Odour Thresholds

in Emergency Management:

A Jurisdictional Review

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Odour Thresholds in Emergency Management

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Executive Summary

In 2014, the Alberta Energy Regulator (AER) and Alberta Health initiated a review of recurrent human health complaints received by AER in relation to odour and air quality in Fort McKay. Results of the evaluation were published in the *Recurrent Human Health Complaints Technical Information Synthesis: Fort McKay Area* (AER and Alberta Health, 2016), and 17 recommendations were made to address gaps relating to air quality and odour management. The present report focuses on Recommendation 2, which states that "policy guidance is needed on the appropriateness of odour thresholds for emergency response purposes in the community of Fort McKay." Findings from the current report are intended to provide information for decision makers to determine how best to fulfill Recommendation 2.

This report summarizes the use of odour thresholds in emergency situations in various jurisdictions, discusses the policy tools used to guide appropriate emergency response, and defines various measures of odour and air quality, including odour thresholds, ambient air quality objectives, and emergency response criteria.

Odour Threshold Definitions

An odour threshold refers to the lowest concentration of an odorant in the air that can be detected by a human being. More specific definitions for odour detection threshold (ODT) and odour recognition threshold (ORT) are as follows:

- ODT: the concentration in air at which 50% of a population detects an odour but does not recognize the odour as a specific compound (AER and Alberta Health, 2016).
- ORT: the minimum concentration that is recognized as having a characteristic odour quality by a specific percentage (usually 50%) of the population [United States Environmental Protection Agency (US EPA), 1992].

For single odorants, odour concentrations are usually expressed in micrograms per cubic metre ($\mu g/m^3$) or parts per million (ppm). For odour mixtures, odour concentration is expressed in measurements of odour units (OU) or OU per cubic metre (OU/m^3). An OU is defined as the dilution level at which 50% of an odour panel cannot distinguish an odour from odourless air.

Another odour value relevant in emergency management is the "level of distinct odour awareness (LOA)." The LOA was developed by the United States and the Netherlands for chemical emergency responders to determine the extent of public awareness of an exposure based on odour perception. The definition is as follows:

- LOA: the concentration above which it is predicted that more than half of the exposed population will experience at least a distinct odour intensity, and about 10% of the population will experience a strong smell (National Research Council, 2013).

Generally speaking, the ODT reflects the level that an odour is first detected in a laboratory setting, while the LOA indicates the level that is likely to cause public awareness and concern in real-world conditions.

Exposure to a chemical above its ODT or LOA is not indicative of toxicity, as odour and toxicity are independent factors. Certain substances can trigger adverse health effects at exposure levels below their ODT or LOA, while others cause adverse health effects at levels above their ODT or LOA. However, exposure to odour itself can also cause indirect health effects. To evaluate the impact of an odorous chemical release, it is important to consider both the direct toxic health effects of the chemical and the other possible indirect health impacts of the odour.

Emergency Response Criteria

Emergency response criteria are emergency exposure guidelines used before or during an unintended release of a hazardous chemical to evaluate potential toxicity. They are intended for one-time acute exposures to a chemical, and do not apply to repeated exposure situations. There are three main emergency response criteria that include reference to odour:

- Acute Exposure Guideline Levels (AEGLs) – developed by the US EPA.
- Intervention Values – developed by the Netherlands National Institute for Public Health and the Environment; similar to AEGLs.
- Emergency Response Planning Guidelines (ERPGs) – developed by the American Industrial Hygiene Association.

For each emergency response criteria, there are three health effect levels based on severity of symptoms. While the exact definition and selected endpoint for a tier level may vary between criteria, the tiers share the same general descriptions: mild, transient health effects (tier 1); serious health effects (tier 2); and life-threatening health effects (tier 3).

AEGLs and Intervention Values, guidelines are based on toxicological endpoints, and odour impacts are not considered in guideline development. Instead, odour information is included as a separate LOA value. The LOA is intended to aid chemical emergency responders in determining the extent of public awareness of an exposure based on odour perception, and indicates the level at which community notifications may be required to reduce or avoid anxiety and stress.

LOA values are currently available for 23 substances in the AEGL dataset, and 89 substances in the Intervention Values dataset. In comparing these data to a list of 27 common odorants in Fort McKay, LOAs are available for 14 of the substances (please see Table 5).

For ERPGs, values are primarily based on toxicological endpoints; however, an ERPG-1 value may be based on a clearly defined objectionable odour. In general, the ERPG-1 represents the level that does not pose a health risk to the community but that may be noticeable due to slight odour or mild irritation; for small non-threatening chemical releases, the community may be notified that odour or slight irritation may be noticeable but that concentrations are below those that could cause unacceptable health effects.

ERPGs also utilize an odour detection indicator (✪) for chemicals that are likely to be detected by odour near their ERPG-1 value. This is the case for many substances with low ODTs, and more than half of the ~150 substances in the current ERPG dataset include the indicator. The information is intended to assist emergency response agencies that handle odour complaint calls from the public.

Response to Odour Complaints

Emergency or environmental response agencies handle a wide range of odour complaint calls, and not all will be related to emergency situations. A suitable tool that can be used to help determine the urgency of a situation is a matrix or flowchart for triaging odour complaints, as recommended by the Clean Air Strategic Alliance. Factors considered in evaluating urgency may include: multiple calls about the same odour; reports of health concerns; unusual odour not linked to normal activity; odours that may signal a serious or dangerous situation; environmental concerns; time the odour was noticed; and access to the potential source.

Application of Odour Information in Emergency Scenarios

Various jurisdictions were reviewed to evaluate how odour information is applied in emergency scenarios. The most relevant findings with regard to odour thresholds are presented below:

- United States National Oceanic and Atmospheric Administration: LOA values and ODTs are used in emergency planning and response to estimate “phone call zones,” *i.e.*, areas where people may smell an odour and become very concerned. This can be done using monitoring data and/or atmospheric modelling. The phone call zone represents the area where public anxiety could be high, and people may contact emergency services, report an odour or gas leak, or report to local hospitals.

- Netherlands National Institute for Public Health and the Environment: LOAs are used to estimate phone call zone, which are described as areas where the public are likely to become anxious and call emergency services or environmental complaint response services in significant numbers. The prediction of the phone call zone allows emergency response agencies to make informed decisions about public communication.
- Scottish Environment Protection Agency: A detailed set of guidelines is used to classify an odour event as a major, significant, or minor odour incident. Their guidance document also outlines steps that can be taken to suspend industry activities causing the odour during major odour incidents. No information was provided regarding quantitative odour thresholds or other recommended protective actions at each tier level.

Community Notification

Various methods have been used to communicate information to the public during odour events, including public health messaging, media releases, social media, alert sirens, door to door notifications, community notification systems, and 24-hour community information lines. For example, the Northeast Region Community Awareness Emergency Response association in Alberta's Industrial Heartland operates a 24-hour phone line that provides the latest status on industrial site activities. Residents in the area can call anytime to obtain information about any unusual industrial activity they may notice, including odours. For community notification systems, emergency and community alert messages are delivered using a subscriber's method of choice (*e.g.*, email, text message, or phone).

The public message may include information such as the cause and source of the odour, the status of the situation, potential health risks, and confirmation that the situation is being monitored.

Summary

Given the perception of risk associated with environmental odours, there is a need for the public to be informed, even in cases when ambient concentrations do not reach toxic levels. Notifying the public about the nature of a smell and the potential health risks can prevent or reduce anxiety and stress-related health impacts.

It is important to note that LOA values are intended to be used in conjunction with their corresponding AEGLs or Intervention Values. The LOA addresses the odour perception component of exposure, while the AEGLs and Intervention Values are used to assess potential toxicity. For some substances, the LOA is higher than one or more of its AEGLs or Intervention Values; this indicates that direct health impacts are likely to occur before distinct odour awareness in the community.

While considerable effort has been made to develop LOAs and ERPG-1 values (including ERPG odour detection indicators), no documentation was found that evaluated the effectiveness of these policy tools in real odour scenarios. Additionally, LOAs and ERPG-1 values have only been developed for single chemicals and do not apply to odour mixtures.

For cases involving odour mixtures, though it may be helpful to identify a total odour level at which to initiate a public health response, no information was found in the literature that related concentration or intensity of odour mixtures to emergency response. The tiered system used by the Scottish Environment Protection Agency to classify odour events as major, significant, or minor odour incidents is applicable to odour mixtures; however, the system is not based on quantitative values.

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Abbreviations

AAAQO	Alberta Ambient Air Quality Objective
AEGL	Acute Exposure Guideline Level
AEP	Alberta Environment and Parks
AER	Alberta Energy Regulator
AIHA	American Industrial Hygiene Association
ALOHA	Areal Locations of Hazardous Atmospheres
AMU	Air monitoring unit
AQHI	Air Quality Health Index
AQOAC	Fort McKay Air Quality and Odours Advisory Committee
AQMG	Air Quality Model Guideline
ATSDR	Agency for Toxic Substances and Disease Registry
BC OGC	British Columbia Oil and Gas Commission
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CAAQS	Canadian Ambient Air Quality Standards
CASA	Clean Air Strategic Alliance
D/T	Dilutions to threshold
ECCC	Environment and Climate Change Canada
EDGE	Environmental Dangerous Goods Emergencies
E-nose	Electronic nose
ERP	Emergency response plan
ERPG	Emergency Response Planning Guideline
EPZ	Emergency planning zone
FMAQI	Fort McKay Air Quality Index
FMSD	Fort McKay Sustainability Department
H_2S	Hydrogen sulphide
HCl	Hydrochloric acid
HVP	High vapour pressure
LOA	Level of distinct odour awareness
MAML	Mobile Air Monitoring Laboratory
MOECC	Ministry of the Environment and Climate Change (Ontario)
NAC/AEGL	National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances
NMHC	Non-methane hydrocarbons
NO	Nitric oxide
NO_2	Nitrogen dioxide

NOAA	National Oceanic and Atmospheric Administration
NOAEL	No observed adverse effect level
NO_X	Nitrogen oxides
NPRI	National Pollutant Release Inventory
NRCAER	Northeast Region Community Awareness Emergency Response
ODT	Odour detection threshold
ORT	Odour recognition threshold
OU	Odour units
OU/m^3	Odour units per cubic metre
PAL	Provisional advisory level
$PM_{2.5}$	Fine particulate matter
ppb	Parts per billion
ppm	Parts per million
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (*Netherlands National Institute for Public Health and the Environment*)
SO_2	Sulphur dioxide
TAGA	Trace Atmospheric Gas Analyzer
TCEQ	Texas Commission on Environmental Quality
TEEL	Temporary Emergency Exposure Limit
THC	Total hydrocarbons
TRS	Total reduced sulphur
$\mu g/m^3$	Micrograms per cubic metre
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency
VOC	Volatile organic compound
WBEA	Wood Buffalo Environmental Association
WHO	World Health Organization

1 Introduction

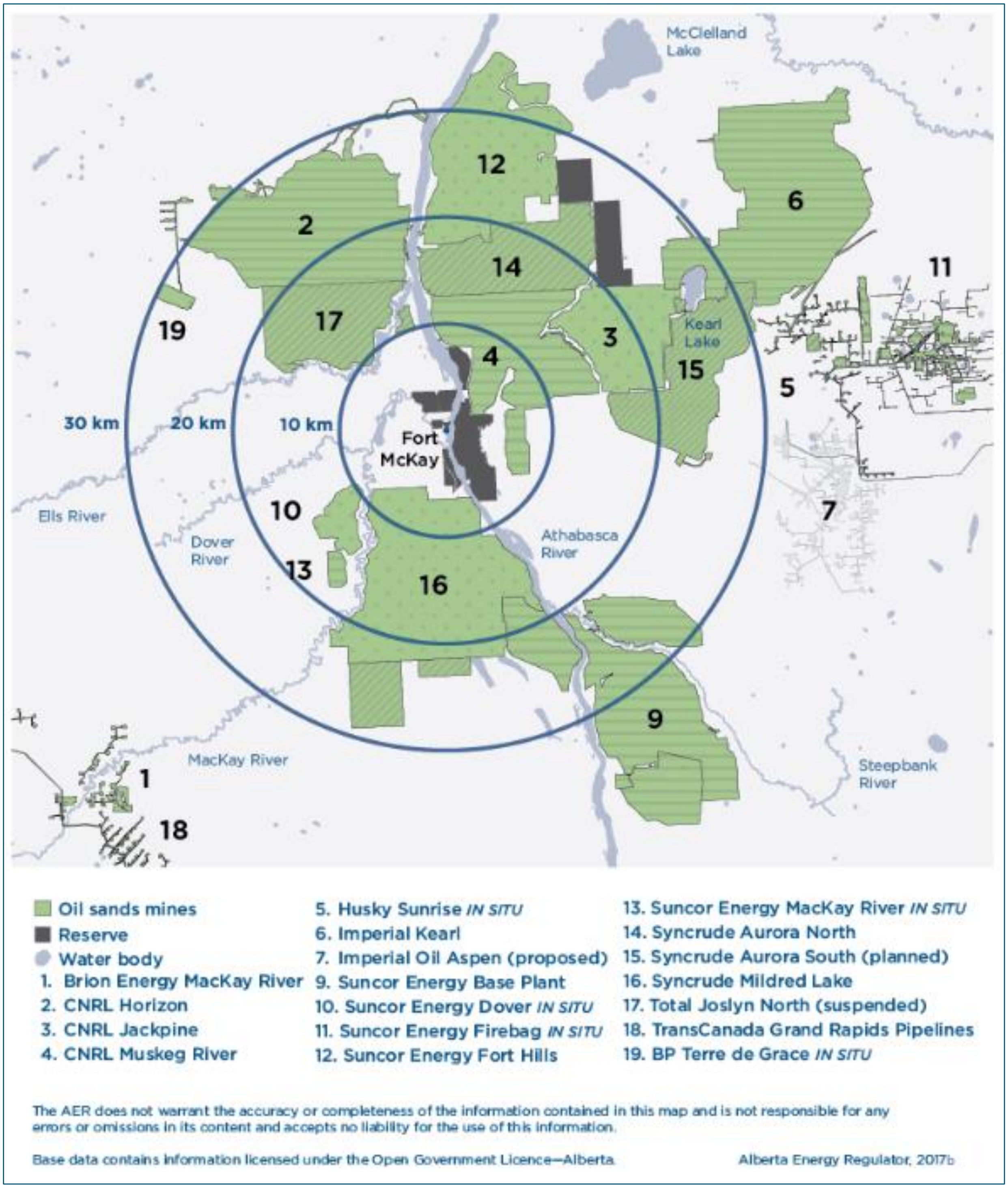
1.1 Purpose of the Report

Fort McKay is a community in northeast Alberta with a predominantly Indigenous population. It is surrounded by numerous oil sands operations. The locations of these operations in relation to Fort McKay are shown in Figure 1. Emissions and odours from the operations have had a negative impact on the Fort McKay community and its residents. In 2014, the Alberta Energy Regulator (AER) and Alberta Health initiated a review of recurrent human health complaints received by AER in relation to odour and air quality in Fort McKay. Results of the evaluation were published in the *Recurrent Human Health Complaints Technical Information Synthesis: Fort McKay Area* (AER and Alberta Health, 2016), herein referred to as the “2016 Technical Synthesis Report.”

The 2016 Technical Synthesis Report identified several gaps relating to air quality and odour management in the area, and a list of 17 recommendations were made to address the issues. For the Fort McKay community and stakeholders, there is a need to better understand when air quality poses an immediate and acute health concern (both directly from toxic effects and indirectly from odour detection). Information regarding emergency response actions in relation to ambient air quality and odours is lacking. The present report provides the evidentiary basis for Recommendation 2, which states that “policy guidance is needed on the appropriateness of odour thresholds for emergency response purposes in the community of Fort McKay” (AER and Alberta Health, 2016, p. 13).

The purpose of this report is to summarize the use of odour thresholds in emergency situations in various jurisdictions, and discuss the policy tools used to guide appropriate emergency response. This report also defines various measures of odour and air quality, including odour thresholds, ambient air quality objectives, and emergency response criteria, and discusses their different purposes and uses. Findings from this report will provide the evidentiary basis for decision makers to determine how odours could be used in emergency response, and fulfill Recommendation 2.

Definitions for various terms related to odours, thresholds, and emergencies can be found in the glossary in Appendix A.



Note: #17 Total Joslyn North is now called CNRL Horizon South; site preparation is expected to begin in November 2020 (AER, 2019).

Figure 1. Oil sands operations around Fort McKay, Alberta

1.2 Intended Audience

The intended audience of this report is Fort McKay residents with concerns about air quality, odours, and emergency response in relation to oil sands operations in the area, as well as other involved stakeholders, including the Fort McKay Air Quality and Odours Advisory Committee (AQOAC), industry, AER, Alberta Environment and Parks (AEP), Alberta Health, monitoring agencies, and other government agencies concerned with air quality and odours. The report may be used to inform policy development for chemical emergencies and odour management in Alberta. The information may also be relevant to other public health professionals and members of the public with an interest in odour management during chemical emergencies.

1.3 Research Questions

The main research question for this report is:

- How do government and regulatory agencies use odour information in periods of emergency response? (Section 5)

Additional sub-questions for this report include:

- To fully answer the above question, it is important to also consider air quality criteria to evaluate the potential toxicity of exposure. This leads to the next research question: What emergency response criteria are used by different agencies during chemical emergencies? (Section 4)
- How are odour thresholds used by different agencies? Both emergency and non-emergency scenarios are considered. (Section 3.4)
- How is odour monitored in Alberta? (Section 3.6)

1.4 Literature Search Methodology

The literature search involved three main steps:

- Preliminary scan
- Literature search
    - Agency websites
    - Google searches
    - Academic databases
- Case study assessment

Details of the search strategy are presented in Appendix B. The agency websites utilized are listed in Appendix C. Relevant material was considered as any article, document, or website that discussed odour thresholds and/or chemical emergencies in an environmental context. The bulk of the material used in the report was obtained from agency websites.

1.5 Out of Scope

Topics considered out of scope for this report include:

- The use and impact of odour thresholds in long-term, low dose scenarios (*i.e.*, odour nuisance), as these scenarios are not relevant to emergency situations when the acute health effects are considered, doses are usually high, and the presence of chemicals (at that level) is supposed to be temporary. However, some material related to odour nuisance was collected and discussed in the report, as it can be difficult to separate the two types of situations (*i.e.*, nuisance *vs.* emergency);
- Substantiating the link between odour and health impacts [a review of odours and human health has recently been published by the Government of Alberta (2017b)];
- Comparison of jurisdictional guideline values for odorous contaminants for non-emergency scenarios (jurisdictions were reviewed for how they applied odour information, but not for the numerical values that were selected);
- Occupational health and safety protocols for responding to odour; and
- Use of odorants for detection of gas leaks (*e.g.*, addition of mercaptan to natural gas for safety purposes).

Additionally, the following topics were not covered in this report, as they are not directly relevant to a discussion on odours and emergency response: strategies for odour control; safety measures to prevent accidental chemical releases; and radiological/nuclear incidents.

1.6 Limitations

Most of the documentation relating to odours and odour thresholds pertains to management of odour nuisance. For many jurisdictions, it was difficult to find documentation outlining the use of odour information in emergency situations, particularly for protocols for responding to odour complaints. Additionally, very few jurisdictions discussed how odour thresholds or emergency guidance values are applied in emergency situations, *i.e.*, the specific protective actions that are taken when a chemical concentration reaches a given threshold.

