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Report to the Clean Air Strategic Alliance Odour Management Team Enforcement/Role of Regulation Task Group

Final Report

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EXECUTIVE SUMMARY

RWDI AIR Inc. (RWDI) was retained by the Clean Air Strategic Alliance (CASA) to conduct a comprehensive detailed review of odour regulation and enforcement approaches and their applicability to the Alberta context. This report is intended to satisfy the key deliverables set out by CASA, and provides a cross-jurisdictional summary of odour standards, method of assessing performance against standards, and associated regulation and enforcement by sector and jurisdiction.

The issue of odours is very complex because odour, which is the sensation that can be caused by single odorant or by a complex mixture of odorants, is very subjective, and therefore, difficult to measure. The possible impacts of odours range from mere detection to a public nuisance or, at elevated concentrations, concern of a health hazard. To completely describe the nuisance characteristics of an odour five different dimensions, which are commonly referred to as "FIDOL", which include the frequency that an odour is detected during a given time period; the intensity of the odour; the duration of the period in which the odour remains detectable, the offensiveness or hedonic tone of the odour; and, the location of the odour.

Odorous emissions are often associated with industrial, institutional and agricultural operations throughout Alberta. This report considers 9 sectors, including municipal solid waste management; municipal waste water treatment; composting, agricultural operations; food production; oil & gas operations; forestry and pulp and paper industries; chemical industries; and transportation.

Existing odour frameworks are present throughout Canada and the world. RWDI has previously summarized the framework across Canada (RWDI 2005; RWDI 2013), and this report includes updated information on provincial guidance on odour regulation. There are numerous other jurisdictions that cover odour in detail, and this report covers selected frameworks in the Americas, Europe, Australia and New Zealand, whether covered under federal, provincial or state legislation.

This report includes a discussion and review of various odour management approaches and how each can be applied in the Alberta context. A comprehensive review of strengths and weaknesses for odour management approach has also been compiled. Ten approaches were considered overall. Of the ten approaches reviewed, three were identified as capable of driving a regulatory framework, three may be considered as supporting approaches, and four approaches were deemed to be not applicable or appropriate in the Alberta context. Due to the complex nature of odour, as well as the numerous industries operating within Alberta, recommendations are split into two different frameworks; application for new developments and reactive odour management. As no single approach is sufficient to efficiently encompass odour management for all applications, the framework approach presented below highlights a tiered system that hopes to take in to consideration an operator's size, nature of their business, and other factors. The three odour management approaches studied in more detail for the regulation of odour in Alberta, included:

- Ambient concentration criteria for odour;
- Minimum separation distances; and,

- Complaint criteria.

Odour is difficult to quantify and can be difficult to regulate. Although the report makes specific recommendations, there are additional factors to consider. A number of case studies were reviewed to identify and explore potential challenges associated with odour regulation. These included the results from the British Columbia Environmental Appeal Board decision regarding West Coast Reduction Ltd; the Alberta Energy Regulator inquiry into odours in the Peace River and Three Creeks areas of Alberta; and a number of anecdotal examples from Ontario. This resulted in a number of general considerations for any potential framework, which have been summarized below

- Clarity is essential to the selection of a suitable odour management approach. If the approach is not clear, and well-defined, it will not work once put to a legal test.

- Good relationships between facilities and surrounding residents are a significant benefit, and should be promoted where possible, regardless of the odour management approach selected.

- The development of best practices guides are highly recommended for various categories of facilities to avoid potential odour issues, or to help identify solutions if/or when issues do arise.

- Cumulative effects from neighbouring facilities, as well as location-specific geography and meteorological conditions can be an issue.

- Certain combinations of geography and meteorological conditions may also exacerbate odour issues, and should be considered in the siting process for new facilities or developments near existing facilities.

- No one approach will apply to all situations or industries, and therefore, some flexibility is critical. Thus implementing more than one approach is likely beneficial, as it can help deal with a wider variety of situations, giving both facilities and the regulator additional options.

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2. ODOURS IMPACTS AND SOURCES OF ODOUR

The issue of odours is very complex, because odour, which is the sensation that can be caused by single odorant or by a complex mixture of odorants, is very subjective, and therefore, difficult to measure. Various measurement techniques, such as gas chromatography or open-path Fourier transform infrared spectroscopy, have been developed to measure odorants; however, such instruments measure only the concentrations of different odorants. Concentrations are then compared to odour threshold values which are developed using human odour panels. Thus, to date, the best instrument for measuring odour is still the human nose. Some individuals have far more sensitive noses, and therefore; will detect an odorant at much lower concentrations than others. In addition, one person may find an odour to be objectionable (e.g., roasting coffee or malt from a brewery) while another may not.

The possible impacts of odours range from mere detection to a public nuisance or, at elevated concentrations, a health hazard. Most odours are believed to constitute a public nuisance rather than a health hazard (Bates and Caton, 2002). However, a number of physiological manifestations of offensive odours have been reported in published literature, including nausea, vomiting, headache, loss of appetite, sleeplessness, upset stomach, and throat irritation.

Odorous emissions are often associated with industrial, institutional and agricultural operations throughout Alberta. The following sections provide details on examples of these operations.

2.1 Municipal Solid Waste Management

The collection, transfer and long-term storage of municipal solid waste (MSW) are among of the most ubiquitous sources of odorants, and in fact go back throughout human history. Today, the management of MSW typical starts with the collection of household waste by trucks, which bring it to transfer stations or directly to long-term storage facilities (e.g., landfills). In some, typically rural areas, residents will drop-off waste at transfer stations; whereas, urban waste is collected and taken to larger facilities such as the Edmonton Waste Management Centre. Once MSW is concentrated at a transfer station or landfill, the management of odour typically becomes a key concern. While fairly ubiquitous, the key odour-causing components of the MSW management system are also fairly localized such as the working face and leachate collection systems.

2.2 Municipal Waste Water Treatment

Municipal waste water treatment includes the collection and treatment of waste water from homes, businesses, and potentially the treated waste water from some industrial operations. While most components of the waste water collection system (the sewer system) may potentially generate odour, it is the waste water treatment facilities where odours tend to result in complaints. Management of odours at waste water facilities is a significant concern in many municipalities, often exacerbated by the situation of these facilities in low lying areas due to the gravity-drained nature of sewer networks. While also ubiquitous, since almost every community above a certain size will have a municipal waste water system, the key odour-causing components of the management system are also typically localized.

2.3 Composting

Composting of residential organic waste and agricultural waste has become a growing trend in recent years, and encompasses everything from residential composting bins to large-scale composting operations at MSW facilities. Odours tend to be similar in character to traditional MSW facilities, but can be more concentrated due to the increased concentration of the organic portion of the waste compared to traditionally mixed MSW streams.

2.4 Agricultural Operations

Similar to MSW management, odorants from agricultural operations have been a part of human society since the beginning. The primary odour issue at agricultural operations revolves around the management of nutrients, which includes the generation, collection, storage and eventual application of animal wastes. Facilities that have no animal husbandry component may still rely on the application of animal waste-based nutrients for crop production, which is often associated with odour complaints. Facilities that do have an animal husbandry operation (e.g. hog farms) will generate waste over time that must be collected and stored for some period of time, and which has odour generation potential. Given the large areas of Alberta dedicated to agriculture, odorants from these operations can best be described as both sporadic and relatively de-centralized.

2.5 Food Production

Food production facilities encompass a huge variety of operations, from abattoirs and meat packing plants to grain and feed mills to large industrial-scale bakeries and dairy processing plants. Given the widely varied nature of this category, it is difficult to provide a detailed discussion. Regardless, the presence of these facilities both in the urban and rural landscape often results in odour concerns, even from seemingly non-offensive operations such as bakeries and coffee roasting.

2.6 Oil & Gas Operations

The oil and gas industry is a major component of the Alberta economy, and some form of the industry can be found in almost all areas of the province. Traditional oil-sands and heavy oil operations are primarily situated in the north of the province, but the pipeline system and the network of trans-shipment facilities

(e.g., truck to pipeline to rail transfers) can be found throughout the province. Refining and other processing operations are mainly located in the Edmonton region in central Alberta, while the natural gas network covers most of the province. Odorants from the oil and gas industry vary widely in character, depending on the nature of the operation, but generalities do exist. Sour gas production generates odorants related to total reduced sulphur compounds, while heavy oil operations may generate odorants related to aromatic hydrocarbon compounds. Although the sources of odour associated with this industry may occur throughout the province, the actual sources of odorants also tend to be very localized, centred on tank vents and process exhausts.

2.7 Forestry and Pulp and Paper Industries

Large areas of Alberta are covered in forests, and the forestry and pulp and paper industries are present in many parts of the province, especially in the north and central areas. Historically, odorants from Kraft pulp mills have received considerable attention. For the most part, this is due to hydrogen sulphide and reduced sulphur compounds released as by-products. Additional, but relatively minor, odorants from the lumber industry can include the cutting of wood at sawmills.

2.8 Chemical Industries

The chemical industry is comprised of companies that produce industrial chemicals and convert raw chemical feedstock into multiple products. Because of the large variation in chemicals and processes involved, odorant emissions from these facilities can vary greatly. Many of the chemical industries in the province are located in and around the industrial parks of the urban centers. Volatile organic compounds (VOC's) can be the source of odour for many of these industries, although reduced sulphur compounds can also be associated with chemical manufacturing, storage, and handling.

2.9 Transportation

With a large network of roads, railway stations and airports, the Alberta transportation system can be looked at for potential odorous compounds. Individual vehicles can emit odorous compounds when incomplete combustion occurs, or poor maintenance results in burning of lubricating oil or other fluids. Stationary facilities such as railway stations, airports or gas stations would be more commonly associated with lingering odours. These odours would be caused from fuel storage and handling, and the high frequency of individual mobile sources.

3. ODOUR CHARACTERIZATION – FIDOL FACTORS

To completely describe the nuisance characteristics of an odour five different dimensions, commonly referred to as "FIDOL", are frequently considered:

- **F**requency – the number of times an odour is detected during a time period,
- **I**ntensity – the concentration or strength of the odour,

- **D**uration of the period in which the odour remains detectable,
- **O**ffensiveness or hedonic tone of the odour, and
- **L**ocation of the odour.

Generally, the more frequently an odour is detected, the greater the potential to lead to an odour complaint. The time of occurrence of an odour can also be important. An odour that occurs when there is a greater likelihood of people being exposed to that odour is more likely to lead to a nuisance, while an odour that occurs while people are not at home is less likely to lead to a nuisance complaint.

Intensity of an odour is a person's perception of it strength. The intensity of an odour is related to the odorant concentration, or the concentration of the compounds involved. A relationship exists between intensity and concentration, but is not proportional. A large increase in concentration may lead to only a small increase in intensity, or vice versa. The intensity of an odour is not its character, quality, offensiveness or hedonic tone (unpleasantness or pleasantness).

The duration of odour impact depends on the variation over time of the odorous emissions from the source. In addition, meteorological conditions can be a strong influence on the duration of odour impact. Stable meteorological conditions, which can be more common overnight, can lead to events of longer duration. Long periods of continuous odour exposure can have two effects; namely, adaptation and sensitisation. Adaptation is where the perceived odour intensity decreases with repeated or continuous exposure. Sensitisation is where perceived intensity increases with repeated or continuous exposure.

The offensiveness, or hedonic tone, of an odorant is related to the perceived pleasantness or unpleasantness of the odorant. This is the most subjective of the FIDOL factors, as it depends on the individual and their response to a specific odour. A person living and working in an agricultural area may be more tolerant and less sensitive to agricultural odorants than a person living in a suburban environment, for example. It must also be noted that offensiveness is not related to the odorant intensity or concentration.

The location of an odour may affect the perceived offensiveness of an odour, especially when an odour would not normally be expected in a given area or at a specific location. More importantly however is the identification of odour sensitive receptors near a given facility, as ensuring adequate separation between odour-generating activities and odour sensitive receptors

Of these FIDOL factors, offensiveness is primarily subjective in nature and therefore difficult to measure. Of course it is also one of the key drivers for complaints. A "non-offensive" odour can be acceptable to a community despite relative high frequency, intensity and duration.

Despite this, the FIDOL factors provide a useful set of terms for describing odours in the environment, and are therefore, used throughout this report.

4. EXISTING ODOUR FRAMEWORKS IN CANADA

Existing odour frameworks are present throughout Canada and the world. RWDI has previously summarized the framework across Canada. This section summarizes all provincial guidance on odour regulation and provides an update to previous work to compile these regulations (RWDI 2005; RWDI 2013).

4.1 British Columbia

British Columbia does not have any province-wide regulation regarding odour, but government of Metro Vancouver is currently undertaking the development of an odour regulation for that area. A proposed regulation was circulated in 2012, but has since been withdrawn, and it is expected that a new, and significantly altered proposed regulation, was to be posted for review in 2014. As of early 2015 the proposed regulation has yet to be posted and therefore, at this time the only regulation of odour is done through application of nuisance law.

The British Columbia Environmental Management Act (BCEMA) does not explicitly define odour, but does define “air contaminants” in such a manner that odour could be construed as an air contaminant. Additional pertinent definitions are “waste” and the phrase “introduced into the environment”.

> *"air contaminant" means a substance that is introduced into the air and that*
>
> *a) injures or is capable of injuring the health or safety of a person,*
>
> *b) injures or is capable of injuring property or any life form,*
>
> *c) interferes with or is capable of interfering with visibility,*
>
> *d) interferes with or is capable of interfering with the normal conduct of business,*
>
> *e) causes or is capable of causing material physical discomfort to a person, or*
>
> *f) damages or is capable of damaging the environment;*
>
> *"waste" includes:*
>
> *a) air contaminants,*
>
> *"introduce into the environment", in relation to waste, includes discharge, emit, dump, abandon, spill, release and allow to escape into the environment;*
>
> *SBC 2003 c53 s1 (1);*

Based on these definitions, if odour could be considered to cause or be capable of causing “material physical discomfort to a person”, it would be considered an air contaminant, and therefore a waste. Under s. 14 of the BCEMA, the introduction of waste into the environment requires a permit; therefore, the BCEMA could be interpreted to require that a facility obtain a permit for odorous discharges.

Specific to the oil and gas industry, the British Columbia *Flaring and Venting Reduction Guideline*, set out by the BC Oil & Gas Commission, does provide specific wording on odours from flares, incinerators and other gas combustion systems. Section 7.1 specifically states that:

> *i. Flares, incinerators and other gas combustion systems, including those using sour gas as a fuel for production or process equipment, must be designed, maintained, and operated so that emissions do not:*
>
> *i. result in off-lease odours, or*
>
> *ii. result in adverse impacts to public health and safety or injury to vegetation*
>
> *ii. Permit holders must modify or replace existing flares or incinerators if operations result in off-lease odours, odour complaints, or visible emissions (e.g. black smoke).*
>
> *British Columbia Flaring and Venting Reduction Guideline, v. 4.3*

Section 7.1.1 further states that a minimum combined flare gas heating value of not less than 20 MJ/m³ when flare stacks have a history of odour complaints.

Section 8 deals with venting and fugitive emissions management requirements, and Section 8.1 sets out as a general requirement that "venting must not result in off-site odours". Section 8.4 further states that:

> *Non-combustible gas mixtures containing odorous compounds including H_2S must not be vented to the atmosphere if off-lease odours may result. Alternatives to venting such gas include flaring or incinerating with sufficient fuel gas to ensure destruction of odorous compounds or underground disposal.*
>
> *British Columbia Flaring and Venting Reduction Guideline, v. 4.3*

The British Columbia Ambient Air Quality Objectives lists two 1-hour average objectives for Total Reduced Sulphur (TRS) measured as H_2S. The "acceptable" objective of 28 µg/m³ (Level B) is higher than in any other province except Nova Scotia. The "desirable" level objective of 7 µg/m³ (Level A) would not be a value used for permitting purposes, but is very stringent. No other contaminant among the Ambient Air quality Objectives is related to odour thresholds.

4.2 Alberta

Releases of odorant emissions in Alberta are generally regulated under the Environmental Protection and Enhancement Act (EPEA), but the EPEA is also not entirely clear with respect to potential impacts due to odours. In fact, the EPEA does not define the term odour, nor is "odour" included explicitly under the definition of "substance". The EPEA does define "adverse effect", as follows:

"adverse effect" means impairment of or damage to the environment, human health or safety or property.

RSA 2000 cE-12 s1;

While this does not specifically mention impacts due to odour, "impairment" of the environment or property due to odour emissions could be construed as an adverse effect.

The EPEA does specifically refer to odour in Section 116, which deals with environmental protection orders regarding offensive odours:

Environmental Protection Orders Regarding Odour

116(1) Where the Director is of the opinion that a substance or thing is causing or has caused an offensive odour, the Director may issue an environmental protection order to the person responsible for the substance or thing.

(2) Subsection (1) does not apply in respect of an offensive odour that results from an agricultural operation that is carried out in accordance with generally accepted practices for such an operation or in respect of which recommendations under Part 1 of the Agricultural Operation Practices Act indicate that the agricultural operation follows a generally accepted agricultural practice.

(3) An environmental protection order under this section may order the person to whom it is directed to take any or all of the following measures:

a) investigate the situation;

b) take any action specified by the Director to prevent the offensive odour;

c) minimize or remedy the effects of the offensive odour;

d) monitor, measure, contain, remove, store, destroy or otherwise dispose of the substance or thing causing the offensive odour or lessen or prevent the offensive odour;

e) install, replace or alter any equipment or thing in order to control or eliminate the offensive odour;

f) construct, improve, extend or enlarge a plant, structure or thing if that is necessary to control or eliminate the offensive odour;

g) take any other action the Director considers to be necessary;

h) report on any matter ordered to be done in accordance with directions set out in the order.

RSA 2000 cE-12 s116;2001 c16 s6

Neither Section 116, nor the EPEA in general provides a definition of the term “offensive”, nor a test as to what constitutes an “offensive” odour. Section 116 does however appear to treat odorous emissions more stringently than other releases into the environment. This can be gleaned from a review of Sections 108, 109 and 113 of the EPEA, and how “approved” releases are handled.

Under EPEA, releases to the environment are either approved or not approved. Under the EPEA:

> *f) “approval” means an approval issued under this Act in respect of an activity, and includes the renewal of an approval;*
>
> *RSA 2000 cE-12 s1;*

Section 108 of EPEA prohibits releases to the environment above the amount specified in the approval. Section 109 explicitly prohibits discharges that may cause an adverse effect when those discharges are not approved. Section 113 further emphasizes this issue by indicating that if a release may potentially cause an adverse effect, an Environmental Protection Order may not be issued if that release was approved. Only an Emergency Environmental Protection Order may be issued, as indicated by Section 114. Section 116, in contrast, does not refer to approvals, and therefore, an Environmental Protection Order Regarding Odour can be issued regardless of whether a source is approved or not under the EPEA.

With respect to H_2S, the Alberta Air Quality Objective is 14 µg/m³ on a 1-hour basis. The 1-hour value is the shortest averaging period for which Alberta has an objective, and is therefore, the most relevant with respect to discussing potential odour impacts. In addition to H_2S, Alberta has 1-hour objectives for ammonia (1400 µg/m^3) and carbon disulphide (30 µg/m^3) based on odour perception and odour threshold.

4.3 Saskatchewan

The Saskatchewan Environmental Management and Protection Act (SEMPA) does not explicitly define odour, but does define adverse effect, discharge and substance (2002).

