detection occurring at less than 0.002 ppm and median recognition occurring at 0.003 to 0.004 ppm. He estimated that odours from H_2S strong enough to cause annoyance occur above 0.010 ppm, which is the 1-hour Alberta Ambient Air Quality Guideline. Nagy[17] found somewhat similar results for H_2S in proposing an odour impact model developed using a sensory panel. He found that a median complaint level for H_2S odours occurred between 0.014 and 0.018 ppm, just slightly above the 1 hour Alberta Ambient Air Quality Guideline. On the basis of these published odour nuisance estimates, the 1 hour Alberta Ambient Air Quality Guideline appears to provide a reasonable benchmark for nuisance odours produced by H_2S alone.

The challenges associated with odours, particularly those as complex as are produced from livestock operations, make the assessment of odour problems from these sources extremely difficult to evaluate. Only a very strategic monitoring survey with specialized methods that are focused on these kinds of odour problems will be likely to characterize, fully, the nature and major contributing factors of any odour nuisance problems. Monitoring strategies based on techniques such as chromatographic sniffing[18] may be necessary to develop a better understanding of these complex odour sources. That odours detected in ambient air can create annoyance to the point of creating a nuisance that can be objectively verified in a community has been documented in the literature.[19, 20] The issues of odour from intensive livestock operations has been active in Europe for decades.[21] Some review of how such problems are currently being managed in Europe may be helpful. There can be no hope of addressing the broader question of odours and health concerns without developing a very strategic study of these odour sources.

5. CONCLUSIONS

The monitoring study has provided a preliminary perspective on conventional air quality measures for livestock operations in the Lethbridge region. Detectable odours were noted by the sampling staff at a number of sampling locations during the survey. The monitored air quality parameters were mainly unrelated to parameters that are likely to cause odour from livestock except for ammonia, H_2S and TRS. Only H_2S showed values that exceeded 1 hour Alberta Ambient Air Quality Guidelines at 2 sites. The observed levels were likely sufficient to contribute to an odour nuisance but are well below H_2S concentrations known to cause direct health effects. Odour nuisance levels may have been present at other locations where H_2S levels were below the 1 hour Alberta Ambient Air Quality Guidelines because H_2S may not be the sole, nor even the primary cause of odour nuisance from livestock operations.

The air quality data reported as 1 hour values should not be compared with criteria specified for different averaging times because concentration and time are always considered together in setting air quality criteria. Considering concentration level for any pollutant without simultaneously considering averaging time does not allow for a valid comparison.

Comparing air quality data collected in this survey with air quality data collected in other surveys across Alberta should only be done with considerable care. Many of the parameters measured are not comprised of one single chemical component and that composition can be expected to vary substantially from urban areas versus specific industrial sources and rural agricultural settings. For those parameters, such as ammonia and H_2S, where specific chemicals are measured, the foregoing caution does not apply, but comparisons for any parameter must consider the design of the sampling program. In the case of this Alberta Environment survey of livestock operations, the sampling crew sought locations where they could detect livestock odours and located their sampling downwind as close as 15 m to the suspected odour source. Such targeted sampling should not be compared directly with random sampling of a region or sampling that may be conducted typically more than 100 m from an emission source. Downwind concentration will decrease roughly in proportion to the square of the distance downwind from an emission source, so sampling location is highly relevant to any attempt at comparing air quality data.

Although the connection between odour perception and specific health effects is likely to remain uncertain for some time to come, the presence of readily detectable odours from some livestock operations is evident. The issues of annoyance and odour associated with livestock operations are likely to remain active as long as offensive odours can be readily detected in ambient air. Consequently, a collaborative approach by all of the interested parties to characterize these issues as fully as the available scientific methods will currently allow appears to be in the best interests of all the stakeholders. Recognizing the practical limits of available scientific tools for this purpose will be an important element of developing a consensus approach for dealing with these issues.