This report is not a comprehensive review, as only a small number of jurisdictions were reviewed for relevant material. The information is limited to that which is publicly available online or published in academic journals. Given this, there is the potential that suitable information may have been missed.

2 Background

This section provides background information on Fort McKay and the odour issues in the area. An introduction to the 2016 Technical Synthesis Report is also included.

2.1 Fort McKay

Fort McKay is an Indigenous community located 58 km north of Fort McMurray, Alberta. The area lies at the centre of numerous oil sands developments, including eight open-pit (six operational, one with operations on hold, and one planned) and three in situ oil sands mining operations within 30 km (Dennis *et al.*, 2015; AER, 2017b). Emissions and odours from these operations have been an ongoing concern for the community.

2.1.1 History of Odour Issues

The history of odour issues in Fort McKay has been described in detail in the 2016 Technical Synthesis Report:

> Odours and air quality have been an ongoing concern for Fort McKay residents. Residents have made multiple complaints about odours that they attribute to the oil sands mines in the vicinity of Fort McKay. Since January 2010, 172 calls to the AER's Fort McMurray Regional Office have been recorded, capturing a variety of concerns. Of those calls, 165 are related to odours.
>
> On October 17, 2014, the Fort McKay Sustainability Department (FMSD) communicated their expectations of industry, requesting that industry identify major odour sources at each operation, identify types of technologies to reduce odours, conduct internal reviews and mitigation for odours during normal operations, produce site maps of odour sources, and initiate on-site odour monitoring groups to report internally on odour sources and odour events. The FMSD recognized this was a long-term plan but progress was required.
>
> Industry responded to these expectations by requesting further dialogue and stating that monitoring technology and coverage may not be sufficient to understand odour sources; initiation of programs required validation of their effectiveness in specific applications/ locations across sites, and government should be part of the process at senior levels.
>
> During 2014 and 2015, the FMSD reached out to the AER and the Government of Alberta in an attempt to bring more attention to this matter. Fort McKay had also been working with oil sands mining companies to discuss the odour issue during this period.
>
> Early in 2015, industry representatives (Suncor) and the FMSD contacted the AER requesting attendance at a March meeting between the FMSD, industry (Suncor, Syncrude, Imperial, Shell, [Canadian Natural Resources Limited]), and other government organizations (Environment Canada, Alberta Health) to discuss air quality and odours.
>
> (AER and Alberta Health, 2016, p. 2-4).

At the meeting held in March 2015, two key issues were identified:

- The odours themselves are experienced on a very frequent basis even with industry operating “normally;” and
- A plan was needed for emergency events and possible evacuation of the community of Fort McKay with respect to odours and air quality.

Subsequently, the AER initiated the recurrent human health complaint process with the Fort McKay First Nation.

2.2 Recurrent Human Health Complaints

2.2.1 Recurrent Human Health Complaint Process

The recurrent human health complaint process is a technical assessment of recurring complaints involving human health concerns (AER, 2015). The process involves: the evaluation of recurrent complaints; identification of any technical gaps and risks; and determination of potential AER actions. The process involves coordination across different government agencies and focuses on inclusive information gathering, transparency, and stakeholder participation (AER and Alberta Health, 2016).

2.2.2 Roles of the Alberta Energy Regulator and Alberta Health

The AER and Alberta Health both play an important role in the recurrent human health complaint process. The responsibilities of each agency are outlined in the 2016 Technical Synthesis Report:

> The AER’s mandate is to ensure the safe, efficient, orderly, and environmentally responsible development of Alberta’s hydrocarbon resources over their entire life cycle. Its environmental protection mandate extends to those elements of the environment that have the potential to affect human health. The AER has serious regard for human health concerns that relate to resource development. However, the AER does not regulate human health directly or have primary responsibility for identifying health concerns in Alberta. Alberta Health and Alberta Health Services are the agencies responsible for health and health concerns. The AER supports these organizations when questions arise about the impact of energy resource development on the health of individuals.
>
> When stakeholders are concerned about energy resource activity in their area, one mechanism to register that concern is a complaint that is directed to AER offices for investigation. Often complaints can recur if a complainant believes the original complaint was not resolved. Recurrent complaints involve multiple complaints from multiple individuals over multiple years. They are often complex, involving multiple government agencies. When recurrent complaints

involve human health, this can be particularly concerning for all stakeholders, industry, and government agencies.

> The AER is not a human health regulator, but as the regulator of energy resource activity in Alberta, the AER does have a responsibility to assess recurrent human health complaints associated with energy resource activities. This is done by gathering industry, regulatory, and environmental information to support further assessment of human health concerns by the human health regulators.
>
> (AER and Alberta Health, 2016, p. 1)

2.2.3 Recurrent Human Health Complaints Technical Information Synthesis: Fort McKay Area

The 2016 Technical Synthesis Report evaluated recurrent health complaints received by the AER in relation to odour and air quality in Fort McKay. Using data covering a five-year period (2010–2014), the evaluation focused on emergency response, inspections and investigations, industry performance monitoring, and ambient air quality monitoring in relation to the complaints. The AER made the following observations:

- In most cases, oil sands facilities were operating under normal conditions and were following the AER's requirements during the time of the complaints;
- There is a link between emissions from oil sands operations in the area and air quality and odours in Fort McKay;
- The air in Fort McKay does at times contain emissions that exceed odour and health thresholds;
- Response protocols for odour and air quality complaints must be improved;
- More work is needed to better understand the connection between emissions and oil sands operators and how exposure to emissions that exceed thresholds may impact health; and
- There is not sufficient information to correlate an odour complaint to a specific emission, emission source, facility, or operation.

(AER and Alberta Health, 2016, p. 23; AER, 2017c)

Several gaps were identified relating to air quality and odour management, and AER and Alberta Health made 17 recommendations to address the issues. The recommendations focused on:

- Emergency response related to air quality exceedances;
- The AER's odour-complaint response protocols;
- Identifying, assessing, and managing emissions from oil sands operations;
- Air quality monitoring; and
- Conducting a human health assessment based on ambient air quality data.

(AER, 2017c)

In Recommendation 17, the AER and Alberta Health advised that a Fort McKay Odour and Air Quality Task Force be established to oversee the implementation of the recommendations (see Section 2.3).

2.2.4 Overview of Recommendation 2

Recommendation 2 (of the above-mentioned 17 recommendations) states that “policy guidance is needed on the appropriateness of odour thresholds for emergency response purposes in the community of Fort McKay.”

This recommendation was based on the following findings in the 2016 Technical Synthesis Report:

> The potential or risk of acute air quality issues requiring emergency response in the community of Fort McKay is extremely low based on controls placed into [*Environmental Protection and Enhancement Act*] approvals and modelling conducted during environmental impact assessments prior to project approval. However, it is critical that the community of Fort McKay understand when air quality poses an immediate and acute health concern. Given that acute evacuation concentrations are known for important air quality parameters, monitoring technology exists for this purpose in other areas, and considering the potential for cumulative air emissions to affect this community, acute air quality monitoring in the community for selected parameters should be considered.
>
> The community of Fort McKay is in a unique situation related to this issue due to:
>
> - Proximity of the cumulative oil sands development to the community;
> - Single entry and exit point into the community;
> - The type of development and diversity of emissions relative to other communities;
> - The uniqueness of the meteorology, wind patterns, and landscape, including the river valley that, under the right conditions, can serve as a conduit of emission to the community; and
> - The uniqueness of upgraders.
>
> The suggestion to consider monitoring of acute air quality for select parameters in the community of Fort McKay for the purposes of emergency response is based on the unique criteria specified above for this community.
>
> There are no established odour levels in policy or regulation that trigger an immediate acute health concern and emergency response. Even if monitoring for acute odour levels were conducted in the community of Fort McKay, no emergency response procedures would be triggered in the absence of this policy direction. Guidance is required from Alberta Health for acute odour thresholds.
>
> (AER and Alberta Health, 2016, p. 12-13)

2.3 Fort McKay Air Quality and Odours Advisory Committee

Established in December 2016, the AQOAC provides leadership, advice, and guidance on the implementation of the recommendations outlined in the 2016 Technical Synthesis Report (AER, 2018b). The multi-stakeholder committee is co-chaired by the AER, Alberta Health, and the Fort McKay First Nation and Métis community, and includes representatives from AEP, Environment and Climate Change Canada (ECCC), and industry. The responsibilities of the AQOAC include:

- Establish sub-committees to refine and scope recommendations and advise on implementation;
- Oversee the development of work plans for recommendations;
- Monitor the progress of sub-committees, provide advice and guidance where needed, and review and support their deliverables;
- Engage with key sector stakeholders on discussions and gather input prior to meetings; and
- Establish a mechanism that provides progressive updates to the Fort McKay community and key stakeholders.

(AQOAC, 2017)

There are three outcomes that the AQOAC aims to achieve:

- Integrated emergency preparedness and response to poor AQ events;
- Protecting community health; and
- Improving air quality in the community.

(AQOAC, personal communication, 2019)

The AQOAC was formed in response to Recommendation 17 of the 2016 Technical Synthesis Report. The committee was previously named the *Fort McKay Odour and Air Quality Task Force*; however, the name was later changed to more accurately reflect the function of the group.

2.4 Jurisdictional Responsibilities

The responsibilities of the various agencies involved in regulating resource development activities are outlined in the 2016 Technical Synthesis Report:

> All public policy-making authority for provincial resource development activities, including energy resources, resides with the Government of Alberta. [AEP] (through its environmental protection mandate) shares regulatory authority for the protection of human health in the province with the Ministry of Health. The AER is not directly involved in human health regulation, but it may implement health policy when it performs its regulatory functions.

> Regulation of the energy resource sector, including environmental protection, now largely resides with the AER. The AER is also responsible for implementing Government of Alberta policy with respect to energy resource activity. This is done for oil sands operators primarily through regulatory approvals under the specified enactments (including [the *Environmental Protection and Enhancement Act*], the *Water Act*, and the [*Public Lands Act*]) and under the energy resource enactments such as the *Oil Sands Conservation Act*. AER regulatory approvals require oil sands mining operators to function within specified parameters that are designed to ensure that policy outcomes are achieved. These may include requiring operators to conduct or participate in monitoring and reporting on emissions and ambient air quality.
>
> The AER works with the Monitoring and Science Division of [AEP] to ensure that regional ambient monitoring is aligned with policy outcomes and regulatory approvals for industry, and that information is gathered, collected, and reported to agencies and stakeholders in a manner that ensures the safe, efficient, orderly, and environmentally responsible development of energy resources.
>
> [ECCC] works with the AER and the Monitoring and Science Division of [AEP] to ensure that regional monitoring addresses federal policy goals, regulatory requirements, and scientific needs. Establishing clarity of these roles and responsibilities within and between governments and their respective agencies, and with external stakeholders, is a priority for the AER.
>
> (AER and Alberta Health, 2016, p. 6)

3 Odours and Odour Thresholds

Odour is the quality of a substance that is perceived by the sense of smell (Government of Alberta, 2017b). The substance that produces an odour is called an odorant, which is defined as a volatile chemical in the air that stimulates sensory neurons in the nasal passage. For example, hydrogen sulphide (H_2S) is an odorant that produces a rotten egg-like odour. The human nose is extremely sensitive, and odorants can be detected at very low concentrations (Environment Agency, 2007)

The four main properties that characterize odour perception are detectability, intensity, hedonic tone, and odour quality or character [United States Environmental Protection Agency (US EPA), 1992].

Detectability refers to the awareness of the presence of an odorant.

Intensity refers to the perceived strength of an odour. Odour intensity is commonly assessed on a 5- or 7-point scale (Millennium EMS Solutions Ltd. and Environmental Odour Consulting, 2015). The 7-point scale, initially described in the German Standard VDI 3882 (Verein Deutscher Ingenieure, 1992), includes the following categories:

0 - No odour/Not perceptible
1 - Very weak
2 - Weak
3 - Distinct
4 - Strong
5 - Very strong
6 - Intolerable

Hedonic tone refers to the perceived pleasantness or unpleasantness of an odour.

Quality/Character is a qualitative description of how an odour smells (*e.g.*, floral, musky, woody, fruity).

The sensitivity to odours varies among individuals. Factors such as age, gender, health status (*e.g.*, illness, allergies), and smoking can affect one's ability to perceive and characterize odours [American Industrial Hygiene Association (AIHA), 2013]. Repeated exposure to an odour and/or exposure to a high odour concentration can cause olfactory fatigue, which is a form of sensory adaptation that leads to a reduced ability to detect the particular odour (Greenberg *et al.*, 2013). Alternatively, repeated exposure to an odour can cause sensitization, whereby perceived odour intensity is increased [Clean Air Strategic Alliance (CASA), 2015].

3.1 Definitions of Odour Thresholds

3.1.1 Odour Detection, Recognition, and Distinct Odour Awareness

An odour threshold (OT), generally speaking, is the lowest concentration of an odorant in the air that can be detected by a human being (US National Library of Medicine, 2007). In the scientific determination of odour thresholds, the terms and definitions are more specific:

> <u>Odour detection threshold (ODT)</u>: the concentration in air at which 50% of a population detects an odour but does not recognize the odour as a specific compound (AER and Alberta Health, 2016). [For an individual, the ODT represents the concentration where that person can just detect the odour 50% of the time (Environment Agency, 2007).]
>
> <u>Odour recognition threshold (ORT)</u>: the minimum concentration that is recognized as having a characteristic odour quality by a specific percentage (usually 50%) of the population (US EPA, 1992).

The terms "odour threshold" and "ODT" are often used interchangeably in the literature. For the current report, odour threshold is used when discussing thresholds as a concept and when referring to all types of odour thresholds, while ODT is used when referring to ODT values determined in a laboratory.

Reported ODT and ORT values for a given odorant may vary over several orders of magnitude. This is due in part to differences in methodology; for example, some older methodologies set the ODT as the level when 100% of an odour panel, as opposed to 50% of the panel, could detect the odour (Ruth, 1986). There is also a large amount of inter- and intra-individual variability in the ability to perceive odours. An individual's perception can vary from day to day, depending on factors such as state of health, time of day, and amount of focus (*i.e.*, paying attention to the odour). It should also be noted that odour concentrations measured by a panel under controlled laboratory conditions tend to be harder to detect in the environment, due to the presence of background odours and a lower level of focus [Rijksinstituut voor Volksgezondheid en Milieu (RIVM), 2009].

Given the variation in reported ODTs and ORTs, it is sometimes difficult to determine the most appropriate threshold values from the literature. Values are often reported as a range (the minimum and maximum values) along with the mean value. The values used by different agencies or jurisdictions may also vary due to the reliance on different sources of reported odour thresholds.

For single odorants, concentrations are usually expressed in micrograms per cubic metre ($\mu g/m^3$) or parts per million (ppm). For odour mixtures, odour concentration is expressed in measurements of odour units (OU) or OU per cubic metre (OU/m^3). Using olfactometry (which is described further in Section 3.6.3.2), an OU indicates the dilution level at which 50% of an odour panel cannot distinguish an odour from odourless air [also known as dilutions to threshold (D/T)]. For example, if an odour sample diluted 10 times is just undetectable by 50% of the panel, the odour concentration would be 10 OU. A value of 1 OU is equivalent to the ODT, and all odorants at 1 OU will generally be perceived as the same intensity.

At odour concentrations above 1 OU, the concentration-intensity relationship differs for different odorants (or odour mixtures). For example, butanol at an odour concentration of 10 OU would be perceived as a weak odour, while H_2S at 10 OU would be perceived as a distinct odour intensity (Government of Western Australia, 2002). It is generally accepted that an odour at its recognition threshold is roughly equivalent to a distinct odour intensity (Government of Western Australia, 2002).

Another odour value to define is the “level of distinct odour awareness (LOA).” The LOA was developed by the US EPA and the Netherlands National Institute for Public Health and the Environment (also known as the RIVM), and is intended to be used by chemical emergency responders to determine the extent of public awareness of an exposure based on odour perception (RIVM, 2009; National Research Council, 2013). The definition is as follows:

> LOA: the concentration above which it is predicted that more than half of the exposed population will experience at least a distinct odour intensity, and about 10% of the population will experience a strong smell (National Research Council, 2013).

Details regarding the derivation and use of the LOA are provided in Sections 4.3.1.1 and 4.3.4.

The general relationship between the ODT, ORT, LOA, and odour concentration for a given odorant is illustrated in Figure 2. The LOA is a slightly higher odour concentration than the ORT; this is because the LOA represents a distinct odour intensity (which, as mentioned above, is roughly equivalent to the ORT) multiplied by a correction factor of 1.33 to account for field conditions (RIVM, 2009).

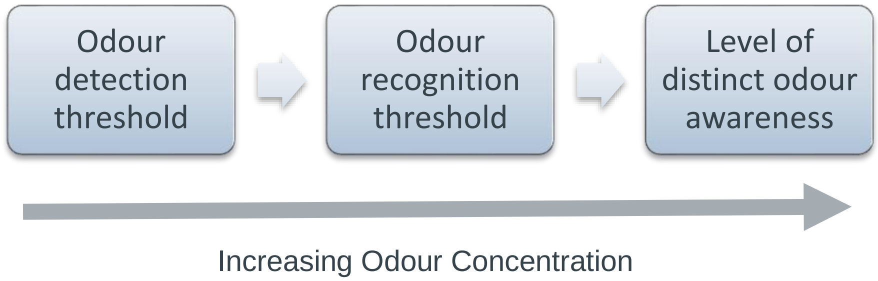


Figure 2. Relationship between odour thresholds, level of distinct odour awareness, and odour concentration for an odorant

3.1.2 Odour Offensiveness and Complaint Thresholds

Two additional odour thresholds that have been used to characterize odorous emissions include:

> Odour offensiveness threshold: the concentration at which 50% of a population, based on the results from an experimental odour panel, would be expected to indicate that the odour is offensive over a short period of exposure (Bokowa, 2008; CASA, 2015).

> Odour complaint threshold: the concentration at which 50% of a population, based on the results from an experimental odour panel, would be expected to complain about an odour if exposed to the odour for a short time period (Bokowa, 2008; CASA, 2015).

These two concepts have been applied in olfactometry evaluations of odour mixtures from various facilities (Bokowa, 2008). Using odour samples collected from facility stacks or ambient locations, standard laboratory olfactometry is conducted to determine the odour concentration (which is also referred to as the ODT or D/T in olfactometry). Using the same panelists and odour samples, the odour panel is then instructed to identify when the presented odour is offensive. The odour offensiveness threshold is identified as the point at which 50% of the panelists indicate the odour is offensive. Similarly, for the odour complaint threshold, the same panelists are asked to identify if they would complain to authorities about the presented odour. The odour complaint threshold is identified as the point at which 50% of the panelists indicate they would complain about the odour.

The above evaluations can be used to compare odorous emissions from different stacks or facilities, determine the effectiveness of odour control agents, and predict when complaints may occur (Bokowa, 2008). For example, if the ODT and odour complaint threshold are similar, it can be expected that complaints will occur as soon as the odour is detected. In some cases, the odour offensiveness and complaint thresholds may be the same.