> *“adverse effect” means impairment of or damage to the environment, or harm to human health, caused by one or any combination of any chemical, physical or biological alteration;*
>
> *“discharge” means a discharge into the environment and includes any drainage, deposit, release or emission into the environment;*
>
> *“substance” means any solid, liquid, particulate or gas that:*
>
> *i. is capable of becoming dispersed in or discharged into the environment; or*
>
> *ii. is capable of becoming transformed in the environment into matter defined in subclause (i);*
>
> *2002, c.E-10.21, s.2*

The Saskatchewan Clean Air Act (SCAA) does provide clear definitions with respect to odour however, as follows:

> *"air contaminant" means a solid, liquid, gas or combination of any of them in the ambient air that contributes to air pollution;*
>
> *"air pollution" means the presence in the ambient air of any air contaminant:*
>
> *i. in a concentration greater than the permissible concentration specified in a permit or prescribed in the regulations;*
>
> *ii. in quantities that are or are likely to:*
>
> *a) be injurious to the health, safety, comfort or well-being of the public;*
>
> *b) be injurious or damaging to property or plant or animal life; or*
>
> *c) interfere with normal business; or*
>
> *iii. that has an offensive or obnoxious odour, regardless of its concentration;*
>
> *1986-87-88, c.C-12.1, s.2*

The SCAA also sets out the permitting requirement for any facility, which indicates that a facility that discharges an odorant requires a permit in order to do so.

> *5 Subject to sections 6 and 7, no person shall:*
>
> *a) operate an industrial source, an incinerator or fuel-burning equipment; or*
>
> *b) alter, add to or change an industrial source, an incinerator or fuel-burning equipment in a manner that affects the emission of air contaminants;*
>
> *unless he holds a valid subsisting permit authorizing him to do so.*
>
> *1986-87-88, c.C-12.1, s.5*

The Saskatchewan Clean Air Regulation sets out the detailed requirements for obtaining a permit, which includes reference to the following:

> *ix. the expected mass rate of release into the ambient air of all air contaminants on a daily basis as well as an annual basis, under normal and maximum production conditions;*
>
> *x. information about the possible variations in the composition of any atmospheric emission or the release rate of any air contaminant under different production rates, during start-up, shut-down or upset conditions;*

> *xi. the calculated ground level concentrations of all air contaminants that may be released under normal and maximum production conditions; calculated ground level concentrations of all air contaminants*
>
> *27 Oct 89 cC-12.1 Reg 1 s3.*

In support of this requirement, Saskatchewan released the Saskatchewan Air Quality Modelling Guideline (SAQMG) in 2012. The SAQMG proposes a tiered approach to modelling, with screening level dispersion models (the U.S. EPA SCREEN3 or AERSCREEN models) acting as the basis for the first tier. If compliance cannot be demonstrated using the screening level dispersion models, a refined tier is available using the AERMOD dispersion model, which is the current regulatory model in the United States. The "specialized" modelling is available only for situations in which the first two tiers are not appropriate, such as where complex terrain or land-water interfaces are a concern or areas where a large frequency of very low wind speeds can be expected. Road and rail traffic infrastructure projects can also be modelled using the approaches in this tier.

Section 11.3 of the SAQMG provides a detailed procedure for conducting an assessment of odour impacts. Section 11.3 also provides draft recommended ambient odour criteria for odour dispersion modelling in Saskatchewan. At this time, Saskatchewan is the only province to have such detailed requirements with respect to odour published in an official guideline. It does share many similarities with the Ontario approach, discussed later in this report.

Aside from odour, the criterion for H_2S provides a useful comparison to other provinces. Saskatchewan Ambient Air Quality Standard (AAQS) for H_2S is 14 µg/m^3. No other compound usually considered odourous is reported in the AAQS since odour itself is considered in the Saskatchewan Clean Air Regulation and SAQMG.

4.4 Manitoba

Releases of odour emissions in Manitoba are covered under the Environment Act (MEA). The MEA also contains a definition of adverse effect that is similar to that provided under the EPEA:

> *"adverse effect" means impairment of or damage to the environment, including a negative effect on human health or safety*
>
> *C.C.S.M. c. E125 s. 1 (2).*

Unlike the EPEA, the MEA defines a pollutant more broadly:

> *"pollutant" means any solid, liquid, gas, smoke, waste, odour, heat, sound, vibration, radiation, or a combination of any of them that is foreign to or in excess of the natural constituents of the environment, and*
>
> *a) affects the natural, physical, chemical, or biological quality of the environment, or*

b) *is or is likely to be injurious to the health or safety of persons, or injurious or damaging to property or to plant or animal life, or*

c) *interferes with or is likely to interfere with the comfort, well being, livelihood or enjoyment of life by a person; (« pollutant »)*

C.C.S.M. c. E125 s. 1 (2).

The MEA controls the release of pollutants through a licensing process for developments.

"development" means any project, industry, operation or activity, or any alteration or expansion of any project, industry, operation or activity which causes or is likely to cause

a) *the release of any pollutant into the environment, or*

b) *an effect on any unique, rare, or endangered feature of the environment, or*

c) *the creation of by-products, residual or waste products not regulated by The Dangerous Goods Handling and Transportation Act, or*

d) *a substantial utilization or alteration of any natural resource in such a way as to pre-empt or interfere with the use or potential use of that resource for any other purpose, or*

e) *a substantial utilization or alteration of any natural resource in such a way as to have an adverse impact on another resource, or*

f) *the utilization of a technology that is concerned with resource utilization and that may induce environmental damage, or*

g) *a significant effect on the environment or will likely lead to a further development which is likely to have a significant effect on the environment, or*

h) *a significant effect on the social, economic, environmental health and cultural conditions that influence the lives of people or a community in so far as they are caused by environmental effects;*

Under the MEA, there is also an odour nuisance management strategy, which includes for the provision of the following clause on licenses for developments, where appropriate:

The Licensee shall not cause or permit an odour nuisance to be created as a result of the construction, operation or alteration of the Development, and shall take such steps as the Director may require to eliminate or mitigate an odour nuisance.

Summary of the Odour Nuisance Management Strategy (2008)

The intent of this clause is place the responsibility for odour nuisance complaints solely on the development in question, and allows for enforcement through the licensing process. Manitoba

Conservation provides a protocol that details how odour nuisance complaints from the public will be handled and the responsibilities of all parties involved.

The Manitoba Ambient Air Quality Criteria, published by Manitoba Conservation, sets out air quality criteria for 25 compounds in addition to odour. These criteria are divided between guidelines and objectives, as well as the Canada Wide Standards for ozone and fine particulate. Manitoba sets two guidelines for odour, 2 OU at residential locations, and 7 OU at industrial locations. These values are used for the assessment of potential impacts from new facilities only, and are not an enforcement tool to be used once the facility is in operation, or for existing facilities.

Aside from odour, the guideline for H_2S provides a useful comparison to other provinces. The Manitoba 1-hour "acceptable" guideline is 15 µg/m³, while the Ontario 10-minute odour-based standard is only 13 µg/m³ and the Alberta odour-based 1-hour ambient objective is 14 µg/m³. Converting the Ontario 10-minute standard to a 1 hour averaging time would result in an even greater discrepancy between the two values (using Ontario's recommended approach to converting from 10-minute values to 1-hour values[1] would give a 1-hour H_2S value of approximately 8 µg/m³). This suggests that a facility that can show compliance with the guideline or standard may still pose a significant odour impact, based on this example of H_2S. It should be noted that Manitoba's "desirable" 1-hour H_2S guideline of 1 µg/m³ is the lowest in Canada, however.

In addition to H_2S, Manitoba has a guideline for maximum acceptable 1-hour level concentrations for two other odourous compounds; phenol (63 µg/m^3) and ammonia (1.4 mg/m^3).

4.5 Ontario

The Ontario Environmental Protection Act (OEPA) defines "adverse effect" much more broadly:

> *"adverse effect" means one or more of,*
>
> *a) impairment of the quality of the natural environment for any use that can be made of it,*
>
> *b) injury or damage to property or to plant or animal life,*
>
> *c) harm or material discomfort to any person,*
>
> *d) an adverse effect on the health of any person,*
>
> *e) impairment of the safety of any person,*
>
> *f) rendering any property or plant or animal life unfit for human use,*
>
> *g) loss of enjoyment of normal use of property, and*

[1] When estimating contaminant concentrations at shorter averaging periods than an hour, 1-hour dispersion modelling results are quite often considered and a conversion factor to estimate a maximum concentration at the averaging period in question is applied (See Section 5.2). Using this conversion factor, the equivalent 1-hour concentration can be calculated.

h) interference with the normal conduct of business;

R.S.O. 1990 c. E.19, s. 1 (1)

The OEPA also defines "contaminant" more broadly:

> *"contaminant" means any solid, liquid, gas, odour, heat, sound, vibration, radiation or combination of any of them resulting directly or indirectly from human activities that causes or may cause an adverse effect; ("contaminant")*
>
> *R.S.O. 1990 c. E.19, s. 1 (1)*

In addition, the OEPA is more explicit with respect to prohibiting discharges of a contaminant, which includes odours, into the environment:

> *No person shall discharge into the natural environment any contaminant, and no person responsible for a source of contaminant shall permit the discharge into the natural environment of any contaminant from the source of contaminant, in an amount, concentration or level in excess of that prescribed by the regulations.*
>
> *R.S.O. 1990, c. E.19, s. 6 (1).*

It is also more explicit with respect to prohibiting the causing of an adverse effect:

> *Subject to subsection (2) but despite any other provision of this Act or the regulations, a person shall not discharge a contaminant or cause or permit the discharge of a contaminant into the natural environment, if the discharge causes or may cause an adverse effect.*
>
> *R.S.O. 1990, c. E.19, s. 14 (1).*

The subsection referred to in Section 14 of the OEPA refer to water treatment and agricultural operations.

Ontario has a comprehensive set of effects-based air quality standards and guidelines, and many of these are odour-based. Under Section 9 of the OEPA, discharges of contaminants into the natural environment that are below these standards and guidelines must be approved under a permitting process:

> *No person shall, except under and in accordance with an environmental compliance approval,*
>
> *a) use, operate, construct, alter, extend or replace any plant, structure, equipment, apparatus, mechanism or thing that may discharge or from which may be discharged a contaminant into any part of the natural environment other than water; or*

> b) *alter a process or rate of production with the result that a contaminant may be discharged into any part of the natural environment other than water or the rate or manner of discharge of a contaminant into any part of the natural environment other than water may be altered.*
>
> *R.S.O. 1990, c. E.19, s. 9 (1).*

If the facility is deemed to cause or is likely to cause an adverse effect, the Ontario Ministry of the Environment and Climate Change (MOECC) should be notified of this by the industry and/or their environmental consultant. Alternately, the MOECC may require a facility to include odour as part of the application for an Environmental Certificate of Approval (ECA), if the MOECC has reason to believe that odour may be a concern. Where facilities are emitting odours from a mixture of compounds, the MOECC can and will include specific terms, performance conditions and Schedules within the ECA. The restrictions applicable to each ECA are separately negotiated with the MOECC and can have different approaches to dealing with OEPA Section 14 "adverse effect" odours. Typically however, the performance condition will set a specific target in terms of allowable odorant concentration that must be met at sensitive receptors (e.g., residences, nursing homes, health care facilities, day cares, schools). This target may also allow for some frequency of excursions above the target, but not always. As such, there is a significant inconsistency from one facility to another when it comes to how odour is handled.

In April 2008 the MOECC's Standards Development Branch published a Technical Bulletin which presents how to undertake dispersion modelling in order to assess compliance with 10-minute odour based Guidelines and Standards; however, the Bulletin does not provide the framework for determining impacts for odours composed of a mix of compounds. At the end of Section 1 of the Technical Bulletin, it is clearly stated that:

> *"Ministry standards and guidelines are contaminant-specific under the context of O. Reg. 419, and are used to assess emissions from a single facility. Odour impacts are typically addressed in relation to adverse effects as defined in Section 14 of the Environmental Protection Act. As such, odour impacts due to aggregate exposure to a mixture of odorous compounds (usually expressed in odour units (OU)) are not addressed in this technical bulletin. In addition, this technical bulletin does not address odourous emissions from multiple facilities. This technical bulletin only deals with a suggested technical method for modelling assessments of contaminant specific standards and guidelines with 10-minute averages concentrations as they apply to individual facilities." [emphasis added]*

4.6 Quebec

The Quebec Environment Quality Act (EQA) does not explicitly define adverse impact, but does define odour as a contaminant:

> *(5) "contaminant": a solid, liquid or gaseous matter, a microorganism, a sound, a vibration, rays, heat, an odour, a radiation or a combination of any of them likely to alter the quality of the environment in any way;*

R.S.Q., 1981, c. Q-2, s. 1.(5)

Under the Quebec Regulation Respecting the Quality of the Atmosphere (QRRQA), promulgated under the Environment Quality Act (EQA), odour is further defined through the definition of "odour level". The regulation also provides the relevant measurement method.

> *1. (8) "odor level": the volume in cubic metres occupied by a cubic metre of contaminated air when diluted at the threshold of perception;*
>
> *R.R.Q., 1981, c. Q-2, r. 38, s. 1*
>
> *96. (i). Odors are determined according to the method entitled Standard Method for Measurement of Odor in Atmospheres (Dilution Method) published by the American Society for Testing Materials (ASTM) under No. D 1391-57 (1967) in the 1974 Book of ASTM Standards*
>
> *R.R.Q., 1981, c. Q-2, r. 38, s. 96*

Under this regulation, odour is regulated using a quantitative emission criterion. This applies only to specific industries, but the criterion for an "asphalt saturation plant" would provide some sense of comparison to a heavy oil site.

> *16. Standard: All odors discharged by a fried food plant or coffee roasting plant, by a smoke house with a capacity greater than 250 kg of meat per week, by a brewery, a distillery, a rubber recycling plant and an asphalt saturation plant shall be ducted and treated so that the concentration of odours discharged into the atmosphere does not exceed 120 degrees of odour per cubic metre.*
>
> *Odours emitted by the processes and general ventilation of a dismembering plant must be ducted and treated by equipment for the treatment of gas. The concentration of the odours emitted by that equipment must be less than 100 degrees of odour per cubic metre.*
>
> *The operating areas for the processes and the stocking areas must be located within closed premises and must be maintained under negative pressure.*
>
> *R.R.Q., 1981, c. Q-2, r. 38, s. 16*[2]

Quebec appears to be singular amongst the provincial legislation in this approach. The benefit of this method is that enforcement can be done through mandatory source testing, which can then provide a specific pass / fail determination. In this respect, it is more effective from a regulatory point of view, and provides a clear set of requirements for facility operators.

[2] This is taken from the English translation of the Quebec Legistation. 100 degrees of odour per cubic metre is assumed to actually translate to units of odour per cubic metre.

The Quebec Clean Air Regulation (QCAR) also has a set of over 116 air quality standards, many of which could be considered to be odorants. Of particular interest are the large number of 4-minute standards, most of which apply to the range of contaminants that would be expected to be odorants.

Although the QCAR does not specifically mention odour, the relationship of the 4-minute standard to odour is suggested by the Quebec *Guide De La Modélisation De La Dispersion Atmosphérique, April 2005 (GMDA)*. Section 9 of the GMDA deals with emissions of odorants, and refers to the need to assess odorants on a 4-minute basis.

Using this rationale, the Quebec 4-minute standard for H_2S is 6 µg/m³. Using the formula provided in the QCAR, converting this standard to a 1-hour basis gives a value of approximately 3.1 µg/m³, which is lower than the Alberta 1-hour objective[3]. Converting the Quebec standard to a 10-minute average using the same formula provides a value of 5.4 µg/m³, which is lower than the Ontario 10-minute standard. In fact, Quebec has the strictest H_2S standard in the country unless considering Manitoba's maximum desirable level. Thirty-six additional compounds are listed for 4 minute standards including ammonia (350µg/m^3) and carbon disulphide (25µg/m^3).

4.7 New Brunswick

The New Brunswick Clean Air Act (NBCAA) defines odour as a potential contaminant. The definition also incorporates the possible effects caused by contaminants. The NBCAA also defines the release of a contaminant.

> *"contaminant" means*
>
> *(a) any solid, liquid, gas, micro-organism, odour, heat, cold, sound, vibration, radiation or combination of any of them, present in the environment,*
>
> *(i) that is foreign to or in excess of the natural constituents of the environment,*
>
> *(ii) that affects the natural, physical, chemical or biological quality or constitution of the environment, or*
>
> *(iii) that endangers the health of human, plant or animal life or the safety or comfort of a human, that causes damage to property or plant or animal life or renders them unfit for use by persons or that interferes with visibility, the normal conduct of transport or business or the normal enjoyment of life or use or enjoyment of property,*
>
> *(b) any pesticide or waste, or*
>
> *(c) anything that is designated by the Minister as a contaminant under s. 7;*

[3] When estimating contaminant concentrations at shorter averaging periods than an hour, 1-hour dispersion modelling results are quite often considered and a conversion factor to estimate a maximum concentration at the averaging period in question is applied (See Section 5.2). Using this conversion factor, the equivalent concentration for additional averaging periods can be calculated.

S.N.B. 1997, c. C-5.2, s. 1.

> *"release", when used with reference to a contaminant or other matter regardless of form, includes the discharging, emitting, leaving, depositing or throwing of the contaminant or other matter and the doing of or the omission to do any other activity in respect of the contaminant or other matter, with the direct or indirect result that the contaminant or other matter enters the air, whether or not the contaminant or other matter previously existed in the air;*

S.N.B. 1997, c. C-5.2, s. 1.

The New Brunswick Air Quality Regulation, promulgated under the NBCAA, sets out air quality standards for 6 compounds, but does not explicitly regulate odorant emissions. Furthermore, it is not clear that the air quality standards for the compounds listed include odour as an effect. Using H_2S as an example of a compound that is typically considered an odorant, the New Brunswick 1-hour objective is 15 µg/m³, while the Ontario 10-minute odour-based criteria is only 13 µg/m³ and the Alberta odour-based 1-hour ambient objective is 14 µg/m³. Converting the Ontario criteria to a 1-hour averaging time would result in an even greater discrepancy between the two values[4]. This suggests that a facility that can show compliance with the objective may still pose a significant odour impact, based on this example of H_2S. No additional compounds that are usually associated with odour are listed in the New Brunswick Air Quality Regulation.

4.8 Nova Scotia

The Nova Scotia Environment Act (NSEA) does not explicitly mention odour, but does contain definitions for "adverse effect", "contaminant", "release" and "substance".

> *"adverse effect" means an effect that impairs or damages the environment or changes the environment in a manner that negatively affects aspects of human health;*
>
> *"contaminant" means, unless otherwise defined in the regulations, a substance that causes or may cause an adverse effect;*
>
> *"release" means to spill, discharge, dispose of, spray, inject, inoculate, abandon, deposit, leak, seep, pour, emit, empty, throw, dump, place, drain, pump or exhaust;*
>
> *"substance" means*
>
> *i. any solid, liquid or gas,*
>
> *ii. any sound, vibration, heat, radiation or another form of energy, or*
>
> *iii. any combination of any of the things referred to in subclauses (i) and (ii);*

S.N.S. 1994-95, c. 1

[4] When estimating contaminant concentrations at shorter averaging periods than an hour, 1-hour dispersion modelling results are quite often considered and a conversion factor to estimate a maximum concentration at the averaging period in question is applied (See Section 5.2). Using this conversion factor, the equivalent 1-hour concentration can be calculated.

Similar to New Brunswick, the Nova Scotia Air Quality Regulation, promulgated under the NSEA, sets out air quality criteria for 6 compounds, but does not explicitly regulate odorant emissions. Also, it is once again unclear that the air quality criteria for the compounds listed include odour as an effect. Once again using H_2S as an example, the Nova Scotia 1-hour criteria is 42 µg/m³, which is nearly 3 times the New Brunswick value. To an even greater extent than in New Brunswick, this suggests that a facility that can show compliance with the criteria may still pose a significant odour impact, based on this example of H_2S. No additional compounds that are usually associated with odour are listed in the Nova Scotia Environment Act.