6. REFERENCES CITED

1. Alberta Environment. 2000. *"Air Quality Monitoring Near Livestock Feeding Operations in the Lethbridge Area: September 1998 to July 1999"* June 26, 2000 Publication No. T/498, ISBN No 0-7785-0926-5, June 26, 2000Alberta Environment, 24 pp.

2. Hasselback, P. 2000. *Letter addressed to Doug Radke, Deputy Minister, Alberta Environment, Re: Request for Air Quality Monitoring*. July 25, 2000, 2 pp.

3. Chinook Health Region. 2000. *Response to Alberta Environment Air Quality Report on Lethbridge area Livestock Operations*. July 12, 2000. 14pp.

4. Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* Chapter 12. Skewed Distributions and Goodness of Fit Tests. Van Nostrand Reinhold. New York.

5. Yasuhara, A., K. Fuwa and M. Jimbu. 1984. Identification of Odorous Compounds in Fresh and Rotten Swine Manure. *Agric. Biol. Chem*. 12: 3001-3010.

6. Banwart, W.L. and J. M. Bremner. 1975. Identification of Sulfur Gases Evolved from Animal Manures. *J. Environ. Qual.* 4: 363-366.

7. Yasuhara, A. and K. Fuwa. 1978. Hydrogen Sulfide and Dimethyl Sulfide in Liquid Swine Manure. Chemosphere. 10: 833-838.

8. O'Neill, D.H. and V.R. Phillips. 1992. A Review of the Control of Odour from Livestock Buildings: Part 3, Properties of the Odorous Substances which have been Identified in Livestock Wastes or in the Air around them. *J. Agric. Eng. Res.* 53: 23-50.

9. Ruth, J.H. 1986. Odor Thresholds and Irritation Levels of Several Chemical Substances: A Review. *Am. Ind. Hyg. Assoc. J.* 47: A142-A151.

10. van Gemert, L.J. and A.H. Nettenbreijer. 1977. *Compilation of Odour Threshold Values in Air and Water.* National Institute for Water Supply and Central Institute for Nutrition and Food Research TNO, Netherlands.

11. CEPA/FPAC Working Group on Air Quality Objectives and Guidelines. 1999. *National Ambient Air Quality Objectives for Particulate Matter. Part 1*: Science Assessment Document. Health Canada. Environment Canada. Cat. No. H46-2/98-220-1E. Ottawa.

12. Cited in reference #3 as: Government of Alberta News Release No. 99-075, Thursday June 20, 2000.

13. Hilderman, T.L., S.E. Hrudey and D.J. Wilson. 1999. A Model for Effective Toxic Load from Fluctuating Gas Concentrations. *J. Hazard. Materials*. A64: 115-134.

14. American Industrial Hygiene Association. 1989. *Odor Thresholds for Chemicals with Established Occupational Health Standards*. AIHA, Akron, Ohio. 90pp.

15. Yasuhara A. 1980. Relation Between Odor and Odorous Components in Solid Swine Manure. *Chemosphere*. 9: 587-592.

16. Shusterman, D. 1992. Critical Review. The Health Significance of Environmental Odour Pollution. *Arch. Environ. Health.* 47(1): 76-91.

17. Nagy, G. Z. 1991. The Odor Impact Model. *J. Air Waste Manage. Assoc.* 41: 1360 – 1362.

18. Kenefick, S.L., B.G. Brownlee, T.R. Perley and S.E. Hrudey. 1995. A Chemical and Sensory Study of Odour Compounds in the Athabasca River. *Water Sci. Technol*. 31(11): 15-21.

19. Van Langenhove, H., A. Lootens and N. Schamp. 1988. Objective Evaluation of an Odour Nuisance Problem Based on Inquiry Results. *Atmos. Environ*. 22: 2509-2513.

20. Miedema, H.M.E. and J. M. Ham. 1988. Odour Annoyance in Residential Areas. *Atmos. Environ*. 22: 2501-2507 .

21. Multiple Authors. 1976/77. Various articles on characterizing and managing livestock odours. *Agriculture and Environment*. 3: 109 – 297.