3.2 Environmental Odours and Health

Environmental odours can originate from many different sources; examples include livestock operations, oil and gas operations, waste landfills, sewage/water treatment plants, power plants, refineries, and industrial factories. Odours can have a negative impact on nearby communities. and cause annoyance- or nuisance-related effects such as headache, nausea, stress, anxiety, mood changes, sleep disturbances, and reduced outdoor activity [Agency for Toxic Substances and Disease Registry (ATSDR), 2017b; Government of Alberta, 2017b].

The development of symptoms is influenced by factors such as odour characteristics (*e.g.*, offensiveness, intensity), the frequency and duration of exposure, individual characteristics (*e.g.*, age, gender, health status, smoking status), and an individual's level of annoyance. The response to an odour is also influenced by an individual's past experience with the odour. For example, a negative emotional reaction to a particular odour may occur because of a negative experience during a previous odour event (Schiffman and Williams, 2005).

Some individuals may be more sensitive to the effects of odours. For example, people with depression, anxiety, migraines, and allergies may feel worse with prolonged odour exposure (ATSDR, 2017a). Additionally, odours can aggravate symptoms of asthma, chronic obstructive pulmonary disease, and emphysema (ATSDR, 2017b).

At lower odour levels, health impacts are more likely to occur with repeated or prolonged exposure. For stronger odours, the impact may be more immediate. People may be concerned that the odour is indicative of an emergency situation. The odour may be perceived as a threat to health, potentially leading to worry, panic, and anxiety-related symptoms (New Zealand Ministry for the Environment, 2016a; RIVM, 2009).

Exposure to environmental odours may also cause health effects via acute toxicity. Acute toxicity refers to the adverse health effects associated with short-term exposure to a substance, and is the result of a direct toxic action. Toxicity is dependent on the concentration of a substance, and the frequency and duration of exposure (ATSDR, 2017b). At low levels of toxicity, the effects may be minor and transient, such as coughing, nausea, eye irritation, and changes in breathing patterns (some symptoms, such as nausea, can also be caused by odour nuisance). At high levels of toxicity, the effects may be more serious and/or permanent, such as severe pulmonary effects or death.

3.3 Acute Toxicity *vs.* Odour Thresholds

Exposure to a chemical above its odour threshold is not indicative of acute toxicity, as odour and toxicity are independent factors (AIHA, 2018). Some chemicals may cause adverse health effects at exposure levels below their odour threshold. For example, reported ODTs for phosgene range between 120 and 5,700 parts per billion (ppb; AIHA, 2013), and acute health effects may occur above hourly exposures of 1 ppb (California Office of Environmental Health Hazard Assessment, 2008). In contrast, some chemicals have odour thresholds that are much lower than their acute toxicity levels. For example, the ODT for carbon disulphide is 8–10 ppb (Ruth, 1986; Government of Alberta, 2019a), and acute health effects may occur above 8,000 ppb [Texas Commission on Environmental Quality (TCEQ), 2017].

Thus, the perception of an odour indicates that a chemical is present in the air, but it is not a reliable indicator of a toxic exposure. The two concepts (odour and acute toxicity) should both be considered when evaluating the impact of an odorous chemical release. Health benchmarks are used to evaluate direct toxicity, while odour benchmarks are used to assess awareness of exposure in the population and indirect health effects such as anxiety and worry (RIVM, 2009).

3.4 Air Benchmarks and Odour Thresholds

Ambient air quality guidelines are used to manage the levels of pollutants in ambient air and protect public and environmental health. Guidelines are set to protect against adverse health effects in the general population, including sensitive individuals such as children and the elderly. In Canada, the federal air quality guidelines are the Canadian Ambient Air Quality Standards (CAAQS), which have been established for sulphur dioxide (SO_2), nitrogen dioxide (NO_2), fine particulate matter ($PM_{2.5}$), and ozone (Canadian Council of Ministers of the Environment, 2017). However, CAAQS are derived based on adverse human health or environmental effects, and consider continuous or repeated exposures over a lifetime, none of the CAAQS are based on odour.

Individual provinces may develop additional air quality guidelines; examples include the Alberta Ambient Air Quality Objectives (AAAQOs), Manitoba Ambient Air Quality Criteria, and Ontario Ambient Air Quality Criteria. The sections below discuss these guidelines in more detail, and provide examples of the use of odour thresholds in air quality management. ODTs have generally been applied to the evaluation and management of nuisance odours.

A summary of the air quality guidelines used in Texas is also included, as odour-based values for various malodorous chemicals are used in the management of odour nuisance.

For the jurisdictions presented below, no references were found that discussed the use of odour thresholds in emergency response.

3.4.1 Alberta

AAAQOs have been established for ~50 substances (Government of Alberta, 2019a). They are based on adverse human and ecological health effects or odour, using 1-hour, 24-hour, or annual averaging periods. AAAQOs are used to evaluate air quality and manage emissions from industrial facilities. AAAQOs are based on odour for three substances: ammonia, carbon disulphide, and H_2S (1-hour averages).

ODTs for various substances have been used in evaluations of odour nuisance and air quality in the Peace River and Fort McKay areas. Examples of the application of ODTs in these areas are provided below. It is not the intention of the report to review the findings in detail, but rather to offer examples of how ODTs have been used. Readers are referred to the original documents for further information.

Peace River area: Government of Alberta (2010, 2011a), Intrinsik (2013), AER (2014b), and Stantec Consulting Ltd (2014)

ODTs were used in the investigation of objectionable odour related to emissions from heavy oil operations in the Peace River Area. Following numerous odour complaints in 2010, air samples were collected at various locations and analyzed primarily for volatile organic compounds (VOCs). Concentrations in the samples were compared to ODT values to determine the possible cause of the odour. ODTs were also used in odour impact assessments to identify odorants that may be perceived in the area, and to evaluate the potential health implications of odour nuisance and discomfort. ODT information presented in the various documents includes:

Government of Alberta (2010): *Table A-1* compared canister sampling data (maximum concentrations detected) to ODTs for more than 80 chemicals.

Intrinsik (2013): *Tables 3-1 and 3-2* compared the near-peak 3-minute average concentrations of VOCs detected in the Three Creeks and Reno areas with ODTs for more than 100 chemicals (or chemical groups).

AER (2014b): *Table 2* compared the near-peak 3-minute average concentrations of VOCs detected in the Three Creeks and Reno areas with ODTs [same data as above (Intrinsik, 2013)].

Stantec Consulting Ltd (2014): ODTs were compared to maximum and average concentrations of odorants in grab samples collected during odour events *(Table 8-8)* and integrated canister samples *(Table 8-12)*.

Fort McKay: AER and Alberta Health (2016)

In the 2016 Technical Synthesis Report, continuous monitoring and canister sampling data from Fort McKay were compared to ODTs to identify chemicals (and possible sources) that may be contributing to the perception of odours in the area. The following comparisons were presented:

Tables 19, 20, and 25 compared ECCC continuous monitoring data with ODTs to determine the number of exceedances and identify trends. Chemicals evaluated include octane, heptane, hexane, benzene/toluene/ethylbenzene/xylenes (BTEX), SO_2, H_2S, total reduced sulphur (TRS), NO_2, and ozone.

Table 29 compared Wood Buffalo Environmental Association (WBEA) 24-hour canister sampling data (collected for the National Air Pollution Surveillance program) with ODTs to determine the number of exceedances. A total of 82 chemicals were evaluated.

During odour events, the FMSD collects 10-minute canister samples from two sites in Fort McKay. The ODTs used to identify potential air contaminants of interest in the samples are listed in four tables in the 2016 Technical Synthesis Report: *Table 31* (target C1 to C4 hydrocarbons); *Table 32* (target reduced sulphur compounds); *Table 33* (target VOCs); and *Table 34* (nontarget VOCs).

Tables 28 and 36 list the ODTs used by AER for comparisons of various parameters collected in ambient air samples.

Fort McKay: [Dennis et al. (2015)]

The FMSD recommends the use of ODTs in odour impact assessments for proposed oil sands projects on Fort McKay's Traditional Territories. To estimate the frequency and duration of potential odour events, a 3-minute averaging time for potential odorants is recommended.

3.4.2 Manitoba

Manitoba Ambient Air Quality Criteria are available for more than 20 contaminants (Province of Manitoba, 2005). The criteria are set to protect the health of the general population, and are used for planning purposes and to evaluate air quality. The criteria are based on averaging times of 1 hour, 24 hours, and 1 year, and may be classified as objectives or guidelines. Objectives are used for air pollutants that are widespread throughout the province and have national limits in place, while guidelines are used for pollutants that have a more localized presence.

The Manitoba Ambient Air Quality Criteria include guidelines for total odour; the maximum desirable level[1] is <1.0 OU (*i.e.*, less than the ODT), and the maximum acceptable level[2] is 2.0 OU for residential zones and 7.0 OU for industrial zones. The total odour guidelines are intended to be used only for evaluating potential impacts on a community during the environmental impact assessment of new or modified developments.

For ammonia, the maximum desirable level (1-hour average) is the same as the 1-hour AAAQO (which is odour-based). It is not clear if the criteria are odour-based for any other substances.

3.4.3 Ontario

The Ministry of the Environment and Climate Change (MOECC) in Ontario has developed Ambient Air Quality Criteria for more than 300 substances (MOECC, 2018b). Ambient Air Quality Criteria values are used to evaluate general air quality, and may be applied in environmental assessments, studies utilizing ambient air monitoring data, and annual air quality reporting. The

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[1] The *maximum desirable level* is the long term goal for air quality and provides a basis for an anti-degradation policy for the pristine areas of Manitoba and for the continuing development of control technology (Province of Manitoba, 2017).
[2] The *maximum acceptable level* is deemed essential to provide adequate protection for soils, water, vegetation, materials, animals, visibility, personal comfort, and well-being (Province of Manitoba, 2017).

criteria may be based on health, environmental, or nuisance effects, although most are based on health effects (MOECC, 2017c). The averaging times used for each substance (10 minutes, 30 minutes, 1 hour, 24 hours, and/or annual) are based on the effect they are intended to protect against. The criteria include numerous substances with 10-minute odour-based limits, such as dimethyl sulphide, H_2S, isobutanol, mercaptans, and TRS. The 10-minute averaging period has been introduced by the ministry to better align odour-based criteria with the complaint characteristics of people in communities impacted by odour (Ontario Ministry of the Environment, 2005). Some substances still have a 1-hour or 24-hour limit based on odour; however, the MOECC plans to update these using the 10-minute averaging time and/or develop health-based limits.

Ontario also utilizes 10-minute odour-based standards and guidelines in evaluations of modelled emissions from regulated facilities (MOECC, 2017d).

3.4.4 Texas

The TCEQ has developed Air Monitoring Comparison Values (to evaluate ambient air monitoring data) and Effects Screening Levels (to assess modelled emissions from proposed facilities for air permitting) to regulate ambient air quality (TCEQ, 2015b). Values are derived for 1-hour, 24-hour, and long-term (annual) averaging periods, and may be based on health effects, odour, or vegetation effects. Odour-based values are developed for chemicals that are considered to be malodorous, with the goal being to prevent odour nuisance conditions (TCEQ, 2015a). The values are derived from ODTs; if an ODT is not available, the ORT may be used. Odour-based values are not developed for chemicals that are likely to cause adverse health effects before its odour is detected; in these cases, the Air Monitoring Comparison Values and Effects Screening Levels would be based on health or vegetation effects.

3.5 Odour Complaints – Nuisance vs. Emergency

Many jurisdictions have established defined protocols to address odour nuisance complaints in non-emergency scenarios (for a review, see Rudolph, 2015, Ch. 3). The information collected often focuses on the FIDOL factors, that is, the frequency, intensity, duration, offensiveness, and location of the odour (CASA, 2015). Protocols for responding to a nuisance complaint typically include investigating and verifying the complaint (during regular working hours), determining if an odour is a nuisance, confirming the presence of adverse effects (if any), and identifying potential measures for mitigation (Rudolph, 2015).

For odour complaints related to a possible emergency situation, a more urgent response may be required. CASA has published a guidance document that advises organizations on how to develop processes for handling odour complaints (CASA, 2015). CASA recommends the use of a matrix or flowchart for triaging odour complaints and guiding appropriate response. An example is outlined in Table 1.

Table 1. Sample matrix for triaging odour complaints

Level 1 event	May be investigated through normal workplace activity.
Level 2 event	Requires additional resources or quicker action.
Level 3 event	Requires immediate action.

(CASA, 2015)

Factors involved in the decision to move from one level to the next may include (CASA, 2015):

- Multiple calls about the same odour;
- Reports of health concerns;
- Unusual odour not linked to normal activity;
- Odours that may signal a serious or dangerous situation;
- Environmental concerns;
- Time the odour was noticed; and
- Access to the alleged source.

3.6 Odour Measurement in Alberta

The purpose of odour (and odorant) monitoring in Alberta is to:

- Ensure adherence to air quality objectives (ammonia, carbon disulphide, and H_2S have air quality guidelines based on odour);
- Ensure compliance with industrial approvals;
- Verify and investigate odour complaints (identify source); and
- Characterize air quality during odour events (*i.e.*, identify what may be causing odour).

3.6.1 Individual Odorants in Ambient Air

Routine monitoring of individual odorants in Alberta consists of continuous (*e.g.*, hourly), intermittent (*e.g.*, 24-hour average every sixth day), and passive (*e.g.*, monthly) networks (Government of Alberta, 2009, 2016a, 2016b, 2017a; Dann, 2016). Examples of odorants (or groups of odorants) monitored continuously include NO_2, nitric oxide (NO), nitrogen oxides (NO_X), ozone, ammonia, SO_2, H_2S, TRS, total hydrocarbons (THC), non-methane hydrocarbons (NMHC), and certain VOCs (ethylene; BTEX and styrene). A summary of continuous monitoring methods, including operating ranges and detection limits, is provided in Table 2.

Continuous monitoring provides (nearly) instantaneous on-site measurements of pollutant concentrations, but has high capital and operating costs (Government of Alberta, 2016a). For intermittent monitoring, pollutants are collected using canisters, reactive tubes, absorbents, or filters and analyzed later at a laboratory; for this reason, data may not be available for several months after sample collection. Examples of odorants monitored intermittently include VOCs and sulphur compounds (Government of Alberta, 2017a).

Table 2. Continuous ambient air monitoring in Alberta – methods and operating limits

Chemical	Monitoring Method	Operating Range	Detection Limit
Ammonia	Chemiluminescence	5 ppm	1 ppb
Hydrocarbons (total hydrocarbons, methane, non-methane hydrocarbons)	FID, GC/FID, or oxidizer/FID	10, 20, or 50 ppm	60 ppb
Hydrogen Sulphide and **Total Reduced Sulphur**	Ultraviolet pulsed fluorescence	0.1 ppm (0.5 or 1.0 ppm for emergency monitoring)	1.0 ppb
Nitrogen Oxides	Chemiluminescence	0.5 or 1 ppm	0.5 ppb
Ozone	Ultraviolet photometry	0.5 or 1 ppm	1 ppb
Sulphur Dioxide	Ultraviolet pulsed fluorescence	0.5 or 1 ppm	2.0 ppb
Volatile Organic Compounds			
BTEX and Styrene	GC or GC/FID	1 ppm	2.0 ppb
Ethylene	GC (various detectors)	1 or 10 ppm	10 ppb

Sources: AER and Alberta Health, 2016; Dann, 2016; Government of Alberta, 2016a, 2017a.

Abbreviations: BTEX: benzene, toluene, ethylbenzene, and xylenes; GC: gas chromatography; FID: flame ionization detection.

To evaluate air quality, monitoring data are compared against AAAQOs, which are based on adverse human and ecological health effects or odour (Government of Alberta, 2019a). Ammonia, carbon disulphide, and H_2S have AAAQOs based on odour. Monitoring data are also compared against CAAQS, where parameters exists, however they are on an annual basis and do not include any odours..

Air quality monitoring is conducted by various organizations including regional airsheds, Alberta Environment, ECCC, industry, and municipalities. Airsheds are not-for-profit, multi-stakeholder organizations that are responsible for monitoring and reporting on air quality in their region, and are involved in developing management plans to address air quality concerns (Government of Alberta, 2016c). There are currently ten airsheds in Alberta: WBEA, West Central Airshed Society, Parkland Airshed Management Zone, Peace Airshed Zone Association, Peace River Air Monitoring Program, Lakeland Industry and Community Association, Fort Air Partnership, Calgary Region Airshed Zone, Palliser Airshed Society, and Alberta Capital Airshed (Alberta Airsheds Council, 2017). Collectively, the airsheds operate more than 70 air monitoring stations across Alberta.

Mobile air monitoring of odorants may be conducted in areas where permanent air monitoring stations are not located. A mobile air monitoring unit (AMU), also known as a mobile air monitoring laboratory (MAML), may be deployed for emergency air monitoring, industrial fenceline monitoring, or in response to public complaints about air quality (Government of Alberta, 2017a). For example, in the case of an industrial incident involving H_2S or SO_2, AER may deploy mobile AMUs to monitor pollutant levels and track emission plumes. The information is used to assess health risk (by comparing concentrations against health-based values) and determine emergency status, establish if shelter-in-place or evacuation concentration criteria have been met, and determine roadblock locations (AER, 2017a). Other odorous substances that can be measured by mobile air monitoring include ammonia, hydrocarbons, NO_X, SO_2, and TRS (Government of Alberta, 2013b).

Individual odorants may also be analyzed in canister samples of whole air (Millennium EMS Solutions Ltd. and Environmental Odour Consulting, 2015). For example, canister sampling is used for analysis of VOCs in areas near odour sources or in response to odour complaints. Depending on the monitoring objectives, the sampling period can be short-term (*e.g.*, 1-minute grab sample) or longer-term (*e.g.*, 24-hours or calendar month) (Government of Alberta, 2017a). In Fort McKay, 10-minute canister samples have been collected during odour events and analyzed for a broad range of VOCs and reduced sulphur compounds (Dennis *et al.*, 2015; AER and Alberta Health, 2016). Using these data, along with wind conditions and regional air monitoring data, possible emission sources and emission types may be identified.

3.6.2 Individual Odorants in Source Emissions

No information was found regarding source emission data for odorants and emergency response.

Individual odorants with AAAQOs (though the objective may not be odour based) may be evaluated using source emission data and dispersion modelling. Approvals under the *Environmental Protection and Enhancement Act* limit the release of emissions and specify monitoring requirements (AER and Alberta Health, 2016). Limits may be set for individual stacks and/or entire sites. Averaging periods (*e.g.*, hourly, daily, 90-day rolling, or 365-day rolling) vary depending on the facility. Source emission regulations focus on SO_2 and NO_X, and monitoring of other odorants is limited.

Dispersion modelling can estimate ambient ground-level concentrations of chemicals using emissions data, topography information, and atmospheric conditions. Accepted models and modelling parameters are defined in Alberta's Air Quality Model Guideline (AQMG; Government of Alberta, 2013a). The AQMG ensures consistency in the use of air quality models by providing uniform benchmarks, a structured approach to selection and application of models, and a scientific basis for using alternatives where appropriate. The modelling data are used to verify that source emissions are compliant with AAAQOs. The AQMG does not specifically address odourants outside those with AAAQOs.

Canada's National Pollutant Release Inventory (NPRI) tracks annual emissions data for over 300 substances, including various VOC and TRS compounds (AER and Alberta Health, 2016; Government of Canada, 2018b, 2019). Operators that meet certain reporting requirements (*e.g.*, emissions thresholds) are required to submit a report to the NPRI by June of each year. The NPRI allows Canadians to be informed about pollutant releases in their communities; the data can be used to identify environmental priorities, encourage facilities to reduce pollution, and track progress over time (Government of Canada, 2019).