4.9 Prince Edward Island

The Prince Edward Island Environmental Protection Act (PEIEPA) explicitly mentions odour under the definition of a contaminant, and contains definitions for "contaminant" and "discharge" (2012).

> *"contaminant" includes any solid, liquid, gas, waste, odour, vibration, radiation, sound, or a combination of them*
>
> *i. which is foreign to or in excess of the natural constituents of the environment into which it is being introduced,*
>
> *ii. which will or may adversely affect, either directly or indirectly, the natural, physical, chemical, or biological quality of the environment,*
>
> *iii. which is or may be injurious to the health or safety of a person or be damaging to property or to plant or animal life,*
>
> *iv. which interferes with or is likely to interfere with the comfort, well-being, livelihood, or enjoyment of life of a person, or*
>
> *v. which is declared by regulation to be a contaminant;*
>
> *"discharge" includes any drainage, deposit, release, spill, leak or emission;*
>
> *R.S.P.E.I. 1988, Cap. E-9. s.1.*

The Prince Edward Island Air Quality Regulation (PEIAQR), promulgated under the NLEPA, sets out air quality standards for 5 compounds, but similar to New Brunswick and Nova Scotia, does not explicitly regulate odorant emissions (2004). Also, it is once again unclear that the air quality standards for the compounds listed include odour as an effect. Once again using H_2S as an example, the Prince Edward Island 1-hour standard is identical to the New Brunswick standard, which again suggests that a facility that can show compliance with the standard may still pose a significant odour impact, based on this example of H_2S. No additional compounds that are usually associated with odour are listed under the PEIAQR.

The PEIAQR is also similar to the Saskatchewan regulation in that it provides a detailed list of requirements under the permitting process for sources of air emissions. Although it does not seem to have an accompanying air dispersion modelling guideline, it is more detailed than in many jurisdictions.

4.10 Newfoundland and Labrador

The Newfoundland and Labrador Environmental Protection Act (NLEPA) explicitly mentions odour under the definition of a "substance". Other relevant definitions provided are "adverse effect", "contaminant", "release" and "substance":

> *"adverse effect" means an effect that impairs or damages the environment and includes an adverse effect to the health of humans;*
>
> *"contaminant" means, unless otherwise defined in the regulations, a substance that causes or may cause an adverse effect;*
>
> *"release", except in Part X, means to spill, discharge, dispose of, spray, inject, inoculate, abandon, deposit, leak, seep, pour, emit, empty, throw, dump, place, drain, pump or exhaust;*
>
> *"substance" means*
>
> *i. matter that may become dispersed in the environment,*
>
> *ii. matter that is capable of becoming transformed in the environment into matter referred to in subparagraph (i),*
>
> *iii. heat, radiation or another form of energy,*
>
> *iv. an odour or a thing that causes an odour or which may be transformed to produce or cause an odour,*
>
> *v. an organism, whether or not it is living, and*
>
> *vi. a combination of things referred to in subparagraphs (i) to (v);*
>
> *SNL2002 CHAPTER E-14.2. s.1.*

The Newfoundland and Labrador Air Quality Regulation (NLAQR), promulgated under the NLEPA, sets out air quality standards for 22 compounds, but similar to New Brunswick, Nova Scotia and Prince Edward Island, does not explicitly regulate odour emissions. Also, it is once again unclear that the air quality standards for the compounds listed include odour as an effect. Using H_2S as an example, the Newfoundland and Labrador 1-hour standard is identical to the New Brunswick standard, which again suggests that a facility that can show compliance with the standard may still pose a significant odour impact, on H_2S alone. Besides H_2S, 1-hour ambient air quality standards for mercaptans expressed as methyl mercaptan (20 µg/m^3) and reduced sulphur compounds expressed as H_2S (30 µg/m^3) are also present in the NLAQR.

Of interest however is that the NLAQR does mandate that any new or modified facility implement the best available control technology (BACT). If a facility emits an odorant, it is therefore possible that the facility would have to implement BACT in order to minimize those emissions. This is not mentioned in any other provincial acts or regulations at this time.

4.11 International Frameworks

Besides Canadian legislation there are numerous other jurisdictions that cover odour in detail. In some countries, odour is covered in federal law, and in others, provincial and state legislation is relevant. Presented below is a list of only a few of the numerous global odour frameworks.

4.11.1 The Americas

In the United States, odour is not federally regulated as a pollutant. The most frequent resolution of odour issues is via state or local nuisance laws. Several states have nuisance based odour regulation on a dilution threshold standard; others have developed standards based on specific odour-causing compounds. In most cases, the implementation and enforcement of odour regulations are based on odour complaints by the public. A survey of state odour regulations was conducted in 2009 (Maine, 2009).

In South America, recent and current work is being done to study the impacts of odour in many of the countries. The Ministry of Environment for Chile issued the document, *Strategy for Odors Management in Chile* (2014-2017) in 2013 (Chile, 2013). A number of papers in the last few years have originated from Brazil focusing on odour assessment tools and methods overviews. Some state regulations in Brazil prohibit emission of odorous compounds in levels that will be perceptibly odorous. At least one other state of Brazil looks at odour emissions combined with technology criteria.

4.11.2 Europe

There are many jurisdictions in Europe that have successful odour management programs. Federal policy for Netherlands was first developed in the early 1970's where it related to mostly agricultural practices. The current policy aims to prevent new and reduce existing odour nuisance. The Netherlands has a source-specific approach to manage odours and a biannual national survey is conducted to gauge the level of annoyance due to odours. Germany uses a unique approach to manage odours that incorporates frequency, duration, and intensity. Hedonic tone (offensiveness) assessment is used, and pleasant odours are therefore treated differently from neutral and unpleasant odours. Germany's approach to manage odours is described more in Section 5.4. The Pollution Preventation and Control regulator (PPC) for England and Wales have defined pollution as "emissions as a result of human activity which… cause offence to any human senses." The Environment Agency for England and Wales has provided numerous guidance notes and reviews in the last 10 years relative to odour after the initial draft *H4 Odour Management* guidance note in 2002. Based on the reviews the updated *H4 Odour Management* guidance note was published in 2011. Odour management for England and Wales includes both control measures and also monitoring.

In addition, the European Committee for Standardization (CEN) formed a technical committee to unify olfactometry standards that follow ISO protocols (CEN, 2003). The EN13725:2003 standard defines an odour unit based on n-butanol as the reference odour. This protocol has unified olfactometry standards in over 18 countries and has started to be incorporated in other legislation around the world.

4.11.3 Australia and New Zealand

Odour laws in Australia started to develop in the 1970s. Legislation and concentration limits of odour vary between states and territories. Of interest is the detail of Australian guidance documents for each of states or Territory. For example, New South Wales looks at the population of an affected community to determine acceptable odour assessment criteria. The technical note outlines odour impact assessments, strategic approaches for avoiding odour along with odour sampling and analysis. In Western Australia, separation distances are used to manage odours and over 150 unique industrial sources are identified in their guidance document, many associated with odour as an impact. In New Zealand, typical odours are managed under the Resource Management Act 1991 although other legislation such as the Health Act is within the general legal framework of nuisance laws.

5. ODOUR MANAGEMENT APPROACHES

There are a wide variety of approaches for managing odours, which can be classified as being related to ambient odour levels, emissions of odours, or possibly a combination of the two. Fundamentally, the components of any of these approaches break down into a series of eight ambient-based systems, and two emission-based systems.

Ambient-based

1. Avoidance of nuisance law;
2. Ambient concentration criteria for individual chemicals (units of $\mu g/m^3$ or ppm);
3. Ambient concentration criteria for odour (units of OU, OU/m^3, OU_E/m^3 or D/T);
4. Episode duration-frequency (units of odour-hours);
5. Minimum separation distances (units of distance);
6. Odour intensity scales;
7. Odour index; and,
8. Complaint criteria

Emission-based

1. Quantitative emission criteria (units of concentration or flow rate); and,

2. Technology criteria.

These approaches are not mutually exclusive and are often used in combination in a single odour management program. The various approaches are discussed in greater detail in the following subsections.

5.1 Avoidance of Nuisance Laws

This type of law is based on either "nuisance" or "quality of life" narrative standards. The exact wording varies from jurisdiction to jurisdiction but essentially requires that odour from a facility will not result in a nuisance or cause pollution. In many jurisdictions, the only regulation related to odour is a nuisance law and all other aspects of the odour management program are simply guidelines that are not enforceable.

The term "nuisance" even in Alberta is defined differently. For example, The Agricultural Operation Practices Act, odour is classified as a nuisance if it *"interferes with the reasonable and comfortable use of a person's property"*. In the Public Health Act for Nuisance and General Sanitation Regulation nuisance "*means a condition that is or might become injurious or dangerous to the public health, or that might hinder in any manner the prevention or suppression of disease."* When referring to nuisance with respect to odour in this document, it is assumed that the definition would be closer to what is defined in the Agricultural Operations Practices Act with the assumption that health effects associated with odorous compounds are covered by other legislation.

5.2 Ambient Concentration Criteria for Individual Chemicals

Many jurisdictions in North America and elsewhere in the world have quantitative ambient concentration criteria for individual chemicals that are odorous. All the criteria that were found during the literature search are summarized in Table 5.2 (see Tables section). The regulatory status of these criteria ranges from guidelines or objectives to enforceable standards. Most, but not all, of the criteria are associated with an averaging period. Very few have associated frequency criteria such as a requirement that observed concentrations must be less than the criteria value 98% of the time. Therefore, these values are assumed to be maximum criteria. Similarly, few of the criteria are associated with a specific land use, and therefore, are most likely applicable at any receptor beyond the facility boundary.

Dispersion modelling used to predict concentrations of a compound usually considers hourly averaging times. A human nose, though, can pick up an odour in seconds. Averaging time for measurements of many odorants usually fall between these two extremes. This leads to a unique issue when comparing odorous substances with ambient background criteria. For odourous substances, many jurisdictions use the 1-hour averaging period, even though it may not be representative of how long an odour could persist. Other jurisdictions have shorter averaging time periods but use 1-hour dispersion modelling results and apply a conversion factor to estimate likely maximum concentrations at the averaging period in question.

This is a limitation of most dispersion models, as the majority of regulatory approved models in Alberta do not support prediction of ambient concentrations using sub-hourly averaging periods. For example in Ontario ten-minute averaging periods are considered while in Quebec four-minute averaging periods are considered. The conversion factor would result in higher predicted concentrations at shorter averaging periods.

5.3 Ambient Concentration Criteria for Odour

Odour is commonly measured using an odour panel, which consists of a number of specially trained personnel. The European, Australian and American standards are the most commonly used for measuring odour using an odour panel. The general concept behind these methods is to dilute air samples with known amounts of odour-free air using an olfactometer or scentometer. The most diluted samples are presented to the odour panel first. Less dilute samples are gradually presented to the panel until 50% of the panel can detect an odour. This is defined as the odour detection threshold. By definition, the odour concentration at the detection threshold is one (1) odour unit per cubic metre of gas at standard conditions (OU/m^3). Higher odour concentrations are expressed in terms of multiples of the detection threshold. For example, if an odour sample must be diluted with 10 equivalent volumes of odour-free air then the odour concentration is 10 OU/m^3.

In some jurisdictions the volume units are ignored and just OU is used. Some European countries, such as the Netherlands, use units of OU_E/m^3 to differentiate between odour concentrations determined using the European standard and concentrations determined using a previous national standard. In the USA, the unit dilutions to threshold (D/T) is used. Korea uses units of odour concentration (OC), which appear to be equivalent to odour units (OU/m^3) because they are a multiple of dilution, where the gas has been diluted until an offensive odour is no longer detectable to the human sense of smell. All of these units are conceptually equivalent (i.e., 1 OU = 1 OU/m^3 = 1 OU_E/m^3 = 1OC = 1 D/T); however, differences in the standard methodologies can lead to differences in the measured odour concentration.

Table 5.3 summarizes ambient odour criteria that for many different jurisdictions. Some of the sources of information were review papers, not the original source documents, and as a result it was not always clear whether the criteria were standards or simply guidelines. In many cases, especially in the USA, the criteria were used specifically for wastewater treatment plants (WWTP) or composting facilities and do not appear to be overall standards for all source types.

Some jurisdictions also apply a frequency limit that allows for a small number of excursions above the specified standard or guideline. This allows for rare meteorological anomalies that result in poor dispersion or instances where a particular source and receptor orientation, combined with worst-case meteorological condition result in rare but elevated concentrations.

As air quality regulation has evolved, two primary standards have developed for the measurement of odours. The first is ASTM International E679-04: Standard Practice for Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits (ASTM E679-04). The ASTM E679-04 Method of limits was developed in 1979 with revisions in 1991 and 2004. The ASTM

E679 is based on a triangular forced choice (TFC). Three samples are provided to the panel where one contains the diluted odorant while the other two samples are blank. A panel member chooses between the three samples and identifies it as a guess, a detection or recognition. The odour panel consists of 5 to 12 trained individuals with no specific hypersensitivity or lack of sensitivity to odours. The results are presented as odorant concentration derived from the panel's response to the laboratory dilution.

The second is the unified European Union Standard EN13725:2003: Air Quality – Determination of Odour Concentration by Dynamic Olfactometry. The European Union Standard EN13725:2003 has been adopted by the European Union with the standard being approved and published in 2003 after a number of years of testing in nineteen different laboratories. The European Union Standard EN13725:2003 takes into consideration sampling procedures, sample containers, olfactometer construction and operation, the olfactometer and interface with the panel member, the odour testing room, methods of data processing and selection, training, and performance of the panel members. A potential panel member must meet predetermined repeatability and accuracy criteria based on a standard odorant of n-butanol.

The EU standard is more stringent than the ASTM standard, with additional requirements of EN13725 improving repeatability, reproducibility and accuracy of odour analysis performed in the laboratory, and has also been adopted by Australia and New Zealand, which refer to their respective standards as AS4323.3-2001 and NZ4323.3-2001. The EN13725:2003 standard has also been referred to in several Asian countries and a number of government agencies throughout North America. A study conducted in the 2001 found that laboratories working in compliance with the proposed EN13725 standard at the time achieved a significantly better repeatability and were closer to acceptable thresholds than other laboratories. Although, one of the most reliable techniques to measure odour, it has been scrutinized as illustrated by the relatively recent British Columbia court case, which is discussed in more detail in Section 8.

5.4 Episode Duration-Frequency

Germany has a unique system for assessing whether a nuisance odour is significant that considers not only the intensity of an odour, but also its duration and frequency (i.e., four of the five FIDOL factors). They assess the existing odour impact in the field, using a systematic process, and add to it the predicted odour impact of a new or modified facility. The total odour impact is compared with immission limit values, which are relative frequencies of odour-hours. It is permissible for odours to occur more frequently in industrial or commercial areas.

The word "immission" is used in the sense of influence of air pollutants, in this case odour, on humans. This establishes an active view of air pollutants influencing receptors, in contrast to the passive view of receptors being exposed to air pollutants. If this semantic difference is ignored, "immission" can be interpreted as exposure (Germany, 2003).

5.5 Minimum Separation Distances

Many jurisdictions manage nuisance, including odours, using minimum separation distances or buffer zones, especially for the agricultural sector. In fact, in a number of jurisdictions, odour issues related to agriculture are handled by a different department or ministry than odour issues related to industrial sources. For example, in Ontario, odour from industrial sources is regulated by the Ministry of the Environment; whereas, minimum separation distance between farms and non-farm uses in rural areas are regulated by the Ministry of Agriculture, Food and Rural Affairs.

Minimum separation distances tend to be either fixed or variable, depending on a number of factors. Table 5.5 lists fixed separation distances used by some jurisdictions and indicates some of the jurisdictions that have variable separation distances. By and large, minimum separation distances are applied to agricultural sources, sewage treatment plants and composting.

Alberta currently has a variable minimum distance separation (MDS) regime, which is set out in the Agricultural Operation Practices Act Standards and Administration Regulation (Alberta, 2012). Tables of pre-calculated MDS are provided for common livestock types, and an equation is provided to estimate the MDS for other agricultural activities. As an example, the MDS for a typical 600 sow farrow-to-finish operation with liquid manure range from 698 m for land zoned for agricultural purposes (e.g., farmstead, acreage residences) to 1860 m for land zoned as rural hamlet, village or town without an urban fringe. This MDS regime only covers agricultural activities.

5.6 Odour Intensity Scales

A number of jurisdictions have developed semi-quantitative odour intensity scales to assist field personnel when they are investigating an odour complaint. This allows field staff to make a determination regarding the intensity of an odour without having to have special training for the use and calibration of certain equipment (such as portable digital olfactometer training) or send an odour sample to a laboratory to undergo olfactometric testing. Training would focus on being able to implement a scale that scales odour intensity. The main advantage of this approach is its simplicity. Various odour intensity scales and any related criteria are provided in Table 5.6.

5.7 Odour Index

The “Odour Index” is used in Japan to quantify the intensity of odours. The odour index is equal to ten times the log of the odour concentration (i.e., Odour Index = 10 x log (Odour Concentration)). The odour concentration is measured using the Triangular Odour Bag Method, in which a panel of six or more people are given a set of three bags, one with a sample in it and two with odour-free air. Panel members are asked to choose the odorous bag. The odorant is gradually diluted and tested until it becomes impossible to identify the bag with odour. The odour index is calculated based on the dilution rate at which the panel can no longer correctly identify the odorous bag. In the case of liquid samples, flasks are used instead of bags. The method also identifies how members of the panel should be selected, how samples should be gathered, and how test results should be calculated. Potential panel members are

screened for olfactory abnormalities using five standard odorants, in a test administered by a trained and qualified Olfactory Measurement Operator. The Olfactory Measurement Operator is an individual that hold a National Certification and has passed a written examination and aptitude test using the standard odorants. Physical and mental health of both potential panel members and Olfactory Measurement Operator is also considered. Specific sampling and testing methodologies exist for airborne samples gathered from at the site boundary, or for liquid samples collected at wastewater outfall points.

Local governments determine the maximum permissible odour index standard, which according to federal law must be in the range of 10 to 21[5]. This range has been determined to be equivalent to odour intensities between 2.5 and 3.5, the levels at which the majority of residents do not feel uncomfortable, through surveys of the relationship between odour intensity and odour index for almost all types of industry.

5.8 Complaint Criteria

Most jurisdictions have a system in place for responding to odour complaints. In many cases, there is a policy to respond to all complaints. In some jurisdictions complaint criteria are expressed in terms of a minimum threshold of complaints required before an investigation is launched or an odour is considered a nuisance. Other jurisdictions also have complaint hotlines that are staffed by the regulatory agency or an answering service that is trained in asking the complainants certain questions used in complaint documentation and reporting.

Some jurisdictions have regulations or guidelines for how the regulator will respond to complaints. Other jurisdictions also clearly set out how they will determine whether a complaint is justified or verified. Typically, once a complaint is deemed to be credible, the investigator will collect information such as the complainant name and address, location of the odour, date, time, frequency, duration of odour, description of alleged effects, description of odour observations, etc. The information is then reviewed to determine whether a nuisance condition is confirmed and whether it is injurious to or adversely affects human health, welfare, animal life, vegetation or property. The degree of enforcement is dependent on this determination. If there is a possibility of an adverse health effect, the complaint is typically prioritized for immediate response.

Another part of the complaint response process is the requirement for the creation of an odour management plan. A procedure for responding to complaints is a required element of such plans. Odour management plans can also be implemented in a more proactive fashion, as a condition for approval of new or modified facility.

5.9 Quantitative Emission Criteria

Other jurisdictions were found to have quantitative emission criteria for either odour or for specific chemicals. These criteria are listed in Table 5.9. Unlike ambient criteria, which were in two distinct formats, the format of the emission criteria appears to be different for each jurisdiction. In general, these

[5] Range has been reported as 10 to 20 (Japan 1999) and 10 to 21 (Japan 2003)

criteria limit the emissions of odourants or specific chemicals at the source, and are essentially in-stack emission limits.

5.10 Technology Criteria

Many jurisdictions have requirements for implementation of state-of-the-science control technology or similar approaches that specify required levels of odour treatment controls or best management practices for new or existing facilities. These requirements are mostly qualitative in nature. Although most jurisdictions do not stipulate which technologies or management practices must be used, some jurisdictions do specify control technologies or management practices for different types of facilities.

Examples of odour control technologies that could be considered as best management practices include: vent gas collection and treatment, vent gas condensation, chemical treatment, biological treatment, adsorption, incineration and dispersion (the last step in an odour control process). A typical control system for heated heavy oil tanks would include a vapour recovery unit (VRU) and destruction unit such as flare, incinerator, or thermal oxidizer.

In 1995, the Canadian Council of the Ministers of the Environment (CCME) published *Environmental Guidelines for Controlling Emissions of Volatile Organic Compounds From Above Ground Storage Tanks*. This guideline provides detailed recommendation for control of emissions from storage tanks, including, but not limited to the use of submerged loading pipe, proper selection, installation and maintenance of seals, vapour recovery and control systems, vapour balancing systems for loading and unloading of the tanks, and the use of pressure vacuum vents.

6. ODOUR MANAGEMENT CONSIDERATIONS

As indicated above, there are a wide variety of approaches for managing odours. This results from the difficulties in determining the best option for controlling odour impacts, which are due to the many different types of sources of odour and the varied and qualitative nature of perception of odour. Odour detection also varies between people, along with the annoyance level associated with an odour. Each management approach has its own strengths and weaknesses which are summarized in Table 6.1.

Almost all jurisdictions have multiple approaches when considering odour. Not any one approach will cover all aspects of odour management. Odour regulations can be applied for pre-emptive measures, or can come as a reactive measure. When considering methods of odour management, it is of use to determine which ones can be applied in a given context. In most cases, the method may well be adept for pre-emptive measures but would not be able to assist in reactive measures or vice versa. In other cases, a management practice that works well for one type of source or facility may not be suited for another type of source. For example, the minimum separation distance approach has been used for agricultural sectors in many jurisdictions, but is harder to apply to industrial facilities that are already established.

Odour legislation can be considered in three different tiers such as:

- Proactive and preventative;
- Ongoing monitoring; or,
- Reactive.

At the planning stage, odour legislation that is proactive and preventative would be considered. Methods such as minimum separation distances and technology criteria would aid in the permitting process. Once a facility is built, ongoing monitoring for odorants can occur. Methods such as the ambient concentration criteria for individual chemicals or odorants could be considered. When an odour issues arises, avoidance of nuisance laws or complaint criteria would be the methods typically referred to. Many methods can be used for more than one of these tiers; for example, odour intensity scales can be used as a tool for ongoing monitoring but can be used as a reactive tool once an odour issue has been determined.

Furthermore, the components of any of these approaches break down into either ambient-based systems, or emission-based systems. These approaches are not mutually exclusive and are often used in combination in a single odour management or regulatory program, and each has relative merits and shortcomings.

Besides the different tiers, different types of facilities must be considered. Ambient concentration criteria for individual chemicals or odours may work well for ongoing monitoring at a large facility that has continuous emissions. This method may be considered excessive for a smaller facility, such as a small agricultural facility, that may only have odour issues when spreading manure on a seasonal basis. Similarly, preventative measures for a large facility may include looking at technology criteria along with determining predicted odorant concentrations in the surrounding region. For a smaller facility, preventative measures may be as simple as to hold off an activity if the wind is blowing to or from a certain direction. When considering amalgamating odour criteria across sectors, benefit vs. cost must also be considered. A method that may be appropriate for one facility may have unreasonable or have unjustifiable financial implications for another facility. On the other hand, a method deemed appropriate for a smaller facility may not take into account all considerations when compared to a larger facility. Additionally, the idea of ownership of odour must also be considered. The question can arise when considering the difference between leasing and owning lands and/or a facility, or when a change of hands of ownership of a facility occurs. It is assumed that operating a facility would carry responsibilities associated with emissions, including odourous ones, regardless of ownership.

Fundamentally, the quantification of odours can be difficult, and therefore, any method must address this in some manner by providing clear guidance or criteria for how an odour will be quantified. Odorants can consist of a single compound or can be made up of a complex mixture. Variations of odours are due to many different factors including, but not limited to, source type, meteorological conditions, and strength of the odour at the source. There is no single technical fix that can be applied to all the different causes of

odours. Even when a single method for odour regulation is considered, there are multiple factors to consider within that method.

Legislation for regulating odour in Alberta was discussed in Section 4.2. There are number of large gaps in Alberta's current odour legislation. The first is ambiguity of many of the terms associated with odour. The EPEA refers to odour in Section 116, but does not define the term odour, nor "offensive" which can be subjective.

Individual sectors address odours in differently. For example, The Agricultural Operation Practices Act (AOPA) (Alberta 2012) provides standards for environmental management for the livestock industry, with confined feeding operations required to meet minimum distance separation distances and has a phone line for complaints of livestock operations which would include odour complains. The Alberta Energy Regulator addresses complaints about off-lease odours with inspection staff verifying off-lease odours with the use of data monitoring of certain compounds that may be associated with odours may be used in the investigation, if available.

7. RECOMMENDATIONS

Many odour management approaches were considered to guide recommendations for legislation in Alberta. The assumed goals of any regulatory approach would be to reduce, minimize, or eliminate the occurrence of off-site odours as a result of industrial, institutional and agricultural operations. Any regulation would need to provide a method to measure whether the objectives of the regulation are being met. Ideally, any regulatory approach would provide a linked framework that includes consideration of odour during the initial application for approval to operate through initial screening, followed by monitoring or measurement to demonstrate ongoing compliance with regulations, and to provide a means by which to address any concerns The legislation would focus firstly on proactive and preventative measures to minimize or prevent odour off-site and any associated odour related conflicts and complaints. Secondly, legislation would focus on monitoring and reactive measures that are quantifiable so that corrective actions or enforcement could be carried out in a timely manner. Finally, a means by which to evaluate the effectiveness of the regulation should be included.

Multiple approaches for odour management would be needed to be incorporated into any odour regulation or legislation in order to make it applicable and viable for all parties across several sectors. Of the ten approaches reviewed, three were identified as key approaches capable of driving a regulatory framework, three may be considered as supporting approaches, and four approaches were deemed to be not applicable or appropriate in the Alberta context. Due to the complex nature of odour, as well as the numerous industries operating within Alberta, recommendations are split into two different frameworks; application for new developments, and odour management for existing facilities. When considering new developments, any regulation would be described as proactive and preventative. When evaluating existing facilities, odour regulation would be focused on monitoring or reactive measures. As no single approach is sufficient to efficiently encompass odour management in all instances and applications, the framework approach presented below aims to address factors such as an operator's size, the nature of

their business, as well as many others. The key approaches and supporting approaches are discussed in detail in the following section and the four approaches that were viewed as not applicable for Alberta are discussed in detail in Section 7.3.

7.1 Recommended Odour Regulation Approaches

As described above, three key odour management approaches are recommended for the regulation of odour in Alberta, which include:

- Minimum separation distances;
- Ambient concentration criteria for odour ; and,
- Complaint criteria.

These approaches would be encompassed within one or more of the three regulatory tiers outlined in Section 6, namely: proactive and preventative, ongoing monitoring, or reactive. The three key approaches can be supplemented by using three supporting approaches and would be used either in conjunction with or as a stand-alone approach which would be determined on a case-by-case basis and would include:

- Technology criteria;
- Odour intensity scale, and;
- Ambient concentration criteria for individual chemicals.

7.1.1 Proactive and Preventative Legislation

Minimum separation distances and ambient concentration criteria for odour would be used during the facility/operation approval application process. The minimum separation distance approach would be aimed at smaller facilities, such as agricultural sources, sewage treatment, and composting facilities but may be applicable to larger facilities in areas that are remote. Currently, minimum separation distance is used for some facilities in Alberta but is quite often not associated with odour potential, but more commonly for safety reasons. Once implemented, this method is a viable low cost management approach and would be crucial for small business applications. The minimum separation distances approach may not be ideal for larger facilities, nor may it be applicable for facilities wishing to expand in regions where build up has occurred. For smaller facilities, the minimum separation distance requirements may be deemed adequate and would reduce cost to assess odorants for new developments. This method would also allow for quick turnaround in the approvals process, and is a proactive method when considering future planning at facilities or urban planning.

When considering the minimum separation distance in Alberta, consideration of what constitutes a small business would have to be taken into account. Currently, only a few sectors use the minimum separation approach in Alberta for odour regulation purposes (i.e., agricultural industry), but other jurisdictions have applied the method for numerous sectors (i.e. Western Australia uses separation distances to manage odours and over 150 unique industrial sources are identified). Currently the minimum separation distance

in Alberta is based on the type and size of the operation. These would have to be considered if applying this method to other sectors. The decision on what facilities and what size of facilities could use the minimum separation distances vs. ambient concentration criteria for odour would have to be determined before final legislation occurred.

For larger facilities, or in areas of higher build up, odorant concentrations can be predicted using dispersion modelling. The ambient concentration criteria for odour approach can be used as a proactive and preventative tool for predicting possible odour issues at a facility. Saskatchewan has taken this approach in recent years to predict concentrations and a section is included in the Saskatchewan *Air Quality Modelling Guideline* (2012). This method is applicable to a large range of odorants and can be used for complex odours when multiple chemicals can be involved in producing the odour. The largest challenge when considering preventative and proactive methods with this approach is to determine odour emissions from a facility before it is built. Additionally, this method can be used when a facility wishes to expand or modify a current industrial process and there is the possibility of increased potential for odour.

When considering the ambient concentration criteria, there are a number of items that would have to be considered before it became part of legislation in Alberta. If preventative predictive modelling, such as that described above, is to be considered, emission factors associated with odour would have to be determined. As outlined in Section 5.3, consideration on the value set for the ambient concentration criteria for odour would have to be taken into account, along with the decision if some outliers outside the criteria would be acceptable. The ambient concentration criteria for odour in Alberta would presently be considered non-existent or in its infancy stage. Additional stakeholder support and consultation would have to occur as the details of the method are studied. Other jurisdictions such as Saskatchewan have now provided a path in which to watch closely.

Technology criteria can be useful to aid in facilities when attempting to reduce odour impacts, or for project planning. Although this is a strong technique to reduce odour impacts, any regulation to pursue best available technology economically achievable (BATEA) during the planning stages may create a situation that would suggest an investment where odour may not be an issue. Additionally, BATEA does not guarantee an odour-free emission. Therefore, although the technology criteria approach may be useful as a supporting odour management approach for proactive and preventative measures to reduce odorants in the planning stages or reactively in an attempt to lower odours based on complaints, is it not a technique that is recommended to drive odour regulations.

7.1.2 Ongoing Monitoring Legislation

The ambient concentration criteria for odour method can be carried forward once a facility is approved and ongoing monitoring may be required to validate or evaluate permitted conditions. Well known methods (as discussed in Section 5.2) have already been developed, studied and implemented for measurements of odour. The European Union Standard EN13725:2003 (2003) has been well established in many jurisdictions and is more stringent than the ASTM E679-04 for measuring odours. EN13725:2003 is considered reliable and reproducible, and is recommended. In BC, this odour unit has been scrutinized for regulatory purposes (see Section 8.1) but no other method for odour measurement

has been recommended to take its place. As mentioned in Section 5.2, laboratories that have adopted the EU standard achieved significantly better repeatability and were closer to acceptable odour detection thresholds than laboratories that do not follow this standard. The ambient concentration criteria for odour approach is applicable to a large range of odorants and can be used for complex odours. As part of a management plan to monitor odour, a facility could proactively conduct ongoing odour measurements around their facilities. This practice could aid in determining the cause or conditions that cause an odour, allowing the facility to best manage that aspect of their activities.

The odour intensity scale odour management approach may be used as a supporting approach to assist field technicians. This could be used to assist the investigation of an odour complaint and allows field staff to make immediate determination regarding odour intensity. Facility operators can also use their own staff to self-monitor in an effort to identify potential odour issues. This method would be cost efficient compared to other management approaches, and multiple locations can be assessed with little time and effort. Because of the subjectivity associated with this approach, there are others, such as the ambient concentration criteria for odour that would be more quantifiable and thus, more easily enforced. Coverage of remote areas in Alberta may also be difficult. Therefore, although useful as a technique to aid managing odours, it is not recommended as a key regulatory approach in Alberta.

The ambient concentration criteria for individual chemicals approach may be viable for some institutions where only one odorous compound is released and/or can easily be identified. Because of the complex nature of odour, an odour may not be captured based on the individual chemicals, and therefore the ambient concentration for odour approach is deemed to be superior for the majority of applications.

7.1.3 Reactive Legislation

For reactive legislation, complaint criteria, in combination with the ambient concentration criteria for odour approach allows the focus to be in areas where high impacts occur. Complaint criteria focuses on areas where a potential problem exists; while the ambient concentration criteria for odour approach would allow for quantitative assessment of the issue. The complaint criteria method is implemented in Alberta currently with the Natural Resource Conservation Board (NRCB), along with the City of Edmonton.

As an example, the NRCB developed its odour assessment process in order to better manage odour complaints associated with confined feeding operations in a consistent and transparent manner. Inspectors investigating an odour complaint determine whether the odour disturbance is inappropriate using FIDO criteria (frequency, intensity, duration, and how objectionable it is). This process has made it easier for NRCB staff to deal with complainants and to resolve odour issues with operators to avoid reoccurrences. Odour information collected can also be analyzed to determine whether or not changes can be made to a facility to help mitigate the weather related frequencies of odour (A. Stuparyk, personal communication, February 19, 2015).

Ultimately, this method is easily applicable and has relative low costs associated with it, since it is the dependent on residents providing insight to the occurrence of potential odour problems. The complaint criteria method allows the focus to be at areas where odour is of concern to the residents and allows for

focused investments (both financial and time) in areas where odour concerns are predominant. Complaint criteria are well established in practice in most jurisdictions and provides an interaction between the public and the regulating body.

The odour intensity scale approach may be used here to support complaint criteria to solidify investigation procedures. Should a complaint be investigated and confirmed, the ambient concentration criteria for odour approach may also be used to determine if odorous emissions from a facility or operation result in a departure from permitted or approved operating conditions.

Finally, a link back to ongoing monitoring should be provided within the reactive legislation umbrella to ensure complaints that have been investigated and confirmed are being addressed.

7.2 Regulatory Process

7.2.1 New Developments

Applications for new facilities would need to consider if a potential offensive odour may occur off-site. If an odour could potentially be detected off-site, a flowchart similar to Figure 7.1 would be considered. The first consideration for odour management would be the minimum separation distance legislation. This legislation would be important for smaller businesses such as small agricultural practices or community-based businesses. There is also potential to use this approach in areas of low population density. If minimum separation legislation is applicable and can be followed, there would be no further assessment of odour required for new facilities.

If minimum separation distance legislation is not applicable or cannot be followed, additional considerations would need to occur. Reasons to bypass the minimum separation distance criteria can vary, such as an expansion on an existing facility, or a facility wanting to address potential odour using an alternate approach. Additional consideration once the minimum separation distance criteria is bypassed would involve identifying all potential odour sources and selecting an appropriate odour impact assessment. An odour impact assessment would look at predicted ambient concentrations for odorants, and if required, potential impacts off-site from the new developments along with partial experience in using odour management techniques for the specific sector. An odour impact assessment would vary dependent on the sector, the size of the facility, and the potential of off-site odours. Predicted ambient concentrations would be determined by the ambient concentration criteria for odour management approach. As a side consideration, if an individual facility is expected to produce only one odourous compound, an argument could be made to focus on that individual compound. The ambient concentration for an individual chemical approach could be applied, provided that the facility offers a reasonable argument why the preferred ambient concentration criteria for odour approach was not used. If the relevant guidelines for odours are met, no further assessment of odour is required.

For assessments that determine potential nuisance odours may be an issue, the proposal must be refined in order to reduce or manage odorous emissions. This can be done by a number of methods including ambient monitoring, limiting emissions during certain meteorological conditions if possible, proposing best

management practices, or proposing best economically available technology. Although legislation would not be driven by instituting technology criteria for managing odour, the approach would be used as a technique to aid facilities in reducing odours, especially when technologies are proven to increase performance. Once the proposal is refined, the impact of odour would once again be assessed to determine if the guideline would be met. If a refined proposal cannot meet the relevant odour criteria, the proposal should not be approved unless additional refinement can be made and the outcome with these refinements needs to be demonstrated or the proponent provides a detailed management plan pertaining to odours.

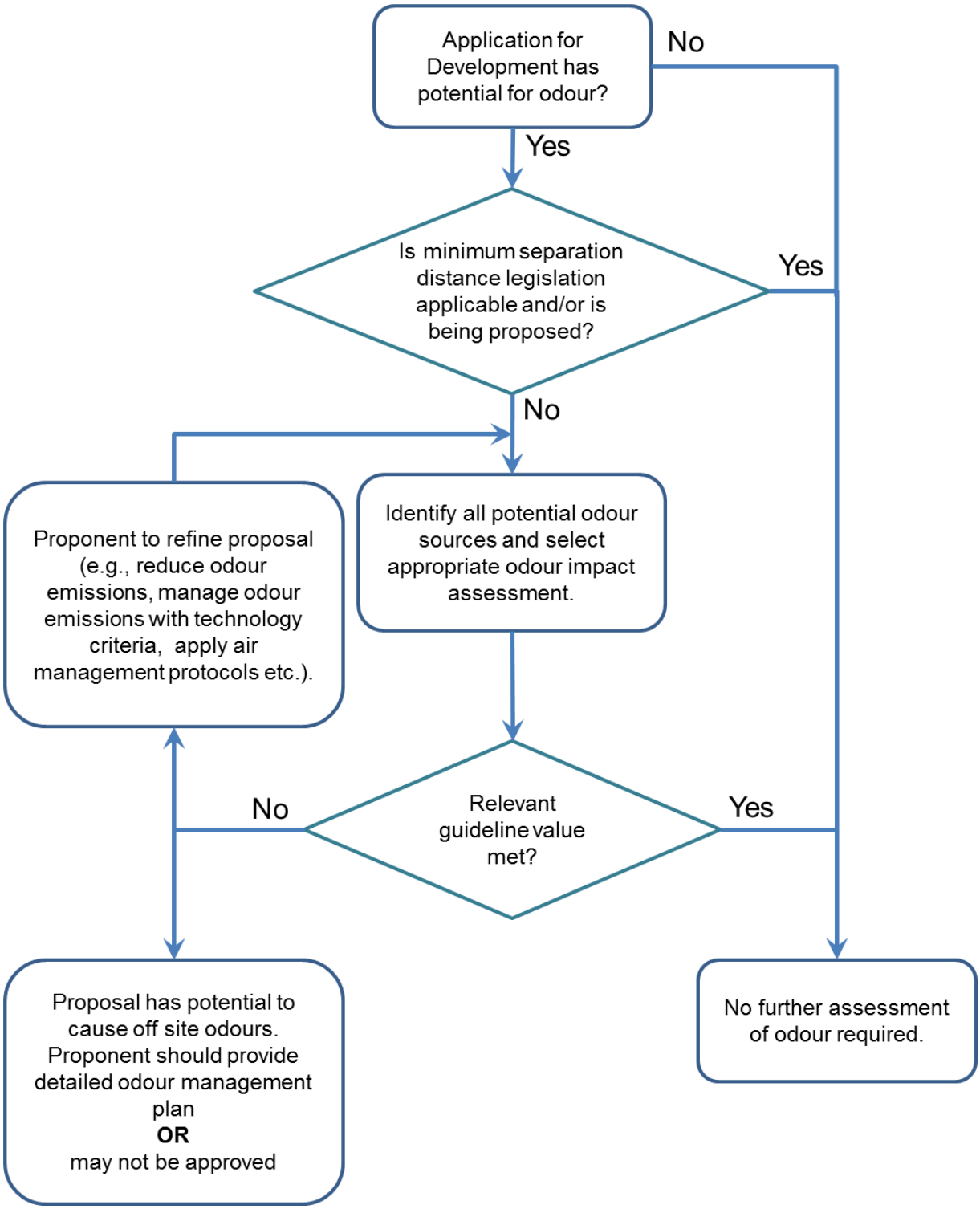

Figure 7-1: Example flowchart for determining what measures would be required to reduce potential odour issues when applying for new facilities or developments.