3.6.3 Odorous Mixtures

There are various methods that can be used to determine the concentration or intensity of whole odorous mixtures, including inspector observations, olfactometry, electronic noses (E-noses), community odour surveys, and odour event diaries (CASA, 2015). These methods may be applied in areas located near industrial source sites or in response to odour complaints.

3.6.3.1 *Inspector Observations*

Following an odour complaint, an inspector may visit a site to investigate the issue, reviewing factors such as odour strength, odour frequency, visible emissions, weather and wind conditions, and compliance history of the operator. The AER's *Hydrocarbon Odour Management Protocol for*

Upstream Oil and Gas Point Source Venting and Fugitive Emissions provides a standardized process to guide inspectors through investigations of hydrocarbon odours (AER, 2014a). The protocol is intended for upstream oil and gas single or multipoint source venting and fugitive emissions, but the process could be applied to other types of odours.

3.6.3.2 *Olfactometry*

Olfactometry refers to the measurement of odour concentration using an olfactometer to deliver dilutions of an odorous sample. Olfactometry may be lab-based or field-based. Lab-based methods utilize six to 12 trained odour panelists that are representative of the general population (CASA, 2015; Millennium EMS Solutions Ltd. and Environmental Odour Consulting, 2015). Panelists are presented with various dilutions of the odour sample as well as odourless air samples, and asked to identify the odour sample. The process begins with sub-threshold odour levels and is repeated using successively higher odour concentrations (Government of Alberta, 2017b). The odour concentration is determined as the dilution level at which 50% of the panel cannot distinguish the odour from odourless air, and is expressed as OU or OU per volume (OU/m^3). Many consider olfactometry to be the best available technology for objectively measuring odours (Millennium EMS Solutions Ltd. and Environmental Odour Consulting, 2015); however, sending odour samples to a laboratory for panel analysis can be costly, with prices in the range of $100–180 or more for a single sample (Government of Saskatchewan, 2011). The cost of express or overnight shipping must also considered, as samples have to be analyzed within 30 hours to avoid sample degradation.

In Alberta, lab-based olfactometry has been used, for example, in the analysis of ambient air samples collected in Fort McKay (Dann, 2016). Lab-based olfactometry can also be used to determine the odour concentration of a sample collected at an emission source. The derived odour concentration can then be entered into a dispersion model to predict odour levels at varying distances from the source (CASA, 2015).

For field-based methods, a portable olfactometer, such as Nasal Ranger or Scentroid, is used to determine the odour concentration in ambient air (CASA, 2015). A portable olfactometer is a dilution device to be used by one observer at a time. The diluted sample is presented to the observer using a face mask, and the observer indicates whether an odour can be detected at each dilution. Similar to lab-based olfactometry, odour concentration is determined as the number of dilutions required to make the odour just undetectable. Field-based olfactometry is primarily a screening tool as it is less accurate than lab-based olfactometry (Rudolph, 2015). Portable olfactometers would be applicable for odour measurements during potential emergency scenarios, as odour level is determined on site in real-time.

3.6.3.3 *E-noses*

An E-nose is an analytical method used to objectively analyze and quantify odours. Using an array of chemical sensors and a data processing unit, E-noses detect odours in a manner that mimics the human nose (Government of Alberta, 2017b). In the presence of volatile compounds, the sensors respond to changes in temperature, mass, and resistance (Millennium EMS Solutions Ltd. and Environmental Odour Consulting, 2015). E-noses can be used to evaluate the strength and frequency of environmental odours, as well as identify odours and odorants based on their chemical fingerprint (*i.e.*, the response pattern of the sensor array).

In 2013, an E-nose pilot program was implemented to identify odour events in Fort McKay and quantify their frequency and magnitude (FMSD, 2014; Dennis *et al.*, 2015). Two E-nose stations were installed, both within 1 km of an air monitoring station (to allow for data comparisons). However, there was a lack of sensitivity observed with the E-noses (Dann, 2016), and the program has since been discontinued.

3.6.3.4 *Odour Event Diaries and Community Odour Surveys*

Odour event diaries and community odour surveys utilize members of an impacted community to monitor odours. Odour event diaries are logs of daily exposures to odour, and are suitable for evaluating short-term odour events and trends over time (CASA, 2015).

Community odour surveys utilize trained community observers to rate odours at defined locations using a standard intensity scale (CASA, 2015; Millennium EMS Solutions Ltd. and Environmental Odour Consulting, 2015). Surveys are suitable for odour monitoring when a community is impacted by multiple odour sources, odours are difficult to sample, or odours vary with meteorological conditions. The results can provide an indication of the long-term impact of odours in an area.

The WBEA has conducted several Community Odour Monitoring Programs to better understand the relationship between odour events and ambient air quality in the Regional Municipality of Wood Buffalo (Dann, 2016). The main objective is to involve the community in identifying and monitoring odours to determine the impact on residents. In past monitoring programs conducted in Fort McMurray and Anzac, volunteer participants provided specific information about odours (*e.g.*, odour type, intensity, and pleasantness) that they perceived during their daily activities by mail, website, or mobile app. In the current edition of the program, all residents in the Regional Municipality of Wood Buffalo have been asked to submit information about ambient odours using a mobile app (WBEA, 2018a). The collected information is compared to ambient air data to identify relationships or trends (WBEA, 2018b).

3.6.4 Odour Monitoring in Fort McKay

There are three WBEA monitoring stations in the Fort McKay area – two within the community (Bertha Ganter and Waskōw Ohci Pimâtisiwin) and one located just south of the community (Fort McKay South). Odorants monitored continuously at one or more stations include SO_2, H_2S, TRS, NO_2, NO, NO_X, ozone, THC, NMHC, and ammonia (WBEA, 2018e). Continuous monitoring data are available for 5-minute and 1-hour averaging periods (WBEA, 2018c). The WBEA utilizes a data monitoring utility called Watch-It to monitor continuous data in near real time for exceedances of air quality objectives (WBEA, 2018c). VOCs are monitored intermittently at two stations.

An additional monitoring station in Fort McKay (Oski-ôtin) is operated by ECCC (AER and Alberta Health, 2016; Government of Canada, 2018a). Odorants monitored continuously include SO_2, TRS, total sulphur, NO, NO_2, NO_X, ozone, and several VOCs (BTEX, n-hexane, n-heptane).

Air quality in Alberta is communicated to the public using the Air Quality Health Index (AQHI), which is calculated using ambient concentrations of NO_2, ozone, and $PM_{2.5}$. As the AQHI is based on only three pollutants, it does not incorporate other pollutants that may contribute to odours; this may cause the air quality in Fort McKay to be reported as good even though residents are experiencing odours (Dennis *et al.*, 2015). To take into account the contribution of odorous pollutants to air quality in the area, the Fort McKay Air Quality Index (FMAQI) was developed. The FMAQI is based on the three AQHI pollutants and three additional odour-causing pollutants – TRS, THC, and SO_2 (WBEA, 2018d). Residents of Fort McKay are advised to use the FMAQI as a general indicator of air quality; an hourly FMAQI that is much higher than the AQHI indicates that odours may be present in the area. It is important to note that neither the AQHI nor the FMAQI are appropriate tools for emergency scenarios, as the tools are not intended to assess health risk associated with emergency levels of pollutants.

The Government of Alberta (2019b) also utilizes special messaging for odour events in a community. Odour events occur when the AQHI is rated as Low or Moderate risk and a specified pollutant [H_2S (or TRS), SO_2] reaches a predetermined odour threshold. The OTs used for H_2S and SO_2 are 10 (the 1h AAAQO) and 100 ppb respectively. An example of a special message may be: *While you may detect an odour or change in visibility or clarity, enjoy your outdoor activities unless you experience symptoms*.

Other methods that have been used for odour monitoring in Fort McKay include canister sampling with follow-up analysis of chemicals of concern, E-noses, and community odour surveys (Dennis *et al.*, 2015; Dann, 2016; WBEA, 2018a).

3.6.5 Importance of Data Availability, Quality, and Reliability

Air quality monitoring data are collected by several government and nongovernment agencies, working groups, and industry. The large volume of data produced by these efforts require quality control and statistical evaluation as a consolidated dataset to gain a full understanding of air quality conditions in the province (AER and Alberta Health, 2016). Due in part to the variety of organizations collecting air quality data and the different purposes for which the data are collected, there is a lack of consistency in monitoring specific compounds, particularly sulphur-based compounds that may play a role in odour events.

Many odorants are measured as a group of compounds, and information may not be available for individual components. For example, continuous monitors measure TRS as a mixture, and information for individual odorants (*e.g.*, methyl mercaptan) is not available. Similarly, for THC, continuous monitors provide a combined THC value, and concentrations of individual components (*e.g.*, benzene) are not known.

The monitoring capabilities of the analytical instruments present another limitation. Typical operating ranges for continuous monitoring of ambient air may not be suitable for emergency levels of pollutants (*i.e.*, the upper limit of the operating range is lower than emergency threshold concentrations). For example, the operating range of continuous SO_2 analyzers is 0.5 or 1 ppm (Table 2), and the SO_2 emergency evacuation level is 5 ppm (15-minute average) (AER, 2017a). Similarly, for continuous H_2S analysis, the operating range of the instrument is 1 ppb to 0.1 ppm, and the voluntary evacuation level is 1–10 ppm (3-minute average). For monitoring of H_2S in an emergency, the operating range can be changed to 0.5 or 1 ppm.

4 Emergency Definitions and Response Criteria

4.1 Definitions of Emergency

In Alberta's *Emergency Management Act*, an "emergency" is defined as an "event that requires prompt co-ordination of action or special regulation of persons or property to protect the safety, health, or welfare of people or limit damage to property" (Government of Alberta, 2000). This differs from the term "disaster," which the *Emergency Management Act* defines as "an event that results in serious harm to the safety, health or welfare of people or in widespread damage to property or the environment."

Under Section 18 of the Act, the Lieutenant Governor may declare a state of emergency relating to all or any part of Alberta; a local authority may declare a state of local emergency applying to all or part of a municipality.

In Alberta, licensees and operators are required to develop and maintain emergency response plans (ERPs) (Government of Alberta, 2011b). For conventional energy facilities, requirements for ERPs are outlined in *Directive 071: Emergency Preparedness and Response Requirements for the Petroleum Industry* (discussed below in Section 4.2), which defines an "emergency" as a "present or imminent event outside the scope of normal operations that requires prompt coordination of resources to protect the health, safety, and welfare of people and to limit damage to property and the environment" (AER, 2017a). For oil sands operations, *Directive 071* does not apply; these types of operations, which fall under the authority of the *Oil Sands Conservation Act*, are required to have an ERP on file that is available upon request by the AER (AER and Alberta Health, 2016).

Alberta's *Petroleum Industry Incident Support Plan* defines an" incident" as "an unexpected occurrence or event that requires action by emergency personnel to prevent or minimize loss of life or damage to property or the environment" (Government of Alberta, 2011b). Following an incident, the level of risk to the public is determined using an incident classification system, which assigns a level of emergency ranging from 1 to 3 based on the consequence of the incident and the likelihood of escalation:

- A **Level-1 emergency** indicates there is no danger beyond the operator or licensee's property, with no threat to the public and minimal environmental impact.
- A **Level-2 emergency** indicates there is no immediate danger outside the operator or licensee's property but there is the potential for the emergency to extend beyond the property. There is moderate threat to the public and/or the environment, and outside and provincial agencies must be notified.
- A **Level-3 emergency** indicates there is a major uncontrolled hazard that presents a threat to public safety with significant and ongoing environmental impacts. Immediate multi-agency municipal and provincial government involvement is required.

No reference to odours was found in the emergency classifications.

4.2 AER Directive 071: Emergency Preparedness and Response Requirements for the Petroleum Industry

The AER's *Directive 071* outlines the emergency response requirements for Alberta's conventional energy facilities, including wells, pipelines, and conventional processing facilities (AER and Alberta Health, 2016; AER, 2017a). For oil sands operations, *Directive 071* is not a requirement, but may be used as a guidance document (AER and Alberta Health, 2016).

Directive 071 ensures that licensees and operators have appropriate ERPs in place for potentially hazardous incidents. An ERP is a comprehensive plan that outlines the criteria for assessing an emergency situation, procedures for mobilizing response personnel and agencies, and measures for communication and coordination among emergency responders and other personnel.

Directive 071 requires that ERPs indicate the area of the emergency planning zone (EPZ). An EPZ is defined as the geographical area surrounding a well, pipeline, or facility containing hazardous product that requires specific emergency response planning by the licensee (AER, 2017a).

Licensees and operators are responsible for ensuring they are fully prepared and capable of responding to any level of emergency. This includes all activities undertaken before an emergency, such as personnel training and preparation of an ERP, as well as activities that occur during an incident. The AER's Field Incident Response Support Team and the Alberta Emergency Management Agency support industry operators and municipal authorities in the response to emergency incidents. If an operator is inadequately prepared for or incapable of handling the incident, trained AER staff may assume control of the response (AER and Alberta Health, 2016).

Directive 071 outlines the air quality monitoring requirements for sour gas releases from manned and unmanned operations). Throughout the emergency, licensees must provide H_2S and SO_2 monitoring data to AEP, the AER, health authorities, and local authorities, as well as to the public on request. The H_2S and SO_2 evacuation requirements, are based on health risk, which are above the odour thresholds.

(AER, 2017a)

For both H_2S and SO_2, their odour thresholds are much lower than the levels established for emergency response. For H_2S, the notification level for voluntary evacuation is 1–10 ppm (3-minute average) and the ODT is 0.00041 ppm (Nagata, 2003). For SO_2, immediate evacuation is required at concentrations of 5 ppm (15-minute average), 1 ppm (3-hour average), or 0.3 ppm (24-hour average), and the ODT is 0.009 ppm (AER and Alberta Health, 2016).

4.3 Emergency Response Criteria

The following section discusses the various emergency response criteria used by different agencies to guide emergency response actions during a chemical release.

Emergency response criteria are developed based on the airborne concentration of a chemical that may result in adverse health effects in a sensitive population from a single exposure. These response criteria allow emergency planners and responders to anticipate the impact of a chemical emergency, and determine appropriate prevention and mitigation actions. The emergency response criteria reviewed in this section include protective action criteria (PACs), provisional advisory levels (PALs), Ontario's emergency screening values, and Intervention Values used in the Netherlands.

4.3.1 Protective Action Criteria (United States)

Protective Action Criteria (PACs) are emergency guidelines for accidental releases of a hazardous chemical in the air. PACs are intended to protect the general public, including susceptible individuals, from health effects associated with rare, one-time exposures to a chemical [Government of Alberta, 2017c; US Department of Energy (US DOE), n.d.]. PACs may be used prior to emergencies for hazard and consequence analyses (*i.e.*, to estimate the severity of potential accident scenarios), or during emergencies to identify potential threat zones and at-risk populations. The information can be used to guide decisions for protective actions, such as shelter in place or evacuation.

The PAC dataset comprises three types of emergency criteria maintained by different agencies:

- Acute Exposure Guideline Levels (AEGLs) – US EPA
- Emergency Response Planning Guidelines (EPRGs) – AIHA
- Temporary Emergency Exposure Limits (TEELs) – US DOE

AEGLs are the preferred emergency value, followed by ERPGs and TEELs. The PAC dataset clearly indicates whether the stated value is an AEGL, ERPG, or TEEL. The main difference between the guidelines is the method by which they are derived. AEGLs and ERPGs are developed following a rigorous review of primary source data. TEELs are based on existing exposure limits and are less reliable than AEGLs and ERPGs. TEELs are used as interim values until AEGLs or ERPGs become available.

The 2016 PAC dataset includes 3146 chemicals (US DOE, 2016); there are AEGL values for over 270 chemicals [final (188), interim (72), and proposed (12)] and ERPG values for over 140 chemicals (AIHA, 2016; US EPA, 2018a).

PACs are based on an exposure duration of 60 minutes and categorized into three health effect levels based on symptom severity:

- **PAC-1** (corresponding to AEGL-1, ERPG-1, or TEEL-1)
  - threshold level for mild, transient health effects.
- **PAC-2** (corresponding to AEGL-2, ERPG-2, or TEEL-2)
  - threshold level for irreversible or other serious health effects that could impair the ability to take protective action.
- **PAC-3** (corresponding to AEGL-3, ERPG-3, or TEEL-3)
  - threshold level for life-threatening health effects.

PAC values have been incorporated into various atmospheric dispersion modeling programs, such as the National Oceanic and Atmospheric Administration (NOAA) and US EPA's Areal Location of Hazardous Atmospheres (ALOHA) software (NOAA, 2019a). Taking into account factors such as chemical emission rate, meteorological conditions, and terrain, dispersion models can predict the movement of a chemical plume and estimate the concentration in the surrounding area. The results can then be used to identify areas where people may be impacted by a chemical release.

One limitation of PACs is that they are not directly applicable to releases of chemical mixtures, as PACs do not account for the potential additive, synergistic, and antagonistic effects that may result from exposure to the mixture (Government of Alberta, 2017c). To account for this, a chemical mixture methodology has been developed that estimates the additive health effects on target organs that may occur from an acute emergency exposure (Yu *et al.*, 2010).

For a more detailed discussion of PACs, readers are referred to the document "*Protective Action Criteria: A Review of Their Derivation, Use, Advantages and Limitations*" (Government of Alberta, 2017c).

The sections below provide a brief introduction to each guideline (AEGLs, ERPGs, and TEELs), including how odour information is incorporated into AEGLs and ERPGs.

4.3.1.1 *Acute Exposure Guideline Levels (AEGLs)*

The AEGL program provides guidance for emergency preparedness programs and emergency responders through the development of hazard level guidelines for releases of airborne chemicals (US EPA, 2019). The guidelines were developed by the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances (NAC/AEGL Committee), a group established by the US EPA. AEGLs are developed for the general public including susceptible populations (identified as infants, children, the elderly, persons with asthma, and those with other illnesses), and derived for five exposure durations (10 minutes, 30 minutes, 60 minutes, 4 hours, and 8 hours).

The three health effect tiers for AEGLs are:

- **AEGL-1**
  - the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- **AEGL-2**
  - the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- **AEGL-3**
  - the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

A sample AEGL table for H_2S is presented in Table 3.

Table 3. AEGLs for hydrogen sulphide

	10 min	**30 min**	**60 min**	**4 hour**	**8 hour**
ppm					
AEGL 1	0.75	0.60	0.51	0.36	0.33
AEGL 2	41	32	27	20	17
AEGL 3	76	59	50	37	31
* Level of distinct odour awareness = 0.01 ppm					

(US EPA, 2016)

Odour is not considered as an endpoint for any AEGLs; instead, odour information is included with the guidelines as a LOA value (shown in the bottom row of

Table). As stated in Section 3.1, the LOA is the concentration above which it is predicted that more than half of the exposed population will experience at least a distinct odour intensity, and about 10% of the population will experience a strong smell (National Research Council, 2013). The LOA allows chemical emergency responders to asses public awareness of the exposure based on odour perception.

LOA values are currently available for 23 substances in the AEGL dataset (US EPA, 2018a); these are listed in Table 4. LOAs are intended to be used in conjunction with the AEGL values. The LOA addresses the odour component of exposure, while the AEGLs are used to assess potential toxicity. For some substances, the LOA is higher than one or more of its AEGL values.

Table 4. LOAs listed in the AEGL dataset

Chemical (CAS number)	**LOA value**
Acetaldehyde (75-07-0)	0.56 ppm
Acetone (67-64-1)	160 ppm
1,3-Butadiene (106-99-0)	3.7 ppm
1,2-Butylene oxide (106-88-7)	0.15 ppm
Cumene (98-82-8)	0.017 ppm
Dimethylamine (124-40-3)	0.53 ppm
1,4-Dioxane (123-91-1)	1.7 ppm
Ethyl mercaptan (75-08-1)	0.00014 ppm
Ethylamine (75-04-7)	0.74 ppm
*** Ethylenimine** (151-56-4)	10.9 ppm
Hydrogen sulphide (7783-06-4)	0.01 ppm
Methanol (67-56-1)	8.9 ppm
Methyl amine (74-89-5)	0.56 ppm
Methyl mercaptan (74-93-1)	0.019 ppm
Methyl methacrylate (80-62-6)	0.11 ppm
*** Perchloromethyl mercaptan** (594-42-3)	0.016 ppm
Phenol (108-95-2)	0.25 ppm
*** Piperidine** (110-89-4)	5.8 ppm
Propionaldehyde (123-38-6)	0.64 ppm
Propylene oxide (75-56-9)	21 ppm
Styrene (100-42-5)	0.54 ppm
Trimethyl amine (75-50-3)	0.00051 ppm
Vinyl acetate (108-05-4)	0.25 ppm

***** Denotes a substance whose LOA value is higher than one or more of its AEGL values.

(US EPA, 2018a)

Derivation of the LOA involves three steps (RIVM, 2009; National Research Council, 2013):

(i) Obtain the ODT value.

(ii) Use the Weber-Fechner equation[3] to determine the odour concentration that leads to "distinct odour detection" (*i.e.*, $I = 3$ in the Weber-Fechner equation). Alternatively, the distinct odour level for an odorant can be directly determined in odour laboratories.

(iii) Apply field correction factors to account for various individual and environmental factors. The value used in the derivation of LOAs is 1.33 which accounts for:

- factors in everyday life, such as sex, age, sleep, smoking, state of health, and distractions, that may increase the ODT by a factor of 4; and
- a factor of 1/3 to adjust for perception of concentration peaks. This allows hourly average concentrations to reflect 5 second peak values.

The Weber-Fechner equation is a widely used and accepted formula, and the LOA derivation method has been used extensively by the US EPA and RIVM. However, no information was found that verified the field correction factor of 1.33 for LOAs.

In 2002, the NAC/AEGL Committee (2002a, 2002b) reviewed how odour information should be incorporated into AEGLs. Over the course of several meetings, committee members discussed the use of odour as an AEGL-1 endpoint versus development of a separate odour-related value. The committee decided against the use of the LOA as a basis for AEGL-1 values; however, given that odour information is useful for emergency responders, LOA values would be provided as a separate value for all chemicals for which an ODT or acceptable estimate is available. The following recommendations were made by the committee:

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[3] $I = K_w \times \log (C \div OT_{50}) + 0.5$

where

I = odour intensity on a 7-point intensity scale ($I = 3$ for "distinct odour detection")

C = concentration of odorant

OT_{50} = odour detection threshold at which 50% of the population can smell the odorant

K_w = Weber-Fechner coefficient. If an experimentally derived K_w is not available for a specific odorant, a default value of 2.33 is used. [Experimental K_w values are only available for a limited number of chemicals; the range of experimental K_w values is small, and the value of 2.33 represents the median (RIVM, 2009).]

> All AEGLs should be health-based. Odour, even as defined by the LOA, will not serve as a surrogate for health-based values without health-based data. The level of distinct odour awareness will not substitute for health-based values. Include the LOA in the [Technical Support Document] as information supplementary to health-based AEGL values.
>
> (NAC/AEGL Committee, 2002b, p. 2)

4.3.1.2 *Emergency Response Planning Guidelines (EPRGs)*

ERPGs are developed by the AIHA to assist emergency response personnel in planning for accidental releases of airborne chemicals (AIHA Guideline Foundation Emergency Response Planning Committee, 2014; AIHA, 2018). ERPGs are based on an exposure duration of 60 minutes, and the three health effect tiers are defined as follows:

- **ERPG-1**
  - the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.
- **ERPG-2**
  - the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.
- **ERPG-3**
  - the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

With regard to ERPG-1 and odour, the AIHA (2018) noted that the property of objectionable odour is subjective, varies between individuals, and is not often published; if data on objectionable odour are not available, more conservative odour detection levels may be used instead, or odour detection levels may be used to estimate an objectionable level. From the information provided in the ERPG dataset (AIHA, 2018), it is not known which ERPG-1 values are based on objectionable odour; however, this information is provided in the technical support documents for each chemical, which are available for purchase (AIHA, 2020).

ERPGs utilize an odour detection indicator (✪) to signify that a chemical is likely to be detected by odour near its ERPG-1 value. For example, ERPG-1 values for dimethyl disulphide, methyl mercaptan, 2-ethyl hexanol, and isoprene include the odour detection indicator (see Table in

Section 5.1 below). The indicator is intended for “those emergency response agencies that incorporate into their planning the possibility that members of the public may call them when they detect an unusual chemical [odour]. This symbol indicates only that a chemical will likely be detected by [odour] near its ERPG-1 value” (AIHA, 2018, p. 17). The guidelines note that odour detection does not imply that a substance is toxic.

The AIHA Guideline Foundation Emergency Response Planning Committee (2014) stated that the ERPG-1 level represents the concentration that does not pose a health risk to the community but that may be noticeable due to slight odour or mild irritation. They further specified that for small non-threatening chemical releases, the community may be notified that they may notice odour or slight irritation but that concentrations are below those that could cause unacceptable health effects.

4.3.1.3 *Temporary Emergency Exposure Limits (TEELs)*

TEELs are emergency criteria developed by the US DOE Subcommittee on Consequence Assessment and Protective Actions. TEELs are based on an exposure duration of 60 minutes, and are intended for use until AEGLs or ERPGs are available (US DOE, 2008; US DOE, n.d.). The three health effect tiers are defined as:

- **TEEL-1**
  - the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- **TEEL-2**
  - the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting, adverse health effects or an impaired ability to escape.
- **TEEL-3**
  - the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

The US DOE TEEL handbook also discusses the use of a TEEL-0 value (US DOE, 2008). TEEL-0 refers to the threshold concentration below which most people will experience no appreciable risk of health effects.

TEEL values do not include any information on odour thresholds.

4.3.2 Provisional Advisory Levels (United States)

Developed by the US EPA's National Homeland Security Research Center, Provisional Advisory Levels (PALs) are health-based emergency guidance values for hazardous chemical exposures (inhalation or oral) of 24-hours, 30-days, 90-days, and 2 years (US EPA, 2018b). PALs complement other emergency response criteria, such as AEGLs, ERPGs, and TEELs, by addressing exposure routes and durations not otherwise covered. During chemical emergencies, PALs may be used to inform decisions regarding protective actions, such as shelter in place, evacuation, and re-entry into affected areas.

PALs are developed for three health effect tiers:

- **PAL-1**
  - represents the assumed, duration-specific continuous dosing level or exposure concentration of a chemical above which changes from a baseline of specific biomarkers or physiological responses could have adverse health effects in the general population. Concentrations at or below PAL-1 are not expected to be associated with adverse health effects. Increasingly greater concentrations above the PAL-1 value could cause progressively harmful effects in the general population, including all age groups and sensitive subpopulations. Critical effects selected for PAL-1 derivation may include, for example, changes in enzyme activity, methemoglobin formation, altered pulmonary function, lacrimation, nasal irritation, or odour/taste detection.
- **PAL-2**
  - represents the assumed, duration-specific continuous dosing level or exposure concentration of a chemical above which serious, possibly irreversible, or escape-impairing effects could result. Increasingly greater concentrations above the PAL-2 value could cause progressively harmful effects in the general population, including all age groups and sensitive subpopulations.
- **PAL-3**
  - represents the assumed, duration-specific continuous dosing level or exposure concentration of a chemical above which lethality in the general population, including all age groups and sensitive subpopulations, could occur.

PALs have been developed for more than 30 chemicals, including odorous substances such as acrolein, ammonia, carbon disulphide, and H_2S (US EPA, 2017a). PALs do not include any information on odour thresholds; however, some PAL-1 values may be based on odour detection.

4.3.3 Emergency Screening Values (Ontario)

The MOECC developed emergency screening values to evaluate health risk associated with short-term chemical exposures. During a chemical emergency, the values are used to inform decisions regarding shelters in place, evacuations, and re-entry (Plain, 2016). No further information was found regarding emergency screening values.

4.3.4 Intervention Values (Netherlands)

For chemical emergencies in the Netherlands, the RIVM has developed Intervention Values for more than 300 substances (Health Council of the Netherlands, 2007; RIVM, 2018). Intervention Values, which are similar to AEGLs, are developed for six exposure durations (10 minutes, 30 minutes, 60 minutes, 2 hours, 4 hours, and 8 hours). The three health effect tiers are:

- **Intervention Value-1: Notification guideline**
  - the level at which people will be inconvenienced for a temporary period and may experience headache or nausea.
- **Intervention Value-2: Warning threshold**
  - the level at which people may develop serious and irreversible health damage.
- **Intervention Value-3: Life-threatening**
  - the level that may cause death.

In the past, odour was used as a basis for derivation of the Notification guideline (Health Council of the Netherlands, 2007); however, odour is no longer used in this manner. Intervention Values are to be based on health impacts only, and the perception of odour is not considered a toxicological endpoint (RIVM, 2018). To reflect this change, Intervention Values for 211 substances have been revised in recent years (RIVM, 2018).

Odour information is now included with the guidelines as a separate LOA value (as is done with US EPA's AEGLs). The LOA is used to indicate the level at which a community may become aware of the presence of a chemical due to its odour, and communicative emergency response activities may be required, even in the absence of toxicological health risk (RIVM, 2007). LOA values are currently available for 89 substances (RIVM, 2018).

LOAs are derived using the same method the US EPA (RIVM, 2009), outlined above in Section 4.3.1.1. RIVM calculates and displays the LOA in units of mg/m^3, while the US EPA utilizes units of ppm (RIVM, 2018; US EPA, 2018a). There is the potential that each agency may select a different ODT value and/or Weber-Fechner coefficient for the calculation; however, the two agencies tend to rely on the same values. Any differences in LOA values are typically due to rounding.

LOAs have generally only been discussed in reference to single chemicals (RIVM, 2009). No guidance was provided on applying the LOA concept to odour mixtures. No further information was found regarding use of LOAs during emergencies scenarios in the Netherlands.

5 Use of Odour Information in Emergency Response Management

5.1 Comparison of Odour Values and Emergency Response Criteria

Table lists odour values (ODTs, LOAs) and emergency response criteria (PACs, Intervention Values) for common odorants in Fort McKay.[4] For comparison purposes, AAAQOs (if available) and analytical detection limits are also included. For each PAC or Intervention Value listed in the table, health effects that may be observed above each health tier are identified, with the basis of each guideline indicated in bold text. The guidelines are primarily derived from no observed adverse effect levels (NOAELs) observed in human or animal studies. If specific information was not available for a particular substance, general descriptions were provided [*i.e.*, mild, transient health effects (tier 1); serious health effects (tier 2); or life-threatening health effects (tier 3)].

For all chemicals listed, the FMSD ODTs (as provided in the 2016 Technical Synthesis Report) are lower than the LOA values; this is expected as the LOA represents the concentration associated with "significant odour awareness," which is based on an odour intensity of 3 (*i.e.*, distinct odour intensity) rather than odour detection (see Section 4.3.1.1 for the LOA calculation). AAAQOs based on odour (ammonia, carbon disulphide, and H_2S) also tend to be lower than LOA values for the same reason. LOA values are intended to be used in conjunction with their corresponding AEGLs or Intervention Values. The LOA addresses the odour component of exposure, while the AEGLs and Intervention Values are used to assess potential toxicity. For

[4] The list of common odorants was derived from the 2016 Technical Synthesis Report Air Quality Focal Parameter List (chemicals with average and upper bound concentration estimates in ambient air above odour and health-based thresholds) and Odorant Focal Parameter List (odorants frequently above odour thresholds during odour events) (AER and Alberta Health, 2016, p. 113-114). Ammonia was also included, as odours in Fort McKay are often described as ammonia-like (AER and Alberta Health, 2016, p. 119).

some substances, such as NO_2, the LOA is higher than its AEGL-1 or Intervention Value-1; this indicates that direct health impacts are likely to occur before distinct odour awareness.

Table 5. Comparison of analytical detection limits, ODTs, LOAs, AAAQOs, PACs, Intervention Values, and health effects for common odorants in Fort McKay

Chemical (CAS number)	**Detection limit**	**ODTs used by FMSD**	**LOA**	**AAAQO (1-hour)**	**PAC* or IV**	**10-min**	**1-hour**	**Health effects that may be observed <u>above</u> each level** (with basis of each guideline indicated in **BOLD**)
	ppm							
Reduced sulphur compounds								
Carbon disulphide (75-15-0)	~0.001 [b]	0.008	3.2 [e]	0.01 [f]	AEGL-1	17	13	• **Alcohol intolerance**, headache.
					AEGL-2	200	160	• **Neurobehavioral effects (animal)**, eye/throat irritation, nervous system effects.
					AEGL-3	600	480	• Psychosis, paralysis, **mortality (animal)**.
					IV-1	24	13	• **Elevated blood acetaldehyde levels**, nausea, headache, eye/airway irritation, lacrimation, chest pain.
					IV-2	288	158	• **Central nervous system effects (animal)**, confusion, tremors, convulsions, loss of consciousness.
					IV-3	853	474	• **Mortality (animal)**, coma.
Carbonyl sulphide (463-58-1)	~0.001 [b]	0.055	-	-	TEEL-1	-	15	• Mild, transient health effects.
					AEGL-2	69	55	• **Clinical signs and brain lesions (animal)**.
					AEGL-3	190	150	• **Mortality (animal)**.
					IV-1	NR [g]	NR [g]	• (Below IV-2 level: eye/nose/throat irritation, nausea).
					IV-2	100	56	• **Clinical signs and brain lesions (animal)**, palpitations, shortness of breath, loss of consciousness.
					IV-3	276	152	• **Mortality (animal)**.
Dimethyl disulphide (624-92-0)	~0.001 [b]	0.0002	0.0004 [e]	-	ERPG-1	-	0.01✪	• Mild, transient health effects.
					ERPG-2	-	50	• **Clinical effects such as lethargy (animal)**.
					ERPG-3	-	250	• **Mortality (animal)**.
					IV-1	NR [g]	NR [g]	• (Below IV-2 level: eye irritation, dizziness, headache).
					IV-2	82	46	• **Tremors (animal)**, irregular breathing, drowsiness, loss of consciousness.
					IV-3	202	110	• **Mortality (animal)**.

Chemical (CAS number)	Detection limit	ODTs used by FMSD	LOA	AAAQO (1-hour)	PAC* or IV	10-min	1-hour	Health effects that may be observed above each level (with basis of each guideline indicated in **BOLD**)
	ppm							
Hydrogen sulphide (7783-06-4)	0.001 [a] ~0.001 [b]	0.00041	0.01 [d e]	0.01 [f]	AEGL-1	0.75	0.51	• **Headache**.
					AEGL-2	41	27	• **Lung edema (animal)**.
					AEGL-3	76	50	• **Mortality (animal)**.
					IV-1	2.6	1.7	• **Headache**, eye/airway irritation, lacrimation.
					IV-2	41	27	• **Lung edema (animal)**, chest tightness, nausea, corneal damage, hyperventilation, loss of consciousness.
					IV-3	78	51	• **Mortality (animal)**.
Methyl mercaptan (74-93-1)	~0.001 [b]	0.00007	0.0019 [d e]	-	ERPG-1	-	0.005	• Mild, transient health effects.
					AEGL-2	40	23	• **Shallow breathing and hypoactivity (animal) –** calculated as one-third of the AEGL-3 value.
					AEGL-3	120	68	• **Mortality (animal)**.
					IV-1	2.6	1.7	• **Headache**, eye/airway irritation, lacrimation.
					IV-2	42	23	• **Shallow breathing and hypoactivity (animal)**, lung edema, chest tightness, nausea, corneal damage, hyperventilation.
					IV-3	125	70	• **Mortality (animal)**, respiratory arrest, convulsions, collapse.
2-Methyl thiophene (554-14-3)	~0.001 [b]	0.00056	-	-	-	-	-	• May cause respiratory irritation; limited data available.
3-Methyl thiophene (616-44-4)	~0.001 [b]	0.00056	-	-	-	-	-	• May cause respiratory irritation; limited data available.
Volatile organic compounds								
Acrolein (107-02-8)	≤0.0005 [b]	0.0036	-	0.0019	AEGL-1	0.030	0.030	• **Eye irritation**.
					AEGL-2	0.44	0.10	• **Severe eye/airway irritation**.
					AEGL-3	6.2	1.4	• **Mortality (animal)**.
					IV-1	0.030	0.030	• **Eye irritation**, lacrimation.
					IV-2	0.42	0.10	• **Severe eye/airway irritation**, chest tightness, lung edema.
					IV-3	6.4	1.4	• **Mortality (animal)**.

Chemical (CAS number)	Detection limit	ODTs used by FMSD	LOA	AAAQO (1-hour)	PAC* or IV	10-min	1-hour	Health effects that may be observed above each level (with basis of each guideline indicated in **BOLD**)
	ppm							
Acetaldehyde (75-07-0)	≤0.0005 [b]	0.0008	0.56 [d] 0.54 [e]	0.05	AEGL-1	45	45	• **Mild eye irritation/respiratory irritation**.
					AEGL-2	340	270	• **Damage to nasal epithelium (animal)**.
					AEGL-3	1100	840	• **Mortality (animal)**.
					IV-1	45	45	• **Mild eye irritation/respiratory irritation**, cough.
					IV-2	495	272	• **Damage to nasal epithelium (animal)**, respiratory irritation, chest tightness, lung edema.
					IV-3	1522	816	• **Mortality (animal)**.
Benzaldehyde (100-52-7)	≤0.0005 [b]	0.005	-	-	TEEL-1	-	4	• **Eye/respiratory irritation**.
					TEEL-2	-	9.9	• Serious health effects (one-sixth of the TEEL-3).
					TEEL-3	-	59	• **Mortality (animal)**.
Benzene (71-43-2)	0.002 [a] ≤0.0005 [b]	2.7	7.5 [d] 7.4 [e]	0.009	AEGL-1	130	52	• **Mild central nervous system effects**, irritation of the skin/eyes/nose/throat.
					AEGL-2	2000	800	• **Central nervous system effects (animal)**, hematotoxicity.
					AEGL-3	9700	4000	• **Mortality (animal)**.
					IV-1	126	52	• **Central nervous system effects**, headache, nausea, irritation of skin/eyes/nose/throat.
					IV-2	1971	801	• **Central nervous system effects (animal)**, chest tightness, severe respiratory irritation, confusion, lung edema.
					IV-3	9856	4004	• **Mortality (animal)**, convulsions, coma, respiratory arrest.
2-Ethyl hexanal (123-05-7)	≤0.0005 [b]	0.00028	-	-	-	-	-	• May cause mucous membrane irritation. High concentrations may cause dizziness and collapse.
2-Ethyl hexanol (104-76-7)	≤0.0005 [b]	0.14	-	0.11	ERPG-1	-	0.1	• Mild, transient health effects.
					ERPG-2	-	100	• Serious health effects.
					ERPG-3	-	200	• Life-threatening health effects.