7.2.2 Expansions and Changes at Pre-Existing Facilities

Pre-existing facilities may decide to expand, which could lead to potential odours occurring off-site. Additionally, new processes at a facility may lead to new odours. When a facility wishes to expand, or change operations, similar considerations to when a new facility is being proposed would need to be considered. Historic odour incidents related to the existing facility would be considered along with any proactive management that the facility has carried out.

7.2.3 Encroachment of New Residential Developments

Encroachment of new residential developments towards existing facilities would also need to be considered when looking at expansions of pre-existing facilities. Depending on the size of the facility and/or the extent of encroachment, minimum separation distance legislation may be viable. Alternately, a more detailed impact assessment may be needed. Special consideration of the extent of encroachment and the type of encroachment (i.e., residential vs. industrial) could potentially be addressed in an updated management plan. The defence of "we were here first" normally carries no legal weight in situations dealing with environmental concerns, so the encroachment of residential developments toward pre-existing facilities carries significant potential risks for the continued operations at the facility. This precedent has been set in Ontario in particular, where no protection is afforded to a facility once encroachment occurs. Only during a re-zoning process can a facility normally restrict encroachment, or seek to have a developer pay for mitigation needed to prevent future complaints. This form of land-use planning dispute resolution is a common occurrence in Ontario, especially as former industrial areas are slated for redevelopment as brownfield sites.

7.2.4 Odour Management for Existing Facilities

Since odours can be caused by multiple compounds and individuals react differently to odours, the complaint criteria approach can be viewed as the driver for reactive odour management. This focuses on areas where odours are perceived as a problem and helps eliminate onerous investment by existing operations where odours may be a known by-product of their business that may either be accepted, or not perceived as an issue. This guides investments to be made in areas with sensitive receptors and/or where odour has been identified as a concern. Figure 7.2 illustrates a possible process to follow once an odour complaint has been received. Once a complaint is received, the odour should be investigated, confirmed and monitored. An investigation would require a trained and qualified technician to go and determine the source of the odour. A standardized investigation procedure would need to be determined, and may have similar qualities as the odour intensity scale approach. If an odour is confirmed and detected, a more quantitative approach could be taken that may include further monitoring and measurement.

It is recommended that the ambient concentration criteria for odour would be used to determine nuisance odours. This can then be compared to objectives and conditions on approvals. If odour is detected and above the acceptable level set by the regulator, but the original approval conditions were not exceeded, a re-valuation of the approval would be required. If the approval conditions are no longer acceptable, or if the operator was non-compliant, the next step would have the operator propose and implement strategies

to reduce odours. The mitigation strategies may include ongoing monitoring, upgrading technology, or reducing odorous emissions. If the mitigation strategies are implemented, a follow up investigation would occur. If mitigation strategies cannot be implemented or are not considered successful, two outcomes can occur. Negotiation processes between operator and residents can take place, or if this is not considered to be feasible, enforcement from the regulator would occur.

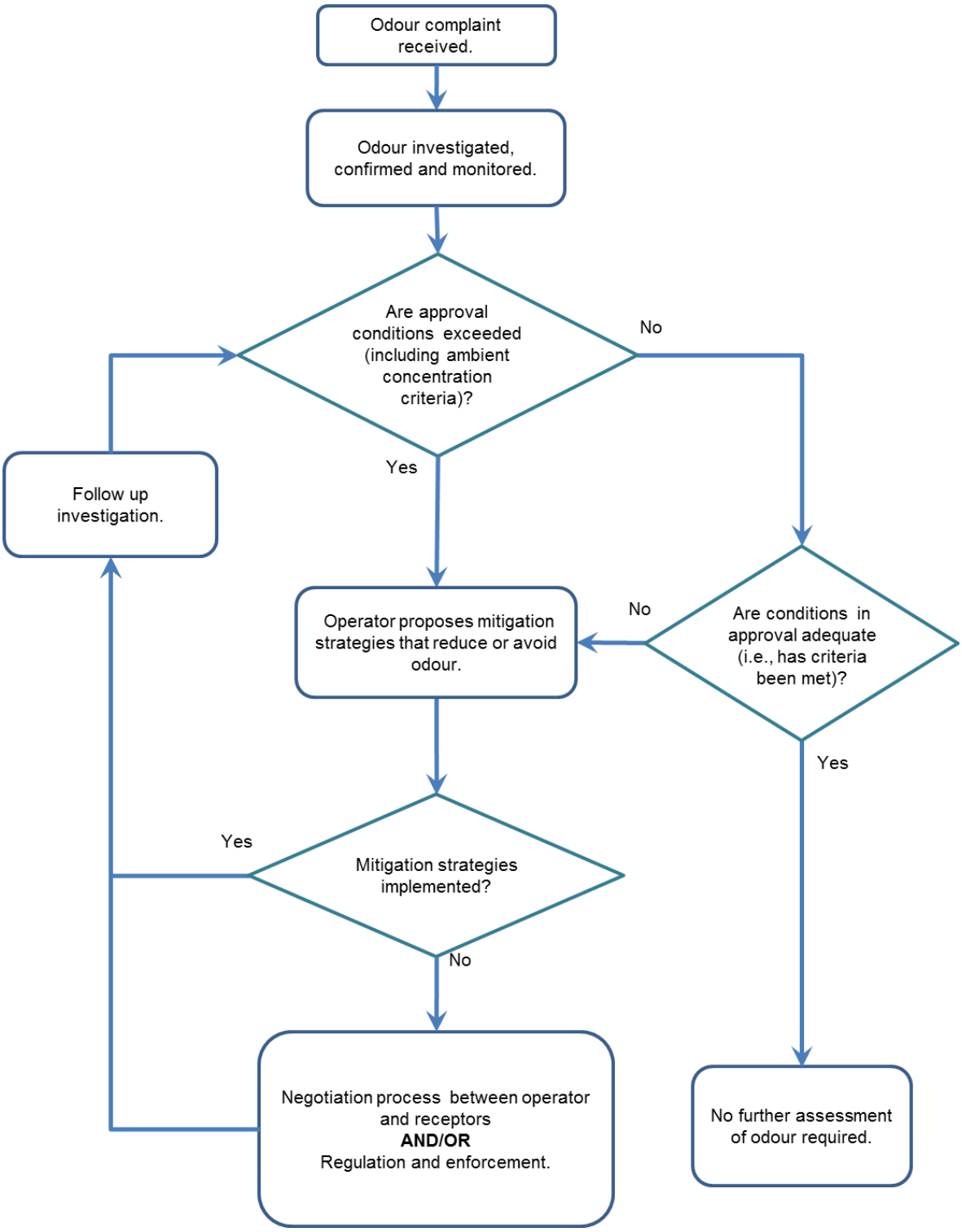

Figure 7-2: Example flowchart for odour management for existing facilities.

7.3 Approaches Deemed not Appropriate for Alberta Regulations

Four approaches were removed from consideration. When considering odour management, the avoidance of nuisance laws is similar in many aspects to the complaint criteria approach but has more weaknesses than the complaint criteria approach. The largest weakness would be that the interpretation of the definition of "nuisance" and "quality of life" may differ between two parties and the quantification of these terms. It is also difficult to quantify the quality of life since it may differ between the situation and the people involved. Avoidance of nuisance laws may be of importance in other matters, (for example, as outlined in the Public Health Act (Alberta 2014) but this approach is not recommended for regulating odours.

The episode duration frequency approach and the odour index both occur in limited jurisdictions and would likely require significant investment to understand how it would best be applied in Alberta. Furthermore, the limitations of these approaches can be addressed through other management approaches. The time frame to implement the episode duration frequency approach is greater than six months and could be considered to be both too expensive and not sufficiently responsive to odour complaints for numerous Alberta industries and applications. One of the interests of this method is that it considers other issues besides intensity that may trigger complaints. (i.e., a bakery although it may emit odours would likely not raise as many complaints as other industries). Although this may be seem straightforward in some incidences, it may be considered to be subjective and difficult to quantify. At the same time, it does consider what would be likely to cause a complaint. The consideration of duration, location and frequency is also of interest. These considerations could be incorporated into survey or questionnaire when implementing the complaint criteria method.

The odour index approach is in many ways similar to the ambient concentration for odour approach. Although perhaps strong in its jurisdiction, since it has been implemented since the 1970s, it does not bring additional strengths that are not already covered by the ambient concentration criteria for odour approach, such as its ability to be applied to a large range of odorants and sources. Similar to the ambient concentration for odour approach, sample degradation, and cost associated with testing is a weakness associated with method. Unlike the ambient concentration for odour approach though, the odour index method is not as widely used, with the use restricted to Japan. Additionally, the panel starts with the more concentrated samples and samples are diluted until the panel can no longer determine the correct bag. This may lead to some desensitizing of the specific odorant to an individual panel member.

The quantitative emission criteria approach was also removed from consideration. This method is based on emissions and would not necessarily indicate an exceedance in ambient odour concentrations at sensitive receptors. This is especially true in Alberta where meteorological conditions and changing terrain can impact the dispersion of compounds into the air just as much as emission rates. Additionally, emissions from non-point sources (such as agricultural sources) may be hard to quantify, and therefore, may be hard to determine for many smaller facilities. Many sources are not consistent over time and emission rates would likely be difficult to determine.

8. CONSIDERATIONS MOVING FORWARD

Odour is difficult to quantify, and difficult to regulate. Although recommendations were outlined in the previous section, there are additional factors to consider. A number of case studies can be reviewed to identify potential challenges associated with odour regulation.

8.1 B.C. Environmental Appeal Board dismissed odour units

8.1.1 Background

In March 2010 West Coast Reduction Ltd (WRC) appealed a decision by the Greater Vancouver Regional District to amend an existing air permit to the British Columbia Environmental Appeal Board (BCEAB) (Decision Nos. 2007-ENA-007(a); 2008-EMA-005(a)). Of particular relevance was that limits on the concentration of odour that could be discharged from the plant were measured in odour units with monthly requirements for odour testing and reporting. Dispersion modelling based on the measurements was to be conducted. WCR argued that the amendment decision was inappropriate because it imposed a new unit of measurement into British Columbia without considering process. WCR submitted that odour units should not be used in a permit for compliance and enforcement purposes given their subjective nature and their shortcomings with respect to accuracy and precision. The BCEAB concluded that measuring odour via odour units is “only a measuring tool” and is not the mechanism for change.

8.1.2 Discussion

Although the BCEAB dismissed odour units as a regulatory tool there was no additional method of quantifying odour proposed. The BCEAB recommended that WCR continue to provide emission samples for odour testing for information and monitoring purposes.

Included in the BCEAB decision were references to a number of odour management approaches that had already failed. These approaches included, but were not limited to;

- Measurements of specific compounds (i.e., VOCs or H_2S). It was determined either that there was no correlation to WCR emissions, or the compounds were emitted at such low levels as to be undetectable;
- Technology criteria. It was noted that implementing various odour control technologies over several years and investing millions to reduce odour did not correlate to a reduction in the complaints in the community; and,
- Complaint criteria. It was noted that an increase in complaints in the community could be due to many factors such as increased awareness and changing demographics in the neighborhood.

Therefore, although measurements of odour units were considered to be subjective in the case, no other method was outlined to quantify and regulate the odour associated with WCR. Of additional interest is the point that odour panel members were selected based on their sensitivity of n-butanol. It was argued that no relationship exists between the sensitivity of a single compound and an odour sample collected in

the field. Although BCEAB dismissed odour units as a viable regulating tool for this case, there is currently no method for regulating odours in place in BC, besides the complaint criteria and ambient concentration criteria for individual compounds.

Based on legislation in BC, odour is not regulated but air contaminants are. Regarding this case, odour was argued to be an air contaminant as defined as "any substance that is emitted into the air and that causes or is capable of causing material physical discomfort to a Person or capable of damaging the Environment. Part of the decision of the Appeal Board was to determine if odour constitutes a "substance". It was determined that even though an odour was not a substance, it is something that is capable of causing air pollution. As illustrated in this case, clear definitions of all terminology would have reduced the work of the BCEAB.

Discussion on the number of complaints, and the way that these complaints were handled, left room for interpretation. An increase in the number of complaints in the years following up to the Appeal had increased, although it was brought forth that it may not necessarily be an increase in odorant concentration but rather the changing demographics and the increased awareness in the neighborhood. Additionally, it was noted that not all odour complaints were independently verified by the regulating body, and are considered substantially verified if wind direction and the odour description is consistent with odour from WRC. It was also noted that other facilities may contribute to some of the complaints in the area. This case study also illustrated the geography and meteorology of an area is of importance when studying the dispersion of odorants. It was noted that some areas closer to the facility did not have as many complaints about odours. The large stack on site was argued to disperse odorants further downwind, leading to some areas close to the plant having little to no odours relative to areas further downwind.

8.2 Peace River Hearing

8.2.1 Background

In response to concerns raised by residents with respect to odours in the Peace River and Three Creeks areas of Alberta, the Alberta Energy Regulator conducted an inquiry in 2013-2014 which:

- Considered concerns of local stakeholders and residents regarding hydrocarbon emissions and odours from cold heavy oil production facilities and related impacts;
- Examined expert information about the linkage between odours, and human and animal health;
- Reviewed existing Government of Alberta and AER policies and air quality standards;
- Explored possible technical and regulatory solutions;
- Assessed the potential impacts on licensees/operations of facilities of mandating reduction or elimination of emissions; and,

- Considered information about the area's reserves and royalty potential, including the potential economic, social and environmental impacts of any recommendations made by the inquiry panel.

The inquiry focused on heavy oil operations involving five main operators and followed several years of scientific investigation, ambient air quality monitoring and public meetings between stakeholders, industry, and government.

8.2.2 Recommendations

Several recommendations were provided by the AER in their final report (AER, 2014). Some of their recommendations which are related to this study included:

- Change operational practices. For example, venting would no longer be permitted; rather, all odour-causing produced gas and tank top gas must be captured using a vapour recovery unit or VRU and the gas would be recovered, destroyed or otherwise conserved;
- Undertake monthly fugitive emission inspections of heavy oil operations and repair any leaking sources within 12 hours;
- Minimize odours released during truck loading and unloading;
- Undertake a regional ambient air quality monitoring survey with progress reporting to stakeholders;
- Amend AER Directive 060 to consider offensive off-lease hydrocarbon odours and provide a protocol for AER inspection staff to identify and issue enforcement actions related to odours; and,
- Request that ESRD assess the feasibility of defining an ambient odour objective for Alberta based on a perception threshold and not be confined to the oil and gas sector alone.

Of interest was that the traditional method of evaluating odour potential and health hazard based on H_2S content in sour gas and the Alberta Ambient Air Quality Objectives alone was not adequate. Some of the facilities in the Peace River/Reno study area were defined as sweet by the AER as the H_2S levels were less than 10 mol/kmol, or 1%, which is their definition of sour. The odours in the study area were found to be related, in many cases, to reduced sulphur species like mercaptans and petroleum hydrocarbons or a combination of these two groups. The last two AER recommendations, related to broadening the regulated definition of nuisance odour, suggest major departures from previous regulatory practices.

8.3 Ontario

8.3.1 Legislation

Ontario has a number of guidelines and technical documents that form a patchwork approach to dealing with odour issues. The Ontario MOECC D-Series Land Use Planning Guidelines provide guidance on the concept of separation distance and land use buffers. These guidelines are an additional tool to help

protect against adverse effect in Ontario; however, these guidelines are currently considered to be unsupported, as the MOECC has not reviewed or updated these guidelines since 1995.

Although Ontario does use the ambient concentration criteria for odour, it is currently tied only to the issuance of ECAs as a performance condition, and is applied generally only in cases where odour complaints have already occurred. In fact, the performance conditions imposed by the MOECC are variable, and there are no guidelines or guidance documents that define odour performance terms or limits, or how they should be developed. In fact, there are no Guidelines or Technical Bulletins dealing with odours from a mixture of compounds. These odour performance conditions have been successfully challenged and removed from ECAs in several instances, so the lack of clear regulatory process in Ontario has created a significant challenge in the regulation of odours in the province.

One area where odour issues do gain more credibility is in land-use planning processes, where the ambient concentration criteria for odour is regularly used to gauge the suitability of proposed re-zoning applications (e.g., industrial to commercial, brownfield redevelopment, etc.). This process is driven by an expert witness-led process however, and the MOECC will not get involved unless forced to do so through a hearing process. As this process is driven by competing expert witnesses, it has the potential to escalate into a lengthy hearing process if the expert witnesses do not come to an agreement.

Many practitioners in Ontario are eager to see a more clearly-defined regulatory process or specific guidance documents, as the current patchwork is not an ideal situation.

8.3.2 Legal History

The use of the ambient concentration criteria-based performance conditions in ECAs issued by the Ontario MOECC allows the prosecution of facilities under the Ontario EPA when odour impacts occur. An ECA is a legal instrument issued under the Ontario EPA that allows the discharge of contaminants into the environment. Failure to comply with an odour-based performance standard, was therefore, deemed to be a violation of conditions of the ECA, which allows the MOECC to prosecute a facility for discharges not covered under that ECA. THE MOECC has used this approach on a number of cases in the last 10 years, as well as pursuing facilities for causing adverse effects.

The 2011 case against Halton Recycling Ltd. led to a guilty plea and a $140,000 fine for two counts for discharging odour into the natural environment that caused or were likely to cause an adverse effect under the Environmental Protection Act. In a number of other situations, the MOECC used the threat of prosecution to force facilities to deal with odours prior to trial, and this approach has been effective in several instances.

8.4 Overall Lessons

Essential to the selection of a suitable odour management approach is clarity. If the approach is not clear, and well-defined, it will not work once put to a legal test. The approach should be outlined in detail, as odour is subjective, and therefore, measurements are considered to be somewhat subjective. The ability to follow clear and detailed methods removes some of the uncertainty that exacerbates issues around

subjectivity. The success of any approach will be determined through the success or failure of a legal challenge, so any approach must be selected with that in mind.

In situations where odour issues arise, or may potentially arise, good relationships between facilities and surrounding residents are a significant benefit, and should be promoted where possible, regardless of the odour management approach selected. Better relationships can lead to less time spent on responding to complaints, conducting enforcement activities, and in the courts. Negotiation can often resolve issues before enforcement is required.

The development of best practices guides are highly recommended for various categories of facilities to avoid potential odour issues, or to help identify solutions when issues do arise. Some industry associations already publish such guides, and can be used both for resolving issues and demonstrating a commitment to the community to manage odour impacts. It is not recommended that these be mandated through legislation, as many of the elements of best practices guides come down to building good relationships between the facilities and their neighbours.