Chemical (CAS number)	Detection limit	ODTs used by FMSD	LOA	AAAQO (1-hour)	PAC* or IV	10-min	1-hour	Health effects that may be observed above each level (with basis of each guideline indicated in **BOLD**)
	ppm							
***p*-Ethyl toluene** (622-96-8)	≤0.0005 [b]	0.0083	-	-	TEEL-1	-	3.05	• Mild, transient health effects (one-eleventh of the TEEL-2).
					TEEL-2	-	33	• Serious health effects (one-sixth of the TEEL-3).
					TEEL-3	-	195	• **Mortality (animal)**.
Isoprene (78-79-5)	≤0.0005 [b]	0.005	0.76 [e]	-	ERPG-1	-	5✪	• Mild, transient health effects.
					ERPG-2	-	1000	• Serious health effects.
					ERPG-3	-	4000	• Life-threatening health effects.
					IV-1	19	19	• **Upper respiratory irritation**, skin/eye irritation, cough.
					IV-2	1980	1095	• **Slight lung congestion (animal)**, drowsiness, loss of consciousness.
					IV-3	3880	2085	• **Mortality (animal)**, coma.
Methanol (67-56-1)	≤0.0005 [b]	4.26	8.9 [d] 9.0 [e]	2	AEGL-1	670	530	• **Headache/dizziness/blurred vision**, local irritation.
					AEGL-2	11000	2100	• **Developmental toxicity (animal)**.
					AEGL-3	40000	7200	• **Methanol intoxication**.
					IV-1	976	533	• **Headache/dizziness/blurred vision**, eye irritation, nausea.
					IV-2	39800	7210	• **Serious methanol intoxication**, severe respiratory and eye irritation, blurred vision, drowsiness, confusion.
					IV-3	60080	11265	• **Lethal methanol intoxication**, loss of consciousness, metabolic acidosis, seizures.
Methyl ethyl ketone (78-93-3)	≤0.0005 [b]	0.008	122 [e]	-	AEGL-1	200	200	• **Sensory irritation, neurobehavioral deficits**.
					AEGL-2	4900	2700	• **Neurobehavioral effects (animal)**.
					AEGL-3	10000	4000	• **Mortality (animal)**.
					IV-1	200	NR [h]	• **Sensory irritation, neurobehavioral deficits,** cough.
					IV-2	333	190	• **Developmental effects (animal)**, severe respiratory and eye irritation, nausea, dizziness, loss of consciousness.
					IV-3	5995	3065	• **Mortality (animal)**.

Chemical (CAS number)	**Detection limit**	**ODTs used by FMSD**	**LOA**	**AAAQO (1-hour)**	**PAC* or IV**	**10-min**	**1-hour**	**Health effects that may be observed <u>above</u> each level** (with basis of each guideline indicated in **BOLD**)
	ppm							
Naphthalene (91-20-3)	≤0.0005 [b]	0.038	-	-	TEEL-1	-	15	• Mild, transient health effects.
					TEEL-2	-	83	• Serious health effects (one-sixth of the TEEL-3).
					TEEL-3	-	500	• **Mortality (animal)**.
Nonanal (124-19-6)	≤0.0005 [b]	0.00034	-	-	TEEL-1	-	0.15	• Mild, transient health effects (one-eleventh of the TEEL-2).
					TEEL-2	-	1.63	• **Dermal toxicity (animal)**.
					TEEL-3	-	70	• **Mortality (animal)**.
***n*-Propyl benzene** (103-65-1)	≤0.0005 [b]	0.0038	-	-	TEEL-1	-	3.7	• Mild, transient health effects (one-eleventh of the TEEL-2).
					TEEL-2	-	41	• **Lowest toxic dose observed (animal)**.
					TEEL-3	-	240	• **Mortality (animal)**.
Toluene (108-88-3)	0.002 [a] ≤0.0005 [b]	0.170	2.5 [e]	0.499	AEGL-1	67	67	• **Notable discomfort**, irritation, neurotoxicity, headache.
					AEGL-2	1400	560	• **Slowed reaction time (animal)**, central nervous system depression, confusion, nausea, loss of coordination.
					AEGL-3	10000	3700	• **Mortality (animal),** respiratory failure.
					IV-1	68	68	• **Irritation and neurotoxicity**, agitation, headache, fatigue.
					IV-2	1410	548	• **Slowed reaction time (animal)**, dizziness, confusion, nausea, loss of coordination.
					IV-3	9920	3655	• **Mortality (animal),** loss of consciousness, respiratory depression.
Xylenes (*m*-, *o*- and *p*- isomers) (1330-20-7)	0.002 [a] ≤0.0005 [b]	0.050 [c]	0.6 [e]	0.53	AEGL-1	130	130	• **Eye irritation**, throat irritation, dizziness.
					AEGL-2	2500	920	• **Poor coordination (animal)**.
					AEGL-3	7200	2500	• **Mortality (animal)**, central nervous system depression.
					IV-1	133	133	• **Eye irritation**, skin/nose/throat irritation, headache, nausea.
					IV-2	2485	881	• **Poor coordination (animal)**, severe respiratory irritation, chest tightness, abdominal pain, loss of consciousness.
					IV-3	7230	2485	• **Mortality (animal)**, convulsions, coma, respiratory arrest.

Chemical (CAS number)	Detection limit	ODTs used by FMSD	LOA	AAAQO (1-hour)	PAC* or IV	10-min	1-hour	Health effects that may be observed above each level (with basis of each guideline indicated in **BOLD**)
	ppm							
Other chemicals								
Ammonia (7664-41-7)	0.001 [a]	-	2.4 [e]	2.0 [f]	AEGL-1	30	30	• **Nasal/eye irritation**.
					AEGL-2	220	160	• **Severe eye/nose/throat irritation**, lung and glottis edema.
					AEGL-3	2700	1100	• **Mortality (animal)**.
					IV-1	30	30	• **Nasal/eye irritation**, cough, hyperventilation.
					IV-2	282	197	• **Severe eye/nose/throat irritation**, lung and glottis edema.
					IV-3	2680	1100	• **Mortality (animal)**.
Nitrogen dioxide (10102-44-0)	0.0005 [a]	0.120	1.9 [e]	0.159	AEGL-1	0.50	0.50	• **Mild symptoms of discomfort in exercising asthmatics**.
					AEGL-2	20	12	• **Marked discomfort and irritation**, respiratory symptoms.
					AEGL-3	34	20	• **Severe respiratory irritation and lung histopathology (animal)**, mortality.
					IV-1	0.50	0.50	• **Mild symptoms of discomfort in exercising asthmatics**, irritation of eyes/airways, cough, headache, nausea.
					IV-2	23	13	• **Respiratory symptoms**, severe eye/respiratory irritation, chest tightness, lung edema.
					IV-3	115	63	• **Severe respiratory irritation and lung histopathology (animal)**, mortality.
Ozone (10028-15-6)	0.001 [a]	0.0032	-	0.076	TEEL-1	-	0.24	• **Lung function, irritation**.
					TEEL-2	-	1	• **Ventilatory changes**.
					TEEL-3	-	10	• **Lung edema**.
					IV-1	-	0.09	• Mild, transient health effects.
					IV-2	-	0.23	• Serious health effects.
					IV-3	-	2.3	• Life-threatening health effects.
α-Pinene (80-56-8)	≤0.0005 [b]	0.010	-	-	TEEL-1	-	60	• **Respiratory irritation**.
					TEEL-2	-	120	• **Lowest toxic concentration (animal)**.
					TEEL-3	-	1500	• Life-threatening health effects.

Chemical (CAS number)	Detection limit	ODTs used by FMSD	LOA	AAAQO (1-hour)	PAC* or IV	10-min	1-hour	Health effects that may be observed <u>above</u> each level (with basis of each guideline indicated in **BOLD**)
	ppm							
Sulphur dioxide (7446-09-5)	0.002 [a] ≤0.0005 [b]	0.009	13.5 [e]	0.172	AEGL-1	0.20	0.20	• **Bronchoconstriction in exercising asthmatics**, irritation of eyes/nose/throat.
					AEGL-2	0.75	0.75	• **Bronchoconstriction in exercising asthmatics**.
					AEGL-3	30	30	• **Mortality (animal)**.
					IV-1	0.75	0.75	• **Bronchoconstriction in exercising asthmatics**, irritation of eyes/nose/throat.
					IV-2	7.5	7.5	• **Bronchoconstriction in exercising asthmatics** (10 times the IV-1 value), lung and glottis edema.
					IV-3	165	90	• **Mortality (animal)**, glottis edema, respiratory arrest.

Sources: AER and Alberta Health, 2016; AIHA, 2016; Government of Alberta, 2017a, 2019a; RIVM, 2018, 2019; US DOE, 2018; US EPA, 2019.

Abbreviations: AAAQO: Alberta Ambient Air Quality Objectives; FMSD: Fort McKay Sustainability Department; IV: Intervention Value (Netherlands); LOA: Level of distinct odour awareness; NR: Not recommended; ODT: Odour detection threshold; PAC: Protective Action Criteria.

* The PAC dataset uses the following hierarchy when selecting values for PACs: 1. AEGLs; 2. ERPGs; 3. TEELs.

✪ ERPG odour indicator. This symbol indicates that odour should be detectable near the ERPG-1 value (AIHA, 2016).

[a] Method detection limit for continuous ambient air analysis (Government of Alberta, 2017a).

[b] Method detection limit for chemical analysis of canister samples (AER and Alberta Health, 2016).

[c] Xylenes (*m*- and *p*- isomers).

[d] LOA reported with AEGLs (US EPA, 2019).

[e] LOA reported with Intervention Values (RIVM, 2018, 2019).

[f] AAAQOs for ammonia, carbon disulphide, and hydrogen sulphide are based on odour. For all other substances with AAAQOs, values are health-based.

[g] Not recommended due to insufficient human or animal data (RIVM, 2019).

[h] IV-1 value is not recommended for the 1-hour duration for methyl ethyl ketone. A concentration of 200 ppm was considered an appropriate NOAEL for sensory irritation and central nervous system effects for all durations (10-min, 30-min, 1-hr, 2-hr, 4-hr, and 8-hr). However, for time periods of 1-hour and greater, the IV-1 value would be higher than the IV-2 level. Therefore, IV-1 values are not recommended for 1-hr, 2-hr, 4-hr, and 8-hr durations (RIVM, 2019).

5.2 Jurisdictional Review: Odour Complaint Response and Use of Odour Information in Potential Emergency Situations

This section reviews how odour information is, or has been, applied to emergency response in various jurisdictions.

The amount of information discussing odours and emergency situations varied widely between jurisdictions; because of this, some jurisdictions are discussed in more detail than others. Overall, very limited information was found regarding the use of odour thresholds to guide responses to odour complaints and emergency scenarios.

5.2.1 Alberta

Energy-related odour complaints are to be directed to the AER's energy and environmental emergency 24-hour response line, known as the Environmental Dangerous Goods Emergencies (EDGE) (AER, 2016, 2018a). If the situation warrants, AER will dispatch emergency responders. If any health symptoms are noted in an odour complaint, the complainant is directed to call the local health authority or Alberta Health.

In response to a complaint, ambient air quality data from the nearest monitoring stations (4–6 hours prior to the event to 4–6 hours after the event) are reviewed to identify variations in any measured parameters (AER and Alberta Health, 2016). If any elevated parameters are identified, facilities may be contacted to determine if any operations or process upsets may have contributed to the odour. Continuous emissions monitoring data may also be requested from facilities.

If a substantial contaminant plume is moving through the area and elevated parameters are observed at multiple stations, the AER's Field Incident Response Support Team may be notified to initiate emergency management procedures. Alberta Health would also be notified.

The AER has two mobile AMUs (one for northern Alberta and one for southern Alberta) that may be deployed in response to an incident to assess health risk and determine emergency response measures. The AMUs are used to monitor H_2S and SO_2 at incident sites, track emissions plumes, determine roadblock locations, and determine if concentrations are at shelter in place or evacuation levels. Other odorous substances that can be measured by mobile air monitoring include ammonia, hydrocarbons, NO_X, SO_2, and TRS (Government of Alberta, 2013b).

5.2.2 British Columbia

Odour complaints related to oil and gas activities are directed to the British Columbia Oil and Gas Commission (BC OGC) 24-hour emergency number (BC OGC, 2013b). Complaints are prioritized and responded to within two hours. Inspectors investigate the cause of the complaint and assist in resolving the situation. The BC OGC may deploy mobile AMUs to monitor air quality in response to oil- and gas-related emergencies or complaints related to petroleum-type odours (BC OGC, 2013a).

For individual facilities, procedures for responding to complaints should be included in ERPs. The BC OGC *Core ERP Content Checklist* indicates that ERPs should contain:

> - Guidelines for prioritizing complaint calls;
> - Procedures for receiving and communicating complaint calls for response;
> - Guidelines for responding to complaint calls;
> - Guidelines for reporting incidents to the [BC OGC] when the complaint investigation discovers an incident has occurred; and
> - Guidelines for complaint documentation.
>
> (BC OGC, 2017, p. 23)

The BC *Guidelines for Industry Emergency Response Plans* provides instructions for shelter in place and evacuation decisions (BC Ministry of Environment, 2002):

> Evacuation decisions require knowledge by local authorities of the projected path of an air-borne chemical cloud, atmospheric dispersion rate, and ground level concentrations. The ability to warn residents on a rapid and reliable basis is also required. Use of appropriate and agreed on warning systems such as sirens, emergency broadcast systems, mobile public address systems and/or house-by-house contacts should be specified in the plan.
>
> In some instances, it may be safer for citizens to remain inside with doors and windows closed rather than to be evacuated. A plume may move past homes very quickly. In these situations, the plan should include appropriate procedures to warn downwind residents to shut off all circulation systems including heating, air conditioning, vent fans and fire places.
>
> (BC Ministry of Environment, 2002, p. 16)

There is no discussion of the use of odour thresholds (or other trigger values) to guide decisions regarding protective actions.

An example of the odour complaint response used in BC was found in an incident report for an odour event involving Terra Energy near Fort St. John (BC OGC, 2014). The response process involved:

- Odour complaints were received by BC OGC and Terra Energy, and an investigation was initiated to determine the source of the odour;
- A gas release at a well site was found by Terra Energy. Using a self-contained breathing apparatus, an employee entered the site to investigate the release; the H_2S concentration in the immediate vicinity of the wellhead was found to exceed 200 ppm. Terra Energy activated its ERP and dispatched response personnel to the site;
- Area residents were informed by door to door notifications. Evacuation was not required, but hotel accommodations were offered for those wanting to leave the area; and
- Terra Energy monitored H_2S concentrations using personal monitors and a mobile AMU. BC OGC conducted independent air quality monitoring. Maximum off-site concentrations of H_2S ranged from 1 to 2 ppm.

5.2.3 Ontario

In Ontario, odour complaints may be directed to the MOECC public pollution reporting hotline or spills action centre (MOECC, 2018a, 2018c). An environmental officer will determine if action is required based on the information collected: odour strength, location, and source; the substance or process causing the odour; facility approvals; and if the odour is related to normal facility operations or a spill.

The MOECC provides modelling and monitoring services to support response activities for chemical emergencies (MOECC, 2017b). Atmospheric modelling may be performed to assess the relation between pollutants released and potential impacts. Additionally, a mobile Trace Atmospheric Gas Analyzer (TAGA) may be deployed to monitor air quality in the vicinity of the emergency. The information is used to determine if downwind concentrations of airborne chemicals are at safe levels; it is not known if odours are considered in this assessment. Air monitoring results may be compared to the MOECC's emergency screening values (Plain, 2016). For example, emergency screening values were used to evaluate public health risk associated with a benzene release in Corunna, ON (see Section 5.3.3).

For odour complaints received by a facility, site staff are advised to follow Ontario's complaint response protocol (MOECC, 2017a). Information to be collected during a complaint includes the complainant's contact details, description of the odour, and weather conditions at the time of the complaint. Staff are also advised to document the facility and operational activities at the time of the complaint, and conduct a site walkthrough to determine if odours are still present and determine the potential cause. If required, the facility is to initiate response procedures to mitigate odours as well as notify the MOECC.

5.2.4 Quebec

Similar to Ontario, Quebec utilizes a mobile TAGA unit to monitor air quality during environmental emergencies (Gouvernement du Québec, 2018). TAGA is equipped with analyzers than can detect and measure a wide range of substances, including many odorous compounds. Examples include BTEX, VOCs, sulphur compounds, and nitrogen oxides.

The monitoring data are used to characterize contaminants in ambient air and determine the extent of the affected area. For example, a TAGA unit was used to monitor air quality following an industrial accident in Varennes, QC (see Section 5.3.4). Atmospheric modelling of pollutants may also be performed. The results help decision-makers determine the seriousness of the situation, and inform shelter in place and evacuation decisions. No further information was found regarding if or how emergency criteria are used in the decision to initiate protective action.

5.2.5 Saskatchewan

The *Saskatchewan Upstream Flaring and Incineration Requirements* (Government of Saskatchewan, 2015) state that if odour complaints are received at a licensed facility or a well, and there is an obvious and measurable risk (or at the discretion of the Saskatchewan Ministry of Energy and Resources), implementation of one or more the following mitigative measure(s) may be required:

- Conduct an air quality investigation or install air quality monitoring equipment;
- Attempt to eliminate the air contaminants at their source;
- Implement good housekeeping to minimize fugitive emissions;
- Develop and implement a public information and consultation program;
- Seal and leak proof storage vessels and equipment;
- Install a vapour recovery unit on storage or process equipment;
- Direct the recovered vapour to properly operating flares; and
- Recover associated gas (gas associated with crude oil production) that may be vented or flared.

(Government of Saskatchewan, 2015)

No further clarity is provided on what constitutes an obvious and measurable risk.

5.2.6 National Oceanic and Atmospheric Administration (United States)

The NOAA is responsible for responding to oil spills, chemical accidents, and other emergencies in US coastal areas. The NOAA utilizes ODTs and/or LOA values in emergency planning and response to estimate “phone call zones,” *i.e.*, zones where people may smell an odour and become very concerned (NOAA, 2019b). The phone call zone represents the area where public anxiety could be high, and people may contact emergency services, report an odour or gas leak, or report to local hospitals. Phone call zones can be estimated prior to or during an odour event or emergency using atmospheric modelling software (*e.g.*, ALOHA).

5.2.7 England

Examples of responses to odour complaints and emergency scenarios in England were found in two incident reports. In the case of an unknown widespread odour (Smethurst and Witham, 2008), the response focused on determining the source using:

- Evaluations of weather and wind conditions;
- Atmospheric dispersion modelling to simulate where air at a certain location will be dispersed to and where it originated; and
- Routine pollutant monitoring data.

In the case of an odour from a suspected source (Lamb, 2014), the response involved:

- Confirming the source using atmospheric modelling of the suspected chemical release from the suspected location;
- Estimating public exposure levels to the contaminant (using modelling and monitoring data) and determining if there is a public health risk by comparing to health effect levels (such as AEGLs) and workplace exposure limits;
- Communicating the health risk to stakeholders in areas affected by the odour;
- Managing the increased volume of odour complaint calls from the public;
- Determining if mobile air quality monitoring units should be deployed (taking into account the estimated exposure levels and the capabilities of the monitoring equipment); and
- Drafting and releasing a public message to inform the population affected by the odour.

5.2.8 Scotland

For chemical releases of odorous substances, the *Odour Guidance 2010* document provides a detailed set of guidelines for classifying an event as a major, significant, or minor odour incident (Scottish Environment Protection Agency, 2010). These incident classification guidelines are summarized in Table . The *Odour Guidance 2010* document also outlines steps that can be taken to suspend industry activities causing the odour (*e.g.*, issue suspension notices). A suspension notice includes the following information: the imminent risk or reason for suspension, what is suspended, what steps need to be taken to lift the suspension, and how the suspension will be lifted. No information was provided regarding quantitative odour thresholds or other recommended protective actions for each tier level.

Table 6. Incident classification guidelines used by the Scottish Environment Protection Agency

A **major odour incident** is one in which the release: A) has a significant and distracting effect on humans; (odour is persistent, widespread and at an intensity, offensiveness, and extent that it leads to a change in behavior of those exposed – *e.g.*, moving out of the affected area, experiencing nausea or sickness.) OR B) could have a major adverse effect on amenity value or economic impact; (*e.g.*, odour prohibits normal activities at an important recreation activity, event, or public space.) OR C) may result in danger to the public. (action is required by emergency services to advise the public on specific actions to be taken, such as the closure of access roads, evacuation of property, or a need to remain indoors.) The odorous release is often caused by an incident at an installation, resulting in a release of odour which is sufficiently strong, offensive, and persistent and interferes with activities or disrupts sensitive receptors.
A **significant odour incident** is one in which the release: A) would result in an abnormal and prolonged disturbance due to odour. This would typically lead to disruption, rather than evacuation of dwellings. OR B) could result in a reduction in amenity value. The odour is sufficiently offensive and persistent that it prevents or significantly restricts the local population's use of an amenity or recreation area such as a park.
A **minor odour incident** is one in which the release: A) would have a minimal effect on humans (*e.g.*, a short-term and/or intermittent odour that affects a small localized population). OR B) could have a minimal effect on amenity value (*i.e.*, a localized, minor, or transitory effect on local amenities that aren't considered sensitive receptors, such as sports fields). People would still be using the area, despite complaints being received.

(Scottish Environment Protection Agency, 2010)

5.2.9 Netherlands

In response to a chemical emergency, the Netherlands decision-making process involves the following (Health Council of the Netherlands, 2007):

- Estimate the chemical concentration in the area around the source, using air monitoring or emissions data with atmospheric modelling;
- If the estimate indicates exceedance of an Intervention Value, appropriate steps can be taken to protect public health;
- For airborne concentrations that will only cause inconvenience (*i.e.*, the notification guideline level), informing the local community is typically sufficient; and
- For airborne concentrations that may cause severe health damage (*i.e.*, the warning threshold), emergency personnel must determine whether shelter in place or evacuation is the most appropriate protective action.

Similar to AEGLs, the Netherlands Intervention Values (Section 4.3.4) include a LOA value for applicable chemicals. LOAs are used to estimate phone call zone, which are described as areas where the public are likely to become anxious and call emergency services or environmental complaint response services in significant numbers (RIVM, 2009). The prediction of the phone call zone allows emergency response agencies to make informed decisions about public communication.

No information was found regarding other protective actions implemented at the LOA.

5.2.10 New Zealand

The *Good Practice Guide for Assessing and Managing Odour* provides a detailed protocol for responding to nuisance odour complaints (New Zealand Ministry for the Environment, 2016a). However, the protocol is limited to “objectionable” or “offensive” nuisance odours and does not apply to emergency scenarios. For odours considered to be “noxious” or “dangerous” (*i.e.*, harmful to health), the *Good Practice Guide for Assessing Discharges to Air from Industry* provides guidance on how to assess the potential for harmful or dangerous effects from chemical releases using health-based assessment criteria (New Zealand Ministry for the Environment, 2016b). For emergency scenarios, the use of AEGLs and ERPGs is recommended for evaluating the potential health impacts of an unintended release.

5.3 Case Studies

5.3.1 Industrial Heartland (Fort Saskatchewan), Alberta

Alberta's Industrial Heartland, situated northeast of Edmonton, is Canada's largest hydrocarbon processing region (Alberta's Industrial Heartland Association, 2018). The area is home to more than 40 companies involved in producing and processing various chemicals, petrochemicals, and fuels.

> **Industrial Heartland, Alberta**
>
> • Canada's largest hydrocarbon processing region.
>
> • A 24-hour phone line, called the UPDATEline, provides residents with the latest status on industrial site activities including emissions of odours.
>
> • No information was found regarding the use of odour thresholds in emergencies.

The Northeast Region Community Awareness Emergency Response (NRCAER) is a mutual aid emergency response association operating in the area (NRCAER, 2018b). The NRCAER administers a 24-hour phone line (called the UPDATEline) that provides the latest status on industrial site activities (City of Fort Saskatchewan, 2018; NRCAER, 2018a). Residents can call anytime to obtain information about any unusual industrial activity they may notice, including odours. Additionally, the NRCAER encourages residents to register for emergency alerts via their community alert programs or the Alberta Emergency Alert system (NRCAER, 2018a).

No information was found regarding chemical emergencies declared in the region or use of odour thresholds in emergencies.

5.3.2 Peace River (Three Creeks), Alberta

The Peace River area, located approximately 500 km northwest of Edmonton, is home to several heavy oil operations. Between 2009 and 2013, the AER received more than 881 odour complaints from community residents (AER, 2014b). A number of air quality surveys have since been conducted in the area (Government of Alberta, 2010, 2011a; Intrinsik, 2013; Stantec Consulting Ltd, 2014). Air samples collected at various locations were analyzed primarily for VOCs, and results were compared to ODTs and ambient air quality guidelines to identify potential source(s) and evaluate odour and health impacts. quality guidelines to identify potential source(s) and evaluate odour and health impacts.

Peace River, Alberta

- More than 800 odour complaints were received by AER between 2010 and 2013.
- Numerous surveys have been conducted comparing air quality data against odour thresholds and air quality guidelines.
- Following a formal inquiry, AER set new rules for heavy oil and bitumen operators to reduce emissions that contribute to objectionable odour.

A formal inquiry launched to address the odours and emissions generated by the Peace River heavy oil operations offered 16 recommendations for reducing and managing odours (AER, 2014b). Based on the recommendations, the AER set new rules under Directive 84 for heavy oil and bitumen operators in the area to reduce emissions that contribute to objectionable odour (AER, 2018c).

The odour issue in Peace River relates to long-term nuisance odours. No information was found regarding chemical emergencies declared in the region or use of odour thresholds in emergencies.

5.3.3 Corunna (Sarnia), Ontario

> **Corunna (Sarnia), Ontario**
>
> • Shell Canada received a public complaint of odour and physical symptoms.
>
> • An investigation into the source of the odour was initiated.
>
> • Air monitoring revealed elevated concentrations of benzene.
>
> • Traffic control and a shelter in place advisory were issued.
>
> • Public notification methods included emergency sirens, the Community Notification Network, and the township Alert FM system.

On April 27, 2016, a chemical incident occurred at Shell Canada in Corunna, ON (Morden, 2016; Plain, 2016). Shell Canada received a call from a resident experiencing odour and physical symptoms. Shell Canada reported to the MOECC spills action centre that an odour had been confirmed on-site at their facility, and that an investigation into the source of the odour was under way. Air quality monitoring conducted by Shell Canada and a third-party consultant revealed elevated concentrations of benzene (0.50 ppm) in the community. Traffic control and a shelter in place advisory were subsequently issued in Corunna. The shelter in place advisory was considered a precautionary measure while the source of the odour was being investigated, and atmospheric modelling was used to determine the shelter in place area. MOECC notified Aamjiwnaang First Nation, Health Canada, Environment Canada, and Michigan State Police, and dispatched environmental response personnel. Public notification methods included emergency sirens, the Community Notification Network (a subscription-based notification system), and the township Alert FM system. The shelter in place advisory and traffic control were lifted after two hours.

Additional air monitoring was conducted by the MOECC mobile monitoring unit. The concentration of benzene in downwind air samples ranged from 0.019–0.024 ppm. Based on the results, the MOECC required Shell Canada to collect additional air samples.

Between April 27 and May 3, the maximum benzene concentrations measured at various sites were well below the MOECC emergency screening values of 52 ppm (1-hour) and 4.5 ppm (8 hour). For comparison, interim AEGL values for benzene are 52 ppm (1-hour) and 9.0 ppm (8 hour), respectively, and the LOA value is 7.5 ppm (NAC/AEGL Committee, 2008). Air monitoring results were also compared with air quality guidelines for short-term repeated exposures (*i.e.*, ambient air quality criteria). The benzene concentration on April 27 was found to exceed the guideline of 0.18 ppm. Air monitoring results for all other contaminants measured were below air quality guidelines.

It was not clear if odour thresholds for benzene were used to guide any public health actions or if an official state of emergency was declared.

5.3.4 Varennes, Quebec

On March 21, 2015, an industrial accident caused the release of 5 tonnes of titanium tetrachloride from a factory in Varennes, Quebec, 30 km east of Montreal (Hughes, 2015; Lindeman, 2015). Homes within 1 km of the plant were evacuated and a highway was closed. For people living in the vicinity but outside of the security perimeter, a confinement order was issued. Five people complained of health effects in connection with the leak and two were hospitalized.

Exposure to titanium tetrachloride may cause breathing difficulties or a burning sensation in the eyes or on the skin (Lindeman and McKenna, 2015). When mixed with water, titanium tetrachloride forms hydrochloric acid (HCl), which occurred as the released chemical reacted with water in snow to form a cloud of HCl. HCl has an irritating, pungent odour, with an ODT of approximately 4.7 ppm (US EPA, 2000). Exposure to HCl may cause eye, nose, and respiratory tract irritation, as well as inflammation and pulmonary edema.

> **Varennes, Quebec**
>
> - An industrial accident caused the release of 5 tonnes of titanium tetrachloride, which reacted with water in snow to form HCl.
> - Protective actions included evacuation, road closure, and a confinement order.
> - Air quality monitoring indicated HCl concentrations were at emergency levels.
> - It is not known if odour thresholds were used to guide protective actions.

The provincial environment ministry conducted air quality monitoring of HCl in the area using a mobile TAGA bus (CTV Montreal, 2015; Lindeman and McKenna, 2015). Normal levels of HCl in the air are 0 ppm; tested concentrations were 50 ppm, which were considered to be emergency levels. The following day, HCl concentrations in the air were 0.1 ppm. The evacuation and confinement orders were lifted, and residents were allowed to return home. Based on the information available, it is not known if odour thresholds were used to guide protective actions or if an official state of emergency was declared.

6 Summary of Policy Tools

6.1 Detection/Identification of an Incident

An important consideration in the discussion of chemical emergencies is how a chemical incident is detected or identified. Methods for identifying a chemical release may include notification from the person(s) responsible for the chemical release, air monitors, pressure and flow sensors, visible or audible evidence of a release (*e.g.*, train accident, explosion, smoke), odour (including odour complaints from the public), health impacts to workers or the public, and notification of other environmental impacts (*e.g.*, dirty surface water, death of wildlife) [World Health

Organization (WHO), 2009]. Additionally, environmental levels of odorous contaminants may be predicted using source emission data and atmospheric modelling. Examples of commonly used dispersion models include AERMOD and CALPUFF (Capelli *et al*., 2013; Odotech, 2013). These models have been extensively validated in the literature and their use has been adopted by numerous environmental agencies (Government of Alberta, 2013a; US EPA, 2017b). For modelling of accidental chemical releases, ALOHA software is also an option (Government of Alberta, 2017c; NOAA, 2019c).

The accuracy of a given model is dependent on the quality of the input data (e.g., source emission data, meteorological conditions), the appropriateness of the model for the particular application, and model performance (New Zealand Ministry for the Environment, 2004; Odotech, 2013). Generally speaking, acceptable dispersion models predict air concentrations to within a factor of two (NOAA, 2019c).

6.2 Response to Odour Complaints

In the initial response to an odour complaint, it is important to determine the urgency of the situation. A suitable tool that can be used to help guide this process is CASA's matrix for triaging odour complaints (Table 1). Factors considered in evaluating the urgency of an odour complaint may include: multiple calls about the same odour; reports of health concerns; unusual odour not linked to normal activity; odours that may signal a serious or dangerous situation; environmental concerns; time the odour was noticed; and access to the alleged source (CASA, 2015).

For more urgent odour complaints, the initial response focuses on investigating the source and identifying the contributing chemical(s). To achieve this, air quality monitoring may be initiated using portable handheld monitors, portable olfactometers, gas detectors, and mobile AMUs or TAGA vehicles. Information from continuous monitoring stations may also be obtained.

6.3 Emergency Response Criteria

Once an issue (or potential issue) has been identified, the effects of exposure may be assessed in terms of both health and odour impacts. Health benchmarks are used to evaluate the direct toxicity of exposure, while odour benchmarks may be used to assess awareness in the population and the potential for indirect health effects such as anxiety and worry (RIVM, 2009).

There are several emergency response criteria available for chemical substances (*e.g.*, PACs, Netherlands Intervention Values), which incorporate odour information in various supplementary manners. The three main emergency response criteria for acute exposures that include reference to odour are AEGLs (LOAs), Intervention Values (LOAs), and ERPGs (ERPG-1 and odour detection indicator).

The US EPA's AEGLs are the preferred emergency guideline value. AEGLs incorporate odour information as a separate LOA value that is reported alongside the AEGL values. The LOA is intended to aid chemical emergency responders in determining the extent of public awareness of an exposure based on odour perception, and indicates the level at which communicative emergency response activities may be required to reduce or avoid anxiety and stress in the community (RIVM, 2009).

LOA values have been used in emergency planning and response to estimate phone call zones. The phone call zone represents the area where public anxiety could be high, and people may contact emergency services, report an odour or gas leak, or report to local hospitals. Prediction of a phone call zone allows emergency response agencies to make informed decisions about public communication. No further information was found regarding application of the LOA. Additionally, no documentation was found that evaluated the effectiveness of the LOA as a policy tool.

LOA values are currently available for 23 AEGL substances (see Table in Section 4.3.1.1). The Netherlands Intervention Values, which are similar to AEGLs, include LOAs for 89 substances. LOAs are currently available for 14 substances on a list of 27 common odorants in Fort McKay (see Table in Section 5.1).

With regard to the AIHA's ERPGs, a different approach is taken to incorporate odour information. ERPG values are primarily based on toxicological endpoints; however, a clearly defined objectionable odour may form the basis of an ERPG-1 value (if the objectionable odour occurs below levels that could cause adverse health effects). In general, the ERPG-1 represents the level that does not pose a health risk to the community but that may be noticeable due to slight odour or mild irritation; for small non-threatening chemical releases, the community may be notified that odour or slight irritation may be noticeable but that concentrations are below those that could cause unacceptable health effects (AIHA Guideline Foundation Emergency Response Planning Committee, 2014).

ERPGs also utilize an odour detection indicator (✪) to indicate that a chemical is likely to be detected by odour near its ERPG-1 value. This information can assist emergency response agencies that handle odour complaint calls from the public. No further information was found regarding application of the odour detection indicator.

For extended exposures of 24 hours to 2 years, PALs may be used to inform decisions regarding protective actions, such as shelter in place, evacuation, and re-entry into affected areas. In terms of odour, detection of odour may be selected as an endpoint for PAL-1 derivation.

The emergency criteria discussed above apply to single odorants. There were no guidelines available to address the indirect health impacts that may occur from exposure to odour mixtures.

6.4 Protective Actions

6.4.1 Community Notification

Communication is critical for effective responses to releases of odorous emissions. Given the perception of risk associated with environmental odours, there is a need for the public to be informed, even in cases when ambient concentrations do not reach toxic levels. Notifying the public about the nature of a smell and the potential health risk can prevent or reduce anxiety and stress-related health impacts (RIVM, 2009). The public message may include information such as the cause and source of the odour, the status of the situation, and confirmation that the situation is being monitored.

Examples of public notification methods used during emergency situations involving odorous chemicals include:

- Public health messaging and media releases (Lamb, 2014; Lindeman and McKenna, 2015);
- Community notification systems and mobile emergency alerts (Morden, 2016; NRCAER, 2018a);
- Alert sirens (Morden, 2016); and
- Door to door notification (BC OGC, 2014).

Communication with the public prior to an incident is also important. This may involve relaying information on hazards, possible incident scenarios, and protective actions the public can take, as well as establishing communication channels (WHO, 2009). In Deer Park, Texas, an area home to numerous petrochemical facilities, a spokes-character was developed to educate and inform residents about protective actions in the event of a chemical emergency (Heath *et al*., 2018). The spokes-character, a turtle named Wally Wise Guy, advises residents to shelter in place when they are notified to do so during a chemical emergency. The Wally character is now used in 28 states by more than 100 local emergency planning committees and is considered an effective method of motivating residents to follow protective action advice.

6.4.2 Suspension Notice

A suspension notice is an order requiring that the activities generating an odour be ceased until the necessary steps have been taken to lift the order. This action is used by the Scottish Environmental Protection Agency (2010) to suspend industry activities that are causing (or are likely to cause) a major odour incident (the classification guidelines for odour incidents are provided in Table in Section 5.2.8).

No information was found evaluating the effectiveness of this odour management option.

6.4.3 Shelter in Place

Shelter in place involves staying indoors, closing all windows and doors, and shutting down ventilation or air-conditioning systems to minimize the movement of air into and out of a building. In general, shelter in place is utilized when an airborne chemical poses a serious threat to health (Health Council of the Netherlands, 2007; WHO, 2009). In the Netherlands, shelter in place is the preferred protective action option when the ambient concentration of a substance reaches the warning threshold level (equivalent to PAC-2); shelter in place may also be advised at the notification guideline (equivalent to PAC-1) to prevent transient health impacts (Health Council of the Netherlands, 2007). Further information relating shelter in place decisions to odour thresholds, LOAs, or PAC levels was limited.

6.4.4 Evacuation and Re-Entry

Evacuation is a complex operation that involves provision of transportation, shelter, food, water, and emergency care as required (WHO, 2009). The time required to implement an evacuation should be included in an ERP. Concerns associated with rapid evacuation include increased stress, traffic accidents, lost children, and health disruptions for the elderly and sick.

No information was found regarding odour thresholds or LOAs and evacuation/re-entry criteria. The decision to evacuate is typically based on health-based emergency criteria, such as PAC-2, PAC-3, or PALs, rather than odour-based values.

Evacuation may be the preferred protective action option if:

- The chemicals are widely dispersed and contamination is extensive and persistent.
- The chemicals are suspected as being hazardous, but cannot be identified readily.
- The chemical is highly hazardous.
- The concentration in the air will be hazardous for a prolonged period.
- There is a risk of explosion.
- The number of evacuees is relatively small.