Cumulative effects from neighbouring facilities, as well as location-specific geography and meteorological conditions can be an issue. Where neighbouring facilities emit odorants of a similar nature, this is especially true, and the potential cumulative impact must be considered. Certain combinations of geography and meteorological conditions may also exacerbate odour issues, and should be considered in the siting process for new facilities or developments near existing facilities. The requirement to conduct a cumulative effects assessment could be required as part of a legislative approach. This could be triggered when two or more facilities of a similar nature are located within some established proximity of one another. A methodology for determination of what facilities are considered “similar” would need to be established, but could be based on sector, feedstock, products, or other key criteria.

No one approach will apply to all situations or industries, and therefore, some flexibility is critical. Thus implementing more than one approach is likely beneficial, as it can help deal with a wider variety of situations, giving both facilities and the regulator additional options.

9. REFERENCES

Alberta, Province of. 2000. Environmental Protection and Enhancement Act. Revised Statues of Alberta 2000 Chapter E-12.

Alberta, Province of. 2012. Alberta Regulation 267/2001: Agricultural Operation Practices Act, Standards and Administration Regulation.

Alberta, Province of. 2013. Alberta Ambient Air Quality Objectives and Guidelines Summary (2013) http://environment.gov.ab.ca/info/library/5726.pdf

Alberta, Province of. 2014. Alberta Regulation 243/2003. Public Health Act, Nuisance and General Sanitation Regulation.

Alberta Energy Regulator. 2014. Report of Recommendations on Odours and Emissions in the Peace River Area – AER Response (April 15, 2014) http://www.aer.ca/documents/applications/hearings/2014-AER-response-PeaceRiverProceeding.pdf

Alberta Energy Regulator. 2001. Directive 055: Storage Requirements for the Upstream Petroleum Industry (December 2001).

Alberta Energy Regulator. 2011. Directive 056: Energy Development Applications and Schedules (September 2011).

Alberta Energy Regulator. 2014. Directive 060: Upstream Petroleum Industry Flaring, Incinerating, and Venting (May 2014)

ASTM (American Society for Testing and Materials). 2004. E679-04 Standard Practice for Determination of Odor and Taste Thresholds by a Forced Choice Ascending Concentration Series Method of Limits. Annual Book of Standards Volume 15.08.

Azocar, G. 2002. Facsimile correspondence regarding Odour Emission rates to Mr. Kirk Easto of RWDI, August 14, 2002. Ontario Ministry of the Environment, Standards Development Branch.

Bates, D.V., and Caton, R.B. 2002. A Citizen's Guide to Air Pollution. Second Edition.

British Columbia, Province of. 2003. Environmental Management Act. Statutes of British Columbia 2003 Chapter 53

British Columbia Ministry of Environment. 2013. British Columbia Ambient Air Quality Objectives, Environmental Standards Branch. http://www.bcairquality.ca/reports/pdfs/aqotable.pdf updated August 10, 2013

BC Oil & Gas Commission. 2013. Flaring and Venting Reduction Guideline. Version 4.3, February 2013.

Canadian Council of the Ministers of the Environment (CCME). 1995. Environmental Guidelines for Controlling Emissions Of Volatile Organic Compounds From Above Ground Storage Tanks (PN 1180).

CEN (Comité Européen de Normalisation). 2003. EN 13725:2003 Air Quality – Determination of Odour Concentration by Dynamic Olfactometry.

Chile, Gobierno de. Ministerio del Medio Ambiente. 2013. Strategy for Odors Management in Chile (2014-2017). Pp 24. www.sinia.cl/1292/articles-55384_Strategy_Odors_Management_2014_2017.pdf

Germany. 2003. Determination and Assessment of Odour in Ambient Air (Guideline on Odour in Ambient Air/GOAA). May 1998. Translation March 2003. http://www.lua.nrw.de/luft/geruche/GOAA_200303.pdf. Accessed January 2005.

Japan, Government of, Ministry of Environment. 1999. Offensive Odor Control Law; Ordinance of the Prime Minister's Office for Offensive Odor Control Law. http://www.env.go.jp/en/laws/air/odor/opm.html#ch1. Accessed January 2015.

Japan, Government of, Ministry of Environment, Office of Odor, Noise and Vibration Environmental Management Bureau. 2003. The Offensive Odor Control Law in Japan. http://www.env.go.jp/en/laws/air/offensive_odor/all.pdf. Accessed January 2015.

Maine Department of Environmental Protection. 2009. Report on Odor and Gas Management at Solid Waste Facilities. Pp17. http://www.maine.gov/dep/waste/publications/legislativereports/documents/odor_gasreport.pdf

Manitoba, Province of. 2012. The Environment Act. Continuing Consolidation of the Statutes of Manitoba 1987-88 Chapter E125.

Manitoba, Province of. Conservation and Water Stewardship. 2008. Summary of the Odour Nuisance Management Strategy.

Manitoba, Province of. 2005. Manitoba Ambient Air Quality Criteria. http://www.gov.mb.ca/conservation/envprograms/airquality/pdf/criteria_table_update_july_2005.pdf

New Brunswick, Province of. 1997. New Brunswick Clean Air Act. Statutes of New Brunswick 1997, c. C-5.2

New Brunswick, Province of. 1997. New Brunswick Regulation 97-133: Air Quality Regulation - Clean Air Act.

Newfoundland and Labrador, Province of. 2002. Environmental Protection Act. Statutes of Newfoundland and Labrador 2002 CHAPTER E-14.2.

Newfoundland and Labrador, Province of. 2004. Newfoundland and Labrador Regulation 39/04: Air Pollution Control Regulations, 2004.

Nova Scotia, Province of. 1994-95. Nova Scotia Environment Act. Statutes of Nova Scotia 1994-95, c. 1

Nova Scotia, Province of. Nova Scotia Regulation 28/2005: Air Quality Regulation.

Ontario, Province of. 2010. Environmental Protection Act. Revised Statutes of Ontario 1990 c. E.19

Ontario Ministry of the Environment Standards Development Branch. 2008 Methodology for Modelling Assessments of Contaminants with 10-Minute Average Standards and Guidelines under O. Reg. 419/05, April 2008.

Prince Edward Island, Province of. 2012. Prince Edward Island Environmental Protection Act

Prince Edward Island, Province of. 2004. Chapter E-9 Environmental Protection Act: Air Quality Regulations. Schedule A. http://www.irac.pe.ca/document.aspx?file=legislation/EPA-AirQualityRegulations.asp

Quebec, Province of. 2013. Environment Quality Act. Revised Statutes of Quebec 1981 c. Q-2

Quebec, Province of. 2013. Quebec Regulation 4.38: Regulation Respecting the Quality of the Atmosphere. R.R.Q., 1981, c. Q-2, r. 38

Quebec, Province of. 2011. Quebec Regulation 4.1: Clean Air Regulation, O.C. 501-2011, Sch. K. http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=%2F%2FQ_2%2FQ2R4_1_A.htm

Quebec Ministry of Sustainable Development, Environment, Wildlife and Parks. 2005. Guide de la modélisation de la dispersion atmosphérique.

Saskatchewan, Province of. 2002. Environmental Management and Protection Act. Statutes of Saskatchewan 2002 Chapter E-10.21

Saskatchewan, Province of. 1989. The Clean Air Act. Statutes of Saskatchewan, 1986-87-88 Chapter C-12.1

Saskatchewan, Province of. 1989. The Clean Air Regulations. Statutes of Saskatchewan, 1986-87-88 Chapter C-12.1, Regulation 1.

Saskatchewan, Province of. 2012. Saskatchewan Air Quality Modelling Guideline, March 2012. TRB 005.

St. Croix Sensory, Inc. 2005. A Review of The Science and Technology of Odor Measurements. Prepared for the Air Quality Bureau of Iowa Department of Natural Resources. pp41.

TABLES

Table 5-2: Odour-Based Standards for Specific Compounds in Concentration Units

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
CANADA								
British Columbia[a]	Formaldehyde	60 µg/m³	1-hour	-	-	Objective	Action (the target used when managing the level of formaldehyde in an airshed)	2005
		370 µg/m³	1-hour	-	-	Objective	Episode (the concentration that starts to be of concern to the health of the general population and is recommended that immediate steps to be taken to reduce the release into the atmosphere	2005
	Total Reduced Sulphur as H_2S	7 µg/m³	1 hour	-	-	Objective	Desirable	1977
		28 µg/m³	1 hour	-	-	Objective	Acceptable	1977
		3 µg/m³	24-hour	-	-	Objective	Desirable	1977
		6 µg/m³	24-hour	-	-	Objective	Acceptable	1977

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
Alberta[b]	Ammonia	1,400 µg/m³	1 hour	-	-	Objective	Based on odour perception	2005
	Hydrogen sulphide	14 µg/m³	1 hour	-	-	Objective		1975
		4 µg/m³	24 hours	-	-	Objective		1975
	Carbon disulphide	30 µg/m³	1 hour	-	-	Objective	Odour threshold	2005
Saskatchewan[c]	Hydrogen sulphide	15 µg/m³	1 hour	-	-	Standard	-	1989
		5 µg/m³	24 hours	-	-	Standard	-	1989
Manitoba[d]	Ammonia	1,400 µg/m³	1-hour	-	-	Criteria	Maximum Acceptable Level	2005
	Hydrogen sulphide	15 µg/m³	1 hour	-	-	Criteria		2005
		5 µg/m³	24 hours	-	-	Criteria		2005
	Styrene	400 µg/m³	24-hour	-	-	Criteria		2005
Ontario (selected contaminants)[ef]	Acetic acid	2,500 µg/m³	30 minutes	-	-	Standard	-	2012
		2,500 µg/m³	24 hours	-	-	AAQC**	-	2012
	Acetophenone	625 µg/m³	30 minutes	-	-	Guideline	-	2012
		850 µg/m³	10 minutes	-	-	AAQC	-	2012
	Acetylene	56,000 µg/m³	30 minutes	-	-	Standard	-	2012
		56,000 µg/m³	24 hours	-	-	AAQC**	-	2012
	Amyl acetate, iso-	53,200 µg/m³	24 hours	-	-	AAQC	-	2012

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Amyl acetate, n-	53,200 µg/m³	24 hours	-	-	AAQC	-	2012
	Biphenyl	60 µg/m³	30 minutes	-	-	Guideline	-	2012
		60 µg/m³	1 hour	-	-	AAQC	-	2012
	Butanol, n-	1,540 µg/m³	30 minutes	-	-	Guideline	-	2012
		2,100 µg/m³	10 minutes	-	-	AAQC	-	2012
	Butyl acetate, n-	735 µg/m³	30 minutes	-	-	Guideline	-	2012
		1,000 µg/m³	10 minutes	-	-	AAQC	-	2012
	Carbon disulphide	330 µg/m³	30-minutes	-	-	Standard	-	2012
		330 µg/m³	24 hours	-	-	AAQC**	-	2012
	Chlorine	230 µg/m³	10 minutes	-	-	AAQC	-	2010
	Decane, n	60,000 µg/m³	1 hour	-	-	AAQC	-	2012
	Diacetone alcohol	990 µg/m³	30 minutes	-	-	Guideline	-	2012
		1,350 µg/m³	10 minutes	-	-	AAQC	-	2012
	Diethylene glycol monoethyl ether	800 µg/m³	30 minutes	-	-	Guideline	-	2012
		1,100 µg/m³	10 minutes	-	-	AAQC	-	2012
	Diethylene glycol monomethyl ether	800 µg/m³	30 minutes	-	-	Guideline	-	2012
	Diisobutyl ketone	470 µg/m³	30 minutes	-	-	Guideline	-	2012

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
		649 µg/m³	10 minutes	-	-	AAQC	-	2012
	Dimethyl amine	1,840 µg/m³	1 hour	-	-	AAQC	-	2012
	Dimethyl disulphide	56 µg/m³	10 minutes	-	-	AAQC	-	2012
	Dimethyl ether	2,100 µg/m³	30 minutes	-	-	Guideline	-	2012
		2,100 µg/m³	24 hours	-	-	AAQC**	-	2012
	Dimethyl sulphide	30 µg/m³	10 minutes	-	-	AAQC	-	2012
	Ethanol (ethyl alcohol)	19,000 µg/m³	30 minutes	-	-	Guideline	-	2012
		19,000 µg/m³	1 hour	-	-	AAQC**	-	2012
	Ethyl acetate	19,000 µg/m³	30 minutes	-	-	Standard	-	2012
		19,000 µg/m³	1 hour	-	-	AAQC**	-	2012
	Ethyl acrylate	4.5 µg/m³	30 minutes	-	-	Standard	-	2012
		4.5 µg/m³	1 hour	-	-	AAQC**	-	208
	Ethyl benzene	1,900 µg/m³	10 minutes	-	-	AAQC	-	2012
	Ethyl ether	700 µg/m³	30 minutes	-	-	Standard	-	2010
		950 µg/m³	10 minutes	-	-	AAQC	-	2010
	Ethyl hexanol, 2-	600 µg/m³	30 minutes	-	-	Guideline	-	2012
		600 µg/m³	1 hour	-	-	AAQC**	-	2012
	Ethyl-3-ethoxy	147 µg/m³	30 minutes	-	-	Guideline	-	2012

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	propionate	200 µg/m³	10 minutes	-	-	AAQC	-	2012
	Ethylene glycol butyl ether (Butyl cellosolve)	350 µg/m³	30 minutes	-	-	Guideline	-	2012
		500 µg/m³	10 minutes	-	-	AAQC	-	2012
	Ethylene glycol butyl ether acetate (But.cell.ace)	500 µg/m³	30 minutes	-	-	Guideline	-	2012
		700 µg/m³	10 minutes	-	-	AAQC	-	2012
	Ethylene glycol ethyl ether (Cellosolve)	800 µg/m³	30 minutes	-	-	Guideline	-	2012
		1,100 µg/m³	10 minutes	-	-	AAQC	-	2012
	Ehtylene glycol ethyl ether acetate (Cell.ace)	220 µg/m³	30 minutes	-	-	Guideline	-	2012
		300 µg/m³	10 minutes	-	-	AAQC	-	2012
	Formaldehyde	65 µg/m³	30 minutes	-	-	Standard	-	2012
	Furfural	1,000 µg/m³	30 minutes	-	-	Standard	-	2012
		1,000 µg/m³	1 hour	-	-	AAQC**	-	2012
	Hydrogen sulphide	13 µg/m³	10 minutes	-	-	AAQC	-	2013
	Isobutanol	2,340 µg/m³	10-minutes	-	-	AAQC	-	2013
		1,720 µg/m³	30-minutes	-	-	Guideline	-	2013
	Isobutyl acetate	1,220 µg/m³	30 minutes	-	-	Guideline	-	2012
		1,660 µg/m³	10 minutes	-	-	AAQC	-	2012
	Isopropyl ether	220 µg/m³	30 minutes	-	-	Guideline	-	2012

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Isopropyl acetate	1,470 µg/m³	30 minutes	-	-	Guideline	-	2012
		2,000 µg/m³	10-minutes	-	-	AAQC	-	2012
	Isopropyl benzene	100 µg/m³	30 minutes	-	-	Standard	-	2012
	Mercaptans (as Methyl mercaptan) –total	13 µg/m³	10 minutes	-	-	AAQC	-	2012
	Methacrylic acid	2,000 µg/m³	30 minutes	-	-	Guideline	-	2012
		2,000 µg/m³	24 hours	-	-	AAQC**	-	2012
	Methyl acrylate	4 µg/m³	30 minutes	-	-	Standard	-	2012
		4 µg/m³	1 hour	-	-	AAQC**	-	2012
	Methyl isobutyl ketone	1,200 µg/m³	30 minutes	-	-	Standard	-	2012
		1,200 µg/m³	24 hours	-	-	AAQC**	-	2012
	Methyl methacrylate	860 µg/m³	30 minutes	-	-	Standard	-	2012
		860 µg/m³	24 hours	-	-	AAQC**	-	2012
	Methyl tert-butyl ether	2,200 µg/m³	30 minutes	-	-	Guideline	-	2012
	Methyl-2-hexanone, 5-	460 µg/m³	30 minutes	-	-	Guideline	-	2012
		630 µg/m³	10minute	-	-	AAQC	-	2012
	Milk Powder	20 µg/m³	24 hours	-	-	AAQC	-	2012
	Monochlorobenzene	4,500 µg/m³	10 minutes	-	-	AAQC	-	2012

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Monomethyl amine	25 µg/m³	30 minutes	-	-	Standard	-	2012
		25 µg/m³	24 hours	-	-	AAQC**	-	2012
	Napthalene	36 µg/m³	30 minutes	-	-	Guideline	-	2012
		50 µg/m³	10 minutes	-	-	AAQC	-	2012
	Octane	45,400 µg/m³	30 minutes	-	-	Guideline	-	2012
		61,800 µg/m³	10-minutes	-	-	AAQC	-	2012
	Propionaldehyde	7 µg/m³	30 minutes	-	-	Guideline	-	2012
		10 µg/m³	10 minutes	-	-	AAQC	-	2012
	Propionic acid	100 µg/m³	30 minutes	-	-	Guideline	-	2012
		100 µg/m³	1 hour	-	-	AAQC**	-	2012
	Propionic anhydride (as Propionic acid)	100 µg/m³	30 minutes	-	-	Guideline	-	2012
		100 µg/m³	1 hour	-	-	AAQC**	-	2012
	Propyl acetate, n-	900 µg/m³	30 minutes	-	-	Guideline	-	2012
	Propylene dichloride	2,400 µg/m³	30 minutes	-	-	Standard	-	2012
		2,400 µg/m³	24 hours	-	-	AAQC**	-	2012
	Propylene glycol methyl ether	89,000 µg/m³	30 minutes	-	-	Guideline	-	2012
		121,000 µg/m³	10 minutes	-	-	AAQC	-	2012
	Propylene glycol monomethyl ether	5,000 µg/m³	30 minutes	-	-	Guideline	-	2012
		5,000 µg/m³	24 hours	-	-	AAQC**	-	2012

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Pyridine	60 µg/m³	30 minutes	-	-	Guideline	-	2012
		80 µg/m³	10 minutes	-	-	AAQC	-	2012
	Styrene	400 µg/m³	30 minutes	-	-	Standard	-	2012
	Tetrahydrofuran	93,000 µg/m³	30 minutes	-	-	Standard	-	2012
		93,000 µg/m³	24 hours	-	-	AAQC**	-	2012
	Toluene	2,000 µg/m³	30 minutes	-	-	Standard	-	2012
		2,000 µg/m³	24 hours	-	-	AAQC**	-	2012
	Total reduced sulphur (as hydrogen sulphide)	13 µg/m³	10 minutes	-	-	AAQC**	-	2013
	Trimethyl amine	0.5 µg/m³	30 minutes	-	-	Guideline	-	2012
		0.5 µg/m³	1 hour	-	-	AAQC**	-	2012
	Xylenes	3,000 µg/m³	10 minutes	-	-	AAQC	-	2012
Quebec[g]	Acetone	8,600 µg/m³	4-minutes	-	-	Standards	-	2011
	Acetophenone	830 µg/m³	4-minutes	-	-	Standards	-	2011
	Acrylic Acid	270 µg/m³	4-minutes	-	-	Standards	-	2011
	Ammonia	350 µg/m³	4-minutes	-	-	Standards	-	2011
	Amyl acetate-n	25 µg/m³	4-minutes	Up to 1% (annually)	-	Standards	-	2011
	Benzaldehyde	200 µg/m³	4-minutes	-	-	Standards	-	2011
	2-Butoxyethanol	210 µg/m³	4-minutes	-	-	Standards	-	2011

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Butyl acetate-n	90 µg/m³	4-minutes	Up to 1% (annually)	-	Standards	-	2011
	Carbon disulphide	25 µg/m³	4-minutes	-	-	Standards	-	2011
	Chloroethane	10,900 µg/m³	4-minutes		-	Standards		2011
	Cumene	40 µg/m³	4-minutes		-	Standards		2011
	o-Dichlorobenzene	4,200 µg/m³	4-minutes		-	Standards		2011
	p-Dichlorobenzene	730 µg/m³	4-minutes		-	Standards		2011
	Diisobutyl ketone	640 µg/m³	4-minutes		-	Standards		2011
	Ethanol	340 µg/m³	4-minutes		-	Standards		2011
	Ethyl acetate	20 µg/m³	4-minutes	Up to 1% (annually)	-	Standards		2011
	Ethylbenzene	740 µg/m³	4-minutes		-	Standards		2011
	Ethyl-3-ethoxy propionate	300 µg/m³	4-minutes		-	Standards		2011
	Formaldehyde	37 µg/m³	15-minutes		-	Standards		2011
	Hexane-n	5,300 µg/m³	4-minutes		-	Standards		2011
	Hydrogen chloride	1,150 µg/m³	4-minutes		-	Standards	-	2011
	Hydrogen sulphide	6 µg/m³	4-minutes		-	Standards	-	2011
	Isobutyl acetate	35 µg/m³	4-minutes	Up to 1% (annually)	-	Standards	-	2011
	Isobutyl isobutyrat	440 µg/m³	4-minutes	-	-	Standards	-	2011
	Isopropanol	7,800 µg/m³	4-minutes	-	-	Standards	-	2011

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Methanol	5,500 µg/m³	4-minutes	-	-	Standards	-	2011
	Methyl ethyl ketone	740 µg/m³	4-minutes	-	-	Standards	-	2011
	Methyl isobutyl	400 µg/m³	4-minutes	-	-	Standards	-	2011
	Methyl methacrylate	200 µg/m³	4-minutes	-	-	Standards	-	2011
	Methyl tert butyl	180 µg/m³	4-minutes	-	-	Standards	-	2011
	Naphthalene	200 µg/m³	4-minutes	-	-	Standards	-	2011
	Phenol	160 µg/m³	4-minutes	-	-	Standards	-	2011
	Sulphur dioxide	1,050 µg/m³	4-minutes	Up to 0.5% (annually) cannot exceed 1,310 µg/m^3	-	Standards	-	2011
	Toluene	600 µg/m³	4-minutes	-	-	Standards	-	2011
	Triethylamine	22 µg/m³	4-minutes	-	-	Standards	-	2011
	Vinyl acetate	400 µg/m³	4-minutes	-	-	Standards	-	2011
	Xylene (o-,m-,p-)	350 µg/m³	4-minutes	-	-	Standards	-	2011
New Brunswick[h]	Hydrogen sulphide	15 µg/m³	1 hour	-	-	Objective	-	1997
		5 µg/m³	24 hours	-	-	Objective	-	1997
Nova Scotia[i]	Hydrogen sulphide	42 µg/m³	1 hour	-	-	Criteria	-	2010
		8 µg/m³	24 hour	-	-	Criteria	-	2010
Prince Edward Island[j]	Hydrogen sulphide	15 µg/m³	1 hour	-	-	Standards	-	2010
		5 µg/m³	24 hour	-	-	Standards	-	2010
Newfoundland and Labrador[k]	Hydrogen sulphide	15 µg/m³	1 hour	-	-	Standards	-	2010
		5 µg/m³	24 hour	-	-	Standards	-	2010

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Mercaptans	20µg/m³	24 hour	-	-	Standards	-	2010
	Reduced Sulphur Compounds	30µg/m³	24 hour	-	-	Standards	-	2010
UNITED STATES								
Arizona[l]	Hydrogen sulphide	45 ppb	1 hour	-	-	-	-	2005
		27 ppb	24 hours	-	-	-	-	2005
Bay Area Air Quality Management District (California, USA)[m]	Hydrogen sulphide	60 ppb	3 minutes	-	-	Regulation 9, Rule 2	-	1999
		30 ppb	60 minutes	-	-			1999
	Sulphur dioxide	500 ppb	3 minute	-	Beyond property line if property is physically secured against public access	Regulation 9, Rule 1	Ships are exempt	1992
		250 ppb	60 minutes	-				1992
		50 ppb	24 hours	-				1992
California[l,n,o,p]	Hydrogen sulphide	30 ppb	1 hour	-	-	State Standard (CAAQS)	Based on nuisance	1969 (reviewed 2005)
		8 ppb		-	-	Reference Inhalation Standard Health-based	California Office of Environmental Health Hazard	2005
Connecticut[n,o]	Hydrogen sulphide	6.3 µg/m³	-	-	-	-	-	2006
	Methyl mercaptan	2.2 µg/m³	-	-	-	-	-	2006
Delaware[l]	Hydrogen sulphide	60 ppb	3 minutes	-	-	-	-	2005
		30 ppb	1 hour	-	-	-	-	2005
Idaho[o]	Hydrogen sulphide	30 ppb	30 minutes	-	-	-	-	

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
		10 ppb	24 hours	-	-	-	-	
Illinois[p,q]	Hydrogen sulphide	10 ppb	8 hours	-	-	Health-based standard	-	2004
Minnesota[l,o,p]	Hydrogen sulphide	50 ppb	30 minutes	Not to be exceeded more than two times per year	Property line	Minnesota Pollution Control Agency Standard for animal feeding operations over 1000 animal units – nuisance based	-	2004
		30 ppb	30 minutes	Not to be exceeded more than two times in a five-day period	-		-	2004
		60 ppb	1 hour	-	Evaluated at the receptor	Minnesota Department of Health Inhalation Health Risk Value	Acute	2004
		7 ppb	3 month	-			Sub-chronic	2007
Missouri[l,p]	Ammonia	144 ppb	-	-	One producer	Ambient acceptable level	-	2011
	Hydrogen sulphide	50 ppb	30 minutes	-	-	Ambient acceptable level	-	2005
Montana[l]	Hydrogen sulphide	50 ppb	1 hour	Not to be exceeded more than once per year	-	-	-	2005
Nebraska[o,p,r]	Total reduced sulphur	100 ppb	30 minutes	-	-	Health-based standard that applies to	Nebraska Department of Environmental	1999

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
						Concentrated Animal Feeding Operations (CAFOs)	Quality (NDEQ)	
Nevada[l]	Hydrogen sulphide	80 ppb	1 hour averaging time	-	-	Ambient air quality standard	-	2005
New Mexico[o,s]	Hydrogen sulphide	30 – 100 ppb	30 minutes		-	-	-	2008
		10 ppb	1 hour	-	-	-	-	-
New York State[l,o,p,t]	Hydrogen sulphide	10 ppb	1 hour	-	-	Standard	Determined by the Cadmium Hydroxide-Methylene Blue method corrected to 25 °C and 760 mm Hg	2005
		0.7 ppb	1 year	-	-	-	-	2005
New York City[n,o]	Hydrogen sulphide	1 ppb	-	-	Off-site at sensitive receptors (e.g., schools or homes)	Guideline	For wastewater treatment plants	2005
North Dakota[u]	Hydrogen sulphide	10 ppm (14 mg/m³ of air)	Instantaneous	Maximum instantaneous (ceiling) concentration not to be exceeded	-	-	Two samples taken at least 15 minutes apart within a 60-minute period	2011

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
		0.2 ppm (280 µg/m³ of air)	1 hour	Not to be exceeded more than once per month	-	-	-	2011
		0.1 ppm (140 µg/m³ of air)	24 hours	Not to exceed more than once per year	-	-	-	2011
		0.02 ppm (28 µg/m³ of air)	Three months	Maximum arithmetic mean concentration averaged	-	-	-	2011
Pennsylvania[o,p,v]	Hydrogen sulphide	100 ppb	1 hour	-	-	-	-	2008
		5 ppb	24 hours	-	-	-	-	2008
Texas[o,w]	Hydrogen sulphide	120 ppb	30 minutes	-	Industrial, vacant or range lands	-	-	2010
		80 ppb	30 minutes	-	Residential / commercial	-	-	2010
Washington (USA)[n,l]	Hydrogen sulphide	3 - 7 ppb	-	-	-	Chambers Creek Wastewater Facility	"practical threshold odor-detection level"	2006
Wisconsin[l]	Hydrogen sulphide	83 ppb	24 hours	-	-	Ambient air standard	-	2004
AUSTRALASIA								
New South Wales (Australia)[x]	Acetaldehyde	0.023 ppm	1 hour	For Level 1 (Screening)	Criteria shall be	Impact assessment	For point sources, the	2001
	Acetic acid	0.11 ppm						

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	n-Butanol	0.16 ppm		Assessment – 100th percentile; For Level 2 (Refined) Assessment – 99.9th percentile	applied at and beyond the boundary of the facility.	criteria for new or modified facilities. They are not used in permits.	results of dispersion modelling shall be used as the basis for developing site-specific emission limits for individual odorous air pollutants.	
	Butyl mercaptan	0.002 ppm						
	Carbon disulphide	0.023 ppm						
	Chlorobenzene	0.023 ppm						
	Cumene	0.004 ppm						
	Cyclohexanone	0.07 ppm						
	Diacetone alcohol	0.15 ppm						
	Diethylamine	0.01 ppm						
	Dimethylamine	0.0052 ppm						
	Diphenyl ether	0.01 ppm						-
	Ethanol	1.1 ppm						
	Ethyl acetate	3.5 ppm						
	Ethyl acrylate	0. 0001 ppm						
	Methanol	2.4 ppm						
	Methylamine	0.0023 ppm						
	Methyl ethyl ketone	1.1 ppm						
	Methyl isobutyl ketone	0.05 ppm						
	Methyl mercaptan	0.00023 ppm						
	Methyl methacrylate	0.027 ppm						
	Methyl styrene	0.0287 ppm						

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Nitrobenzene	0.00052 ppm						
	Perchloroethylene	0.52 ppm						
	Phenol	0.0052 ppm						
	Phosphine	0.0023 ppm						
	n-Propanol	0.016 ppm						
	Pyridine	0.0023 ppm						
	Styrene (monomer)	0.027 ppm						
	Toluene	0.09 ppm						
	Triethylamine	0.05 ppm						
	Xylene	0.04 ppm						
	Hydrogen sulphide	1.38 µg/m³	0.1-1 second (nose response time –average)	99th percentile	Urban area (≥2000 people)		-	-
		2.07 µg/m³		99th percentile	500 to 2000 people		-	-
		2.76 µg/m³		99th percentile	125 to 500 people		-	-
		3.45 µg/m³		99th percentile	30 to 125 people		-	-
		4.14 µg/m³		99th percentile	10 to 30 people		-	-
		4.83 µg/m³		99th	Single		-	-

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
				percentile	residence (≤2people)			
Tasmania[y]	Acetaldehyde	0.042 ppm	3 minutes	100th percentile for screening assessment and 99.9th percentile for refined assessment	-	-	-	2001
	Acetic acid	0.20 ppm			-	-	-	
	Acetone	20 ppm			-	-	-	
	Acrylic acid	0.094 ppm			-	-	-	
	Benzyl chloride	0.0094 ppm			-	-	-	
	1,3-Butadiene	0.45 ppm			-	-	-	
	n-Butanol	0.3 ppm			-	-	-	
	Butyl mercaptan	0.004 ppm			-	-	-	
	Carbon disulphide	0.042 ppm			-	-	-	
	Chlorobenzene	0.042 ppm			-	-	-	
	Cumene	0.008 ppm			-	-	-	
	Cyclohexanone	0.12 ppm			-	-	-	
	Diacetone alcohol	0.285 ppm			-	-	-	
	Diethylamine	0.02 ppm			-	-	-	
	Dimethylamine	0.0094 ppm			-	-	-	
	Diphenyl ether	0.02 ppm			-	-	-	

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Ethanol	2.0			-	-	-	
	Ethyl acetate	6.3 ppm			-	-	-	
	Ethyl acrylate	0.0002 ppm			-	-		
	Hydrogen sulphide	0.0001 ppm			-	-	Does not apply to bleached eucalypt kraft pulp mills	
	Methanol	4.26 ppm			-	-	-	
	Methylamine	0.0042 ppm			-	-	-	
	Methyl ethyl ketone	2.0 ppm			-	-	-	
	Methyl mercaptan	0.00042 ppm			-	-	Does not apply to bleached eucalypt kraft pulp mills	
	Methyl methacrylate	0.05 ppm			-	-	-	
	Methyl styrene	0.052 ppm			-	-	-	
	Methyl isobutyl ketone	0.1 ppm			-	-	-	
	Nitrobenzene	0.00094 ppm			-	-	-	
	Perchloroethylene	0.94 ppm			-	-	-	
	Phenol	0.0094 ppm			-	-	-	-
	Phosphine	0.0042			-	-	-	-

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
		ppm						
	n-Propanol	0.03 ppm			-	-	-	-
	Pyridine	0.0042 ppm			-	-	-	-
	Styrene (monomer)	0.05 ppm			-	-	-	-
	Toluene	0.17 ppm			-	-	-	-
	Triethylamine	0.09 ppm			-	-	-	-
	Xylene	0.08 ppm			-	-	-	-
ASIA								
Japan[z,aa]	Acetaldehyde	0.05 - 0.5 ppm	-	-	Measured at the plant or business boundary	-	Range of maximum permissible concentrations at ground level on the boundary line of a place of business	2003
	Ammonia	1 - 5 ppm	-	-		-		
	Butyl aldehyde	0.009 - 0.08 ppm	-	-		-		
	Butyric acid	0.001 - 0.006 ppm	-	-		-		
	Dimethyl disulphide	0.009 - 0.1 ppm	-	-		-		
	Dimethyl sulphide	0.01 - 0.2 ppm	-	-		-		
	Ethyl acetate	3 - 20 ppm	-	-		-		
	Hydrogen sulphide	0.02 - 0.2 ppm	-	-		-		
	Isobutyl aldehyde	0.02 - 0.2 ppm	-	-		-		
	Isobutyl alcohol	0.9 - 20 ppm	-	-		-		

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
	Isovaleraldehyde	0.003 - 0.01 ppm	-	-		-		
	Isovaleric acid	0.001 - 0.01 ppm	-	-		-		
	Methyl isobutyl ketone	1 - 6 ppm	-	-		-		
	Methyl mercaptan	0.002 - 0.01 ppm	-	-		-		
	Propionaldehyde	0.05 - 0.5 ppm	-	-		-		
	Propionic acid	0.03 - 0.2 ppm	-	-		-		
	Styrene	0.4 - 2 ppm	-	-		-		
	Toluene	10 - 60 ppm	-	-		-		
	Trimethylamine	0.005 - 0.07 ppm	-	-		-		
	Valericaldehyde	0.009 - 0.05 ppm	-	-		-		
	Valeric acid	0.0009 - 0.004 ppm	-	-		-		
	Xylene	1 - 5 ppm	-	-		-		
Korea[bb],[cc]	Ammonia	2 ppm	-	-	Industrial area	-	Measure using UV-spectroscopy	2003
		1 ppm	-	-	Residential area	-		
	Methyl mercaptan	0.004 ppm	-	-	Industrial area	-	Measure using GC-FPD (Gas	

Jurisdiction	Compound	Standard	Averaging Time	Frequency Criteria	Land Use	Use	Comments	Date
		0.002 ppm	-	-	Residential area	-	Chromatograph – Flame Photometric Detector)	
	Hydrogen sulphide	0.06 ppm	-	-	Industrial area	-		
		0.02 ppm	-	-	Residential area	-		
	Dimethyl sulphide	0.05 ppm	-	-	Industrial area	-		
		0.01 ppm	-	-	Residential area	-		
	Dimethyl disulphide	0.03 ppm	-	-	Industrial area	-		
		0.009 ppm	-	-	Residential area	-		
	Trimethyl amine	0.02 ppm	-	-	Industrial area	-	Measure using GC-FID (Gas chromatograph – Flame Ionization Detector)	
		0.005 ppm	-	-	Residential area	-		
	Acetaldehyde	0.1 ppm	-	-	Industrial area	-		
		0.05 ppm	-	-	Residential area	-		
	Styrene	0.8 ppm	-	-	Industrial area	-		
		0.4 ppm	-	-	Residential area	-		

* (POI) Point of Impingement Limit
(AAQC) Ambient Air Quality Criteria
** AAQC is to be updated in the future using an average time more relevant to odour effects (i.e., 10 minutes)

#	Status of the Standard/Guideline is interim
(A)	AAQC Chemicals listed in Regulation 337 (formerly Regulation 296) under the Environmental Protection Act.
UD	Under Development

[a] B.C. Ministry of Environment. 2013. British Columbia Ambient Air Quality Objectives, Environmental Standards Branch. http://www.bcairquality.ca/reports/pdfs/aqotable.pdf

[b] Alberta, Province of. 2013. Alberta Ambient Air Quality Objectives and Guidelines Summary (2013) http://environment.gov.ab.ca/info/library/5726.pdf

[c] Saskatchewan, Province of. 1989. Appendix to Regulation 1: The Clean Air Regulations. Ambient Air Quality Standards. http://www.environment.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=6b1f40c1-7d4a-499b-a366-e5ffa76324d5&MediaID=1539&Filename=Saskatchewan+Ambient+Air+Quality+Standards.pdf&l=English

[d] Manitoba, Province of. 2005. Manitoba Ambient Air Quality Criteria. http://www.gov.mb.ca/conservation/envprograms/airquality/pdf/criteria_table_update_july_2005.pdf

[e] Ontario Ministry of the Environment, Standards Development Branch. 2012. Summary of Standards and Guidelines to support Ontario Regulation 419: Air Pollution – Local Air Quality, February 2008. PIBS # 6569e. https://archive.org/details/std01079181.ome

[f] Ontario Ministry of the Environment Standards Development Branch 2012. Ontario's Ambient Air Quality Criteria, April 2012. PIBS# 6570e01. http://www.airqualityontario.com/downloads/AmbientAirQualityCriteria.pdf

[g] Quebec, Province of. 2011. Quebec Regulation 4.1: Clean Air Regulation, O.C. 501-2011, Sch. K. http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=%2F%2FQ_2%2FQ2R4_1_A.htm

[h] New Brunswick, Province of. 1997. New Brunswick Regulation 97-133: Air Quality Regulation - Clean Air Act.

[i] Nova Scotia, Province of. 2010. Air Quality Regulations made under Section 112 of the Environment Act, S.N.S. 1994-95, c. 1. https://www.novascotia.ca/just/regulations/regs/envairqt.htm

[j] Prince Edward Island, Province of. 2004. Chapter E-9 Environmental Protection Act: Air Quality Regulations. Schedule A. http://www.irac.pe.ca/document.aspx?file=legislation/EPA-AirQualityRegulations.asp

[k] Newfoundland and Labrador, Province of. 2004. Newfoundland and Labrador Regulation 39/04: Air Pollution Control Regulations, 2004. http://www.assembly.nl.ca/legislation/sr/regulations/rc040039.htm

[l] U.S. Department of Health and Human Services. Toxicological Profile for Hydrogen Sulfide – Regulations and Advisories (2006). http://www.atsdr.cdc.gov/toxprofiles/tp114.pdf

[m] Bay Area Air Quality Management District – Rules and Regulations http://www.baaqmd.gov/?sc_itemid=D39A3015-453E-4A0D-9C76-6F7F4DA5AED5

[n] Mahin, T., Pope, R., McGinley, C. Water Environment Federation. 2000. When is a smell a nuisance? http://www.wef.org/applications/periodicals/

[o] Mahin, T. Massachusetts Department of Environmental Protection. 2001. Comparison of Different Approaches Used to Regulate Odours Around the World. Presented at 1st IWA International Conference on Odour and VOCs. March 2001. Sydney, Australia.