(WHO, 2009, p. 57)

The decision between shelter in place and evacuation will depend on exposure level and duration. Evacuation is the preferred option when the area is not yet exposed but will be after a certain period of time, and the likely duration of the exposure means that shelter in place will not adequately protect human health (WHO, 2009). Other factors that may impact the decision include condition of housing (*i.e.*, amount of air exchange), time of day, transportation networks/road geometry, and road conditions. In areas with limited roads, decision makers must consider if evacuees will be required to move towards the source of the chemical release in order to leave the area. This is particularly important for Fort McKay, as there is only one entry and exit point into the community.

The decision to authorize return to an evacuated area depends on environmental monitoring data and other metrics to confirm the area is safe (WHO, 2009). The ability to provide essential services for the returning population is also required.

As some chemicals eliminate the sense of smell, the absence or reduction of chemical odours should not be used as an indicator that an area is safe for re-entry (US Department of Transportation, Transport Canada, and the Secretariat of Communications and Transportation of Mexico, 2016).

7 Conclusions and Applicability of Protective Actions Based on Odour

This report focused on answering the following research questions:

- How is odour threshold information used by different agencies? (Section 3.4)
- How is odour monitored in Alberta? (Section 3.6)
- What emergency response criteria are used by different agencies during chemical emergencies? (Section 4)
- How do government and regulatory agencies use odour information in periods of emergency response? (Section 5)

The first two bullets (Sections 3.4 and 3.6) provide a background on the general use of odour thresholds (including non-emergency scenarios) and a review of odour monitoring in Alberta. The third and fourth bullets (Sections 4 and 5) focus on the use and application of odour information (and odour thresholds) in emergency scenarios, and are discussed further below.

From the material presented in Section 4, there are three emergency response criteria for acute exposures that include a reference to odour: AEGLs (LOAs), Intervention Values (LOAs), and ERPGs (certain ERPG-1 values based on objectionable odour; odour detection indicator). LOA values are currently available for 23 substances in the AEGL dataset, and 89 substances in the Intervention Values dataset. In comparing these data to a list of 27 common odorants in Fort McKay, LOAs are available for 14 of the substances. For the ERPG dataset, it is not known which ERPG-1 values are based on a clearly defined objectionable odour; however, this information is provided in the technical support documents for each chemical, which are available for purchase from the AIHA. The ERPG odour detection indicator denotes when an odour is likely to be detected at the level of the ERPG-1, and this is true for many substances with low odour thresholds. Of the ~150 substances in the 2018 ERPG dataset, more than 80 have the odour detection indicator (AIHA, 2018). Though odour is mentioned as a consideration in several of these response criteria, none are fully based nor reference odours in as the basis for their response

From the material presented in Section 5, the most relevant findings with regard to the use of odour thresholds in emergency scenarios include:

- US NOAA: LOA values and ODTs are used in emergency planning and response to estimate phone call zones, which are described as areas where people may smell an odour and become very concerned. The phone call zone represents the area where public anxiety could be high, and people may contact emergency services, report an odour or gas leak, or report to local hospitals.

- Netherlands National Institute for Public Health and the Environment: In the same manner as the NOAA above, LOAs are used to estimate phone call zones, which are described as areas where the public are likely to become anxious and call emergency services or environmental complaint response services in significant numbers. The prediction of the phone call zone allows emergency response agencies to make informed decisions about public communication.

- Scottish Environment Protection Agency: A detailed set of guidelines is used to classify an odour event as a major, significant, or minor odour incident. Their guidance document also outlines steps that can be taken to suspend industry activities causing the odour during major odour incidents.

In summary, notifying the public about an odour and the potential health risks can prevent or reduce anxiety and stress-related health impacts.

It is important to note that LOA values are intended to be used in conjunction with their corresponding AEGLs or Intervention Values. The LOA addresses the odour component of exposure, while the AEGLs and Intervention Values are used to assess potential toxicity. For some substances, the LOA is higher than one or more of its AEGLs or Intervention Values; this indicates that direct health impacts are likely to occur before distinct odour awareness in the community.

While considerable effort has been made to develop LOAs and ERPG-1 values (including ERPG odour detection indicators), no documentation was found that evaluated the effectiveness of these policy tools in real odour scenarios. Additionally, LOAs and ERPG-1 values have only been developed for single chemicals and do not apply to odour mixtures.

For cases involving odour mixtures, even though it would be ideal to identify a total odour level at which to initiate a public health response, no information found in the literature that related concentration or intensity of odour mixtures to emergency response. The tiered system used by the Scottish Environment Protection Agency to classify odour events as major, significant, or minor odour incidents is applicable to odour mixtures; however, the system is not based on quantitative values and, apart from issuing notices to suspend industry activity, no guidance was provided regarding recommended protective actions at each tier level.

8 Scientific and Policy Gaps

Many factors can influence the acuteness of the sense of smell, which can lead to a great deal of uncertainty in the derivation of odour thresholds. These factors may include individual characteristics (*e.g.*, age, gender, health status, smoking status, past experience with an odour), odour properties (*e.g.*, pleasantness, type of odour), and physiochemical properties of the odorant (*e.g.*, molecular structure, receptor binding affinity). Further adding to the complexity of environmental odour perception is the influence of meteorological factors, such as wind speed and temperature.

Given the wide variation in individual sensitivity to odours, odour thresholds are not precise values and are typically reported as a range. The values used by different agencies may also vary, due to the reliance of different sources of reported odour thresholds.

Odour management strategies typically focus on ongoing or repeated odour nuisance issues rather than isolated odour episodes (such as an accidental chemical release). To prevent or limit odour nuisance, many jurisdictions regulate ambient odours based on odour concentration, with most values ranging from 1 to 10 OU (for a review, see Brancher *et al.*, 2017). However, no information was found regarding the application of OU guidelines for emergency scenarios. Overall, there is a lack of information available regarding appropriate emergency response to odour mixtures.

Another issue relates to the use of continuous air quality measurements to trigger emergency alarm notifications, as the operating ranges for the continuous monitors may not be suitable for emergency levels of pollutants (*i.e.*, the maximum detection limits of the instrument are lower than emergency concentrations). This is also the case for some substances at the LOA level. For example, for benzene, the LOA value is 7.5 ppm and the maximum detection limit for continuous monitoring (of BTEX and styrene) is 1 ppm (Government of Alberta, 2017a).

Use of LOAs is relatively new and limited guidance was available regarding their practical application. Additionally, no reviews were found that evaluated the use of LOAs in real scenarios.

As with ODTs, there is a large degree of uncertainty in LOA values. Additionally, there was limited evaluation of the field correction factors applied in the derivation of LOAs.

For PACs, a significant amount of material has been published discussing their methods of derivation; however, limited information was found regarding recommended protective actions for each tier level.

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Appendix A Glossary

acute toxicity	Adverse health effects associated with short-term exposure to a substance.
emergency planning zone	A geographical area surrounding a well, pipeline, or facility containing hazardous product that requires specific emergency response planning by the licensee.
emergency response plan	A comprehensive plan to protect the public that includes criteria for assessing an emergency situation, procedures for mobilizing response personnel and agencies, and establishing communication and coordination among the parties.
e-nose	A device that identifies the specific components of an odour and analyzes its chemical make-up to identify it.
evacuation	Organized, phased, and supervised withdrawal of members of the public from dangerous or potentially dangerous areas to safe areas.
FIDOL	An odour assessment framework that considers the characteristics of Frequency, Intensity, Duration, Offensiveness, and Location.
fugitive emissions	Unintended emissions from any openings, such as doors, windows, trucks waiting to load or unload odorous materials, valves, phalanges, or pumps.
hedonic tone	The perceived pleasantness or unpleasantness of an odour.
in situ	Oil sands facilities that recover bitumen that is too deep to mine.
incident	An unexpected occurrence or event that requires action by emergency personnel to prevent or minimize loss of life or damage to property or the environment.

level of distinct odour awareness (LOA)	The concentration above which it is predicted that more than half of the exposed population will experience at least a distinct odour intensity, and about 10% of the population will experience a strong smell.
odorant	A volatile chemical in the air that stimulates sensory neurons in the nasal passage.
odour complaint threshold	The odour concentration at which 50% of a population would complain about after a short period of exposure.
odour detection threshold	The odour concentration at which 50% of a population detects an odour but does not recognize the odour as a specific compound.
odour intensity	The perceived strength of an odour.
odour offensiveness threshold	The concentration at which 50% of a population, based on the results from an experimental odour panel, would be expected to indicate that the odour is offensive over a short period of exposure.
odour panel	A group of assessors who are qualified to judge samples of odorous gas using an olfactometer.
odour quality	The qualitative description of how an odour smells (*e.g.*, floral, musky, woody, fruity).
odour recognition threshold	The odour concentration at which 50% of a population is expected to recognize and identify an odour.
odour threshold	The lowest concentration of an odorant in the air that can be detected by a human being.

odour unit (OU)	A measurement of odour concentration defined as the dilution level at which 50% of an odour panel cannot distinguish an odour from odourless air. For example, if an odour sample diluted 10 times is just undetectable by 50% of the panel, the odour concentration would be 10 OU. A value of 1 OU is equivalent to the odour detection threshold.
olfactometer	A dilution instrument used for measuring the concentration of an odour. The instrument mixes an odour sample with odour-free air at specific ratios, and the diluted odour is presented to a panel of human assessors.
olfactometry	The measurement of odour concentration using an olfactometer to deliver dilutions of an odorous sample.
olfactory fatigue	A decrease in sensitivity to an odour caused by a repetitive process of making and recording odour observations.
shelter in place	Remaining indoors for short-term protection from exposure to toxic gas releases.
sour gas	Natural gas that contains measurable amounts of H_2S. It is a colourless, flammable gas that smells like rotten eggs and can be poisonous to humans and animals.
total reduced sulphur (TRS)	A group of sulphur compounds that includes hydrogen sulphide, mercaptans, dimethyl sulphide, dimethyl disulphide, and other sulphur compounds, but not sulphur dioxide.
volatile organic compound (VOC)	Organic chemicals that have a high vapour pressure at ordinary room temperature. They can be toxic to humans and animals.

Appendix B Literature Search Methodology

The literature search methodology involved three main steps:

- Preliminary scan
- Literature search
  - Agency websites
  - Google searches
  - Academic databases
- Case study assessment

Searches were conducted between January and April 2018, with additional searching conducted in September 2018. Relevant material was considered as any article, document, or website that discussed odour thresholds and/or chemical emergencies in an environmental context.

Two additional rounds of editing were completed in August 2019 and February 2020. Updated versions of several web pages and documents, such as the *Alberta Ambient Air Quality Objectives and Guidelines Summary* (Government of Alberta, 2019a), were reviewed for new relevant material.

B.1 Preliminary Scan

A preliminary scan was conducted to obtain background information on odour thresholds, review odour issues in Alberta, and identify terms related to odour thresholds and chemical emergencies. This was done using broad Google searches with the following terms:

- odour threshold
- odour chemical emergency
- Alberta odour

For each search, websites and documents from the first 50 results were reviewed. From this information, a list of odour-related terms and emergency-related terms relevant to the topic(s) of interest was developed (Table B-1). The preliminary scan also helped to identify organizations to include in the list of agencies to review (Appendix C).

Table B-1. Key terms

Odour-related terms *	Emergency-related terms
Odour Odour awareness Odour detection Odour threshold Odour recognition	Emergency Emergency criteria Emergency response Chemical emergency Chemical event Chemical release

*for all instances of the term "odour", the alternative spelling ("odor") was also used.

B.2 Literature Search

B.2.1 Agency Websites

The primary search method involved a search of agency websites. The list of agencies included various provincial, state, federal, and international health and environmental organizations involved in regulation or research of odours and/or chemical emergencies (Appendix C). The list was approved in advance by the AQOAC. Four searches were conducted on each website by entering the following terms in the website's search bar:

Search #1a	"odour threshold" or "odor threshold"
Search #1b	odour (odor) AND threshold
Search #1c	odour (odor) AND emergency
Search #1d	chemical AND emergency

The searches above indicate a broad use of the odour- and emergency-related search terms (*e.g.*, use of the term "chemical" instead of "chemical emergency" and "chemical event"). This was done to capture as much relevant information as possible from each agency. For each search on each website, up to 50 results were scanned for relevant material. If the search populated very few results for a particular agency, the term "odour" (or odor) was searched on its own.

Relevant material was considered as any website or document that discussed the use of odour thresholds and/or chemical emergencies in an environmental context.

For jurisdictions in Alberta, any websites or documents that discussed air monitoring or management of air quality were also included. This information was used to provide background information on current processes used in Alberta.

B.2.2 Google Searches

To supplement the above agency website search, Google searches were conducted using combinations of odour-related terms (odour threshold, odour detection, odour recognition, odour awareness) with emergency-related terms (emergency, chemical release, chemical event). Terms were entered into *www.google.ca* in the following manner:

Search #2a	(“odour threshold” | “odor threshold”) AND (emergency | “chemical release” | “chemical event”)
Search #2b	(“odour detection”| “odor detection”) AND (emergency | “chemical release” | “chemical event”)
Search #2c	(“odour recognition” | “odor recognition”) AND (emergency | “chemical release” | “chemical event”)
Search #2d	(“odour awareness” | “odor awareness”) AND (emergency | “chemical release” | “chemical event”)

For each search, the first 150 results were reviewed for material from reputable sources (*e.g.*, government, non-governmental organizations, peer-reviewed articles) that discussed odour thresholds and/or chemical emergencies in an environmental context.

B.2.3 Academic Databases

Two academic databases (*Scopus* and *Pubmed*) were used to search for peer-reviewed articles or reviews published in English. To capture current information regarding odours and emergencies, the database search was limited to material published between 2000 and 2017. For both databases, two separate search strings were used. The first search string combined odour with emergency-related terms. The second search string took a slightly different approach with the aim of capturing information that discussed responses to a chemical release but did not use the term “odour;” the terms “threshold” or “response” were used in place of “odour.”

Search #3a	(odour OR odor) AND (emergency OR “chemical release” OR “chemical event”)

Search #3b	(threshold OR response) AND (“chemical emergency” OR “chemical release” OR “chemical event”)

Results from Search #3a and #3b were combined to yield 290 articles in *Scopus* and 122 articles in *Pubmed*. The results from each database were exported to a reference manager; following removal of duplicates, the total number of unique articles was 324.

Very few relevant articles were found in the academic database search. Only three studies were considered suitable and included in the current report. The low hit rate was somewhat expected given that odour is a very broad topic, and the focus was on a very specific application of odour. No information was found discussing the use of odour thresholds in emergency scenarios; the included articles primarily provided background information on odour thresholds and protective actions in chemical emergencies.

B.3 Case Study Assessment

To review the use of odour thresholds in past emergency situations, a case study search was conducted. Locations of interest were provided in advance by the AQOAC. The list included: Three Creeks, AB; Industrial Heartland (Fort Saskatchewan), AB; Sarnia, ON; Montreal, QC; and Denver, CO.

As per the instructions from the AQOAC, the above five locations were to be searched using the following approach:

- Conduct a cursory news media search to identify any chemical- or odour-related emergencies that have occurred in that location.
    - If yes, review the use of odour thresholds during the emergency.
    - If no, end the search for that location.

For the news media search, Google searches were conducted using the following search string:

Search #4	(odour | odor | chemical) AND emergency AND [location name]

The first 50 hits of each search were analyzed to identify any chemical or odour incidents in the given area. Information was found for 4 of the 5 locations. The cursory search did not identify any relevant emergencies in Denver.

Appendix C List of Agencies

Agency	Website
Canada – Provincial/regional agencies	
Government of Alberta • Alberta Emergency Management Agency • Alberta Environment and Parks • Alberta Health	https://open.alberta.ca/publications www.aema.alberta.ca/index www.alberta.ca/environment-and-parks.aspx www.alberta.ca/health.aspx
Alberta Energy Regulator	www.aer.ca/search
Clean Air Strategic Alliance [a]	www.casahome.org/past-projects/
Cumulative Environmental Management Association	http://library.cemaonline.ca/
Fort McKay Sustainability Department [a]	http://fortmckay.com/annual-reports/
Wood Buffalo Environmental Association	https://wbea.org/
Government of British Columbia • Emergency Management BC • Ministry of Environment and Climate Change Strategy	www2.gov.bc.ca/gov/content/home
BC Oil and Gas Commission	www.bcogc.ca/
Government of Manitoba	www.gov.mb.ca/index.html
Government of New Brunswick	www2.gnb.ca/
Government of Newfoundland and Labrador	www.gov.nl.ca/
Government of Northwest Territories	www.gov.nt.ca/
Office of the Regulator of Oil and Gas Operations	www.orogo.gov.nt.ca/
Government of Nova Scotia	https://novascotia.ca/search/
Government of Nunavut	www.gov.nu.ca/
Government of Ontario	www.ontario.ca/page/government
Ontario Energy Board	www.oeb.ca/
Government of Prince Edward Island	www.princeedwardisland.ca/en

Agency	Website
Gouvernement du Québec [b] • Centre d'Expertise en Analyse Environnementale du Québec • Ministère de l'Environnement et de la Lutte contre les Changements Climatiques	www.quebec.ca/en/ www.ceaeq.gouv.qc.ca/index.asp www.environnement.gouv.qc.ca/
Government of Saskatchewan	www.saskatchewan.ca/
Government of Yukon	www.gov.yk.ca/
Canada - Federal agencies	
Canadian Council of Ministers of the Environment	www.ccme.ca/
Government of Canada • Environment and Climate Change Canada • Health Canada • Natural Resources Canada • Public Health Agency of Canada • Public Safety Canada • Transport Canada • National Energy Board	www.canada.ca/en.html
United States – State Agencies	
California Air Resources Board	ww2.arb.ca.gov/
California Office of Environmental Health Hazard Assessment	https://oehha.ca.gov/
Texas Commission on Environmental Quality	www.tceq.texas.gov/
United States – Federal Agencies	
American Industrial Hygiene Association	www.aiha.org/
Federal Emergency Management Agency	www.fema.gov/
Federal Energy Regulatory Commission	www.ferc.gov/
United States Government • Centers for Disease Control and Prevention • US Department of Energy • US Department of Transportation • US Environmental Protection Agency	www.usa.gov/ www.cdc.gov/ www.energy.gov/ www.transportation.gov/ www.epa.gov/

Agency	Website
International	
Australia Department of the Environment and Energy Australian Energy Regulator Government of Western Australia	www.australia.gov.au/ www.aer.gov.au/ www.wa.gov.au/
Netherlands National Institute for Public Health and the Environment (RIVM)	www.rivm.nl/en/
United Kingdom • Department for Business, Energy and Industrial Strategy • Department for Environment, Food and Rural Affairs • Environment Agency • Public Health England	www.gov.uk/
European Union	https://europa.eu/european-union/index_en
World Health Organization	www.who.int/

[a]For the Clean Air Strategic Alliance (CASA) and Fort McKay Sustainability Department (FMSD), a search function was not available on the website. Instead, the *Past Projects* and *Current Initiatives* (CASA) and *Annual Reports* (FMSD) pages were reviewed for relevant material.

[b]The search of the Gouvernement du Québec in English produced limited results. Instead, the websites of the *Ministère de l'Environnement et de la Lutte contre les Changements Climatiques* and the *Centre d'Expertise en Analyse Environnementale du Québec* were reviewed for relevant material.