[p] Osterberg, D., Melvin. S. Iowa State University and the University of Iowa Study Group. 2002. Iowa Concentrated Animal Feeding Operations Air Quality Study – Final Report. http://www.public-health.uiowa.edu/ehsrc/CAFOstudy/CAFO_1.pdf

[q] Epstein, E. and B.C.S. Freeman, 2004. Legal and Regulatory Aspects Related to Odors, WEF/A&WMA Odors and Air Emissions, pp. 104-110(7).
[r] Nebraska Administrative Code. Title 129 - Department of Environmental Quality. Chapter 4 - Ambient Air Quality Standards http://www.deq.state.ne.us/RuleandR.nsf/dd5cab6801f1723585256474005327c8/13c412500b561a86862565e700771bb1!OpenDocument
[s] New Mexico (2008). Natural Resources and Wildlife – Oil & gas- hydrogen sulfide gas. Energy, Minerals and Narutarl resources Department, Oil Conservation Division. http://www.nmcpr.state.nm.us/nmregister/xix/xix22/19.15.11.htm
[t] EPA Quality of Life performance Standards (2006) http://www.epa.gov/hudson/quality_of_life_06_04/section6.pdf
[u] North Dakota (2011). Chapter 33-15-02 – Ambient Air Quality Standards. http://www.legis.nd.gov/information/acdata/pdf/33-15-02.pdf?20131122200049
[v] Pennsylvania, Department of Environmental Protection (2008). Ambient Air Quality Standards. http://www.dep.state.pa.us/dep/deputate/airwaste/aq/standards/standards.htm
[w] Texas (2010) Interim Guidelines for setting odor-based Effects Screening levels. http://www.tceq.state.tx.us/assets/public/implementation/tox/esl/guidelines/odor.pdf
[x] New South Wales Environmental Protection Authority, Australia (2001) http://www.environment.nsw.gov.au/resources/air/ammodelling05361.pdf
[y] Tasmania Department of Primary Industries, Water and Environment (2004) Environment Protection Policy (Air Quality) 2004. http://epa.tas.gov.au/documents/epp_air_quality_2004.pdf
[z] Japanese Ministry of the Environment Website – page related to Control of Offensive Odour
[aa] Japanese Ministry of the Environment, 2003. The offensive odor control law in Japan. http://www.env.go.jp/en/laws/air/offensive_odor/all.pdf
[bb] Sung Bong Yang, University of Ulsan, Korea. 2003. A Comparative Study on Odor Regulation in Japan and Korea. http://www.env.go.jp/en/air/odor/measure/02_2.pdf
[cc] Park, Sang Jin. Woosong University, Korea. 2003. The Regulation and Measurement of Odor in Korea. http://www.env.go.jp/en/air/odor/measure/02_1_5.pdf

Table 5-3: Ambient Odour Criteria in Odour Units (OU/m^3, OU, OU_E/m^3) or Dilutions to Threshold (D/T)

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
CANADA								
City of Calgary (Canada)[a]	20 D/T	-	<100 hours/year non-compliance	Rural with growing residential	Wastewater treatment plant	-	-	2003
Manitoba [b]	2 OU	2 tests not less than 15 minutes apart nor more than 60 minutes apart	-	Residential Zone	-	Guideline – Maximum acceptable level	-	2008
	7 OU		-	Industrial Zone	-	Guideline – Maximum acceptable level	-	2008
	<1 OU		-	-	-	Guideline – Maximum Desirable Level	Less than the odour threshold	2008
Saskatchewan[c,d]	1	1 hour	99.5% compliance	Urban residential zones	-	Odour Criteria for Modelling	Saskatchewan Air Quality Modelling Guideline.	2012
	2	1 hour	99.5% compliance	Urban commercial zones or mixed residential and commercial zones	-			2012
	4	1 hour	99.5% compliance	Industrial or restricted business zones and	-			2012

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
				rural zones with mixed utilisation				
	6	1 hour	99.5% compliance	Industrial or agricultural zones with predominantly agricultural utilisation	-			2012
	2 D/T	2 tests not less than 15 minutes apart nor more than 60 minutes apart	-	Residential/Urban zone	-	Odour Criteria for Field Investigation	-	-
	4 D/T		-	Mixed residential and commercial/Rural zone	-		-	-
	7 D/T		-	Industrial/Agricultural zone	-		-	-
Ontario [e]	1	10 minutes	-	At the most impacted Sensitive Receptor	-	-	Proposed standard	-
UNITED STATES								
Allegheny County Sanitation District (Pennsylvania, USA) [a,e,f,g]	4 D/T	2 minutes	<50 hours/year non-compliance	Residential with highway	Wastewater treatment plant	Design goal	Model output adjusted from 60- to 2-minute averaging time using a factor of 2	2003
Bay Area Air	5 D/T	-	-	Fence-line	-	-	Five or more	2010

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
Quality Management District (California, USA)[e,h]							confirmed complaints per year averaged over three years.	
Central Contra Costa County Sanitary District (California, USA)[a]	4 D/T	-	<100 hours/year non-compliance	Industrial with some residential and highway	Wastewater treatment plant	-	-	2001
City of Oakland (California, USA)[e]	50	3 minutes	-	-	-	-	-	2003
City of Philadelphia (Pennsylvania, USA)[a]	20 D/T	-	<100 hours/year non-compliance	Residential	Wastewater treatment plant	-	-	2003
Maine (USA)[i,j]	Developing Quantitative Odor Management Standards	-	-	All	All sources	-	-	Under public consultations 2013
City of San Diego WWTP (California, USA)[e]	5 D/T	5 minutes	99.5% compliance	At plant fence-line	Wastewater treatment plant	-	Model output adjusted from 60- to 5-minutes using factor of 2.29	1989
City of Seattle WWTP (Washington, USA)[e,k]	5 D/T	5 minutes	-	-	Wastewater treatment plant	-	-	2000
Colorado (USA)[l]	7 D/T	-	-	Residential or commercial	Anything but manufacturing	-	Barnebey-Chaney	2013

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
	15 D/T	-	-	Other land uses	process or agricultural operation	-	Scentometer: 2 measurements taken at least 15 minutes apart in one hour	2013
	127 D/T	-	-	All	All sources except housed commercial swine feeding operations	-		2013
	7 D/T	-	-	Property Boundary	Housed Commercial Swine Feeding Operations	Permit to Operate		2013
	2 D/T	-	-	Any receptor (occupied dwelling, school, place of business or boundaries of a municipality)				2013
Connecticut (USA)[f,m]	7 D/T	-	-	Beyond property boundary	-	-	Scentometer: 3 samples or observations in 1 hour separated by 15 minutes	2006
East Bay Municipal Utility District (California, USA)[a]	50 D/T	-	<10 hours/year non-compliance	Industrial turning into residential	Wastewater treatment plant	-	Phase 1 of odour control	2010
	20 D/T	-	<100 hours/year non-compliance			-	Phase 2 of odour control	2010
Illinois[n]	8 D/T	-	-	Adjacent to residential, recreational, institutional,	-	-	-	-

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
				retail, hotel or educational premises				
	24 D/T	-	-	On or adjacent to industrial premises	-	-	-	-
	16 D/T	-	-	Other premises	-	-	-	-
Iowa (USA)[o]	15	4 hours	-	Odour at Confined Feeding Operations (CFO) property line.	-	-	This concentration can be exceeded up to 14-days per year with 48 hour notice	2002
	7	-	-	Odour at residence or public use area.	-	-	Exceedance = 2 excessive measurements separated by 4 hours in 1 day	2002
Kentucky (USA)[p]	7	-	-	-	-	-	Scentometer	1988
King County (Washington, USA) [a,k]	0 – 3 D/T	-	<50 hours/year exceeding threshold	-	-	Recommended policy for new Waste Water Treatment Plants (WWTPs)	-	2003
	0 – 5 D/T	-	<100 hours/year exceeding threshold	-	-	Recommended policy for existing WWTP retrofits	0-3 routine operating range, 3-5 non-routine operating range	2003

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
Massachusetts (USA) [e]	5 D/T	1 hour	-	Offsite	Composting	Draft guidance	Converted to lower averaging times by power law equation, case-by-case. Draft policy. Regional agencies can set more stringent limits based on site-specific conditions	2001
Missouri (USA)[q]	5.4 D/T	-	-	At the property line	-	In field measured from scentometer	-	-
	7 D/T	-	-	-	-	Olfactometry Panel	-	-
Nevada[n]	8 D/T	-	-	-	-	-	Measurements must be separated by at least 15 minutes within 1 hour	-
New Jersey (USA)[e,f]	5 D/T	5 minutes or less	-	At sensitive receptor with the highest impact as predicted by dispersion modelling	For biosolids/sludge handling and treatment facilities	-	Alternative for existing facilities is to remove 95% of target odour-causing compounds such as H_2S or NH_3 and achieve an outlet	-

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
							concentration below the individual compound thresholds	
North Carolina[r]	7 D/T	30 min	-	Swine farms	-	-	-	2009
North Dakota (USA)[e]	2 D/T	-	-	Fence-line	-	-	Scentometer	2001
Orange County Sanitation District (California, USA)[a,s]	20 D/T	-	<100 hours/year non-compliance	Residential with highway	Wastewater treatment plant	-	-	2003
Portland (Oregon, USA)[e]	1 to 2 D/T	15 minutes	-	-	-	Considered a nuisance	Measured with Scentometer. Odour with duration less than 15 minutes is exempt.	2003
Sacramento County Regional Sanitation District (California, USA)[a]	20 D/T	-	<100 hours/year non-compliance	Rural with growing residential	Wastewater treatment plant	-	-	2003
Wyoming (USA)[t,n]	7	-	-	-	-	-	At least two measurements within an hour, separated by at least 15 minutes	-
Yountville (California, USA)[a]	4 D/T	-	<100 hours/year non-compliance	Golf course	Wastewater treatment plant	-	-	2003
AUSTRALASIA								

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
New Zealand[e,u]	2	1 hour	99.5% compliance	-	-	-	-	2002
New South Wales (Australia)[t]	2	0.1-1 second	99th percentile	Urban area (≥2000 people)	-	Criteria are not used in permits. They are used for new facility design.	Odour performance criteria shall be applied at the nearest existing or likely future off-site sensitive receptor based on population density (see Eqn. 3.2 of NSW, 2001) NSW also has criteria for individual pollutants	2003
	3	0.1-1 second	99th percentile	500 to 2000 people	-			2003
	4	0.1-1 second	99th percentile	125 to 500 people	-			2003
	5	0.1-1 second	99th percentile	30 to 125 people	-			2003
	6	0.1-1 second	99th percentile	10 to 30 people	-			2003
	7	0.1-1 second	99th percentile	Single residence (≤2people)	-			2003
Queensland (Australia)[e]	10	1 hour	99.5% compliance	-	-	-	-	2003
South Australia[v]	2	3 minutes	99.9% compliance	2000 or more people	-	These are guidelines used for determining setback distances. They are not enforceable per se	-	2007
	4	3 minutes	99.9% compliance	350 or more people	-		-	2007
	6	3 minutes	99.9% compliance	60 or more people	-		-	2007
	8	3 minutes	99.9% compliance	12 or more people	-		-	2007
	10	3 minutes	99.9% compliance	Single residence (<12	-		-	2007

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
				people)				
Tasmania (Australia)	2	1 hour	99.5% compliance	-	-	-	Tasmania also has criteria for individual pollutants	2004
Western Australia[e,w]	2	3 minutes	99.5th percentile	Sensitive land uses, e.g. residences, hospitals, schools, play grounds, aged care facilities etc.	Other than poultry farms	Used to determine setback distances for new proposals or expansion only	Criteria are not intended as limits that define a level of unreasonable odour. As such their direct use for odour management may be inappropriate.	2003
	7	3 minutes	99.5th percentile		Poultry farms			2003
EUROPE								
Austria[x,y]	1	-	92% compliance	-	-	-	-	2003
	3	-	97% compliance	-	-	-	-	2003

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
Denmark[e,f]	5 to 10	1 minute	99% compliance	Residential areas outside the plant site (limit in industrial and rural areas may in some cases be increased by a factor of 2-3)	-	-	Equivalent 60-minute average standard is 0.6 to 1.2 OU/m^3 Calculated as the average of anticipated peak values in neutral to moderately unstable conditions with a wind speed of 4.5 m/s	2003
France[z]	5 ou_E/m^3	1 hour	98 % compliance	-	Existing sources	-	-	2004
	5 ou_E/m^3	1 hour	99.5% compliance	-	New sources	-	-	2004
Germany[x,f]	1	-	97% compliance	Pure residential areas	-	-	1-hour odour concentrations predicted using a dispersion model are multiplied by a factor of 10	2003
	1	-	95% compliance	Residential and structured areas	-	-		2003
	1 and 3	-	92% and 97%	Restricted business areas and village area with mixed utilisation	-	-		2003
	1 and 3	-	90% and 95%	Village areas	-	-		2003

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
			respectively	with predominantly agricultural utilisation				
Ireland[aa]	1.5 ou_E/m^3	1 hour	98%	-	-	Licensing	Target Value - draft	2003
	3.0 ou_E/m^3	1 hour	98%	rural	New pig production unit	Licensing	Limit Value - draft	-
	6.0 ou_E/m^3	1 hour	98%	rural	Existing pig production unit	Licensing	Limit Value - draft	-
Newbiggin-by-the-Sea & Debby WWTPs (UK)[e]	5	-	98% compliance	-	Wastewater treatment plant	-	-	-
The Netherlands[bb,cc]	>>5 ou_E/m^3	1 hour	98%	-	Bakeries	Used in permitting process to compare with results of dispersion models or nomograms used to calculate dispersion of emissions calculated using emission factors.	No limit value	2003
	1.5 ou_E/m^3	1 hour	98%	Built-up areas or other objects sensitive to odours	Meat Processing		Limit value	2003
	0. 8 ou_E/m^3	1 hour	98%				Target value	2003
	2.5 ou_E/m^3	1 hour	98%	Built-up areas etc.	Grass dryers		Limit value	2003
	5 ou_E/m^3	1 hour	98%	Built-up areas etc.	Bakeries, pastry		Target value	2003
	3.5 ou_E/m^3	1 hour	98%	-	Coffee roasters		Limit value for existing facilities (limits lower for new facilities)	2003
	3.5 ou_E/m^3	1 hour	98%	Built-up areas etc.	Flavours & fragrances		Limit value	2003
	2.0 ou_E/m^3	1 hour	98%				Target value	2003

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
	0.5 ou_E/m^3	1 hour	98%	Densely populated residential areas	Wastewater Treatement Plant (WWTP), Greenfield site		Limit value	2003
	1.0 ou_E/m^3	1 hour	98%	Rural area or industrial estate	WWTP, Greenfield site		Limit value	2003
	1.5 ou_E/m^3	1 hour	98%	Densely populated residential areas	WWTP, existing site		Limit value	2003
	3.5 ou_E/m^3	1 hour	98%	Rural area or industrial estate	WWTP, existing site		Limit value	2003
	1 ou_E/m^3	1 hour	98%	Densely populated residential areas	Livestock feed production		Limit value	2003
	1.5 ou_E/m^3	1 hour	98%	Residential area or other sensitive receptors	Composting, organic fraction of domestic waste, Greenfield site		Limit value	2003
	0.5 ou_E/m^3	1 hour	98%				Target value	2003
	3.0 ou_E/m^3	1 hour	98%		Composting, organic fraction of domestic waste, existing facility		Limit value	2003
	1.5 ou_E/m^3	1 hour	98%				Target value	2003
	1.5 ou_E/m^3	1 hour	98%	Built up areas	Slaughterhous		Limit value	2003

Jurisdiction	Offsite Standard or Guideline (OU/m^3)	Averaging Time	Frequency Criteria	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments	Date of Regulation or Guideline
	0.55 ou_E/m^3	1 hour	98%	Built up areas	es		Target value	2003
	1.5 ou_E/m^3	1 hour	98%	Sensitive receptors	Large Breweries		Limit value	2003
United Kingdom[dd]	1.5 ou_E/m^3	1 hour	98%	-	Offensive odours	-	-	2007
	3 ou_E/m^3	1 hour	98%	-	Moderately offensive odours	-	-	2007
	6 ou_E/m^3	1 hour	98%	-	Less offensive odours	-	-	2007
ASIA								
Hong Kong (Siu Ho Wan WWTP)[e,ee]	5	5 seconds	-	-	Wastewater treatment plant & landfill	-	-	2001
Korea[ff]	20	-	-	Plant boundary	Companies in industrial areas	-	Measure using "Air Dilution Sensory Test" described in Sang Yin Park (2003)	2003
	15	-	-	Plant boundary	Companies in other areas	-		2003
Taiwan[e]	50	-	-	-	Applied to a Petrochemical park	-	-	2001

[a] King County (2003) http://your.kingcounty.gov/dnrp/library/wastewater/wtd/response/odorcontrol/030318_OdorPreventionRec.pdf
[b] Manitoba Environmental Act – Odour Nuisance Management Strategy, 2008.
http://www.gov.mb.ca/conservation/envprograms/airquality/pdf/odour_nuisance_revised_document_exec_summary_english.pdf
[c] Saskatchewan (2012). Saskatchewan Air Quality Modelling Guideline
[d] Saskatchewan (2014). Saskatchewan Air Modelling and Odour Guideline. Presented by Imran Maqsood, January 17, 2014.
[e] Mahin (2001)
[f] DEFRA. 2010. Odour Guidance for Local Authorities. Local Environmental Protection. Department for Environment Food and Rural Affairs.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69305/pb13554-local-auth-guidance-100326.pdf
[g] Welsh Assembly Government (2005)
[h] Bay Area Air quality Management District (2011), CEQA Guidelines.
[i] Department of Environmental Protection, Mane, 2013 Proposing odor rulings http://www.maine.gov/dep/rules/#608375
[j] Tech environmental e-news letter, July 2010. http://www.techenv.com/E-News/Enews0710.htm
[k] Nuisance Regulation for Washington Cities and Counties, 2000. Municipal Research & Services Centre of Washington
http://www.mrsc.org/publications/nuisance.pdf
[l] Colorado Air Quality Control Commission (2013) https://www.colorado.gov/pacific/cdphe/aqcc-regs
[m] Connecticut Government, Air Regulations, Section 22a-174-23; Control of odors (2006) http://www.ct.gov/deep/lib/deep/air/regulations/mainregs/sec23.pdf
[n] Maine Department of Environmental Proteection (2009). Report on Odor and Gas Management at Solid Waste Facilities.
[o] Iowa State University and the University of Iowa Study Group (2002)
[p] Kentucky Natural Resources and Environmental Protection Cabinet, 1988. Air Quality, Chapter 224, General Provisions 401 KAR 53:005.
http://www.epa.gov/region04/air/sips/ky/KY-Ch-53.pdf
[q] Osterberg and Melvin (2002)
[r] North Carolina, Air Quality Regulations, Section .1800 Control of Odors (2009). http://daq.state.nc.us/rules/rules/secD1800.pdf
[s] South Coast Air Quality Management District -Rule 410 – Odors from Transfer Stations and Material Recovery Facilities (2006).
http://www.aqmd.gov/rules/reg/reg04/r410.pdf
[t] EPA NSW (2001)
[u] Ministry for the Environment (2002). Odour Assessment. http://www.mfe.govt.nz/publications/air/odour-guidelines-jun03/html/page6.html
[v] South Australia EPA (2001)
[w] Western Australia EPA (2002)
[x] Schauberger *et al.* (2001) Predicting odour impact using the Austrian odour dispersion model (AODM)
[y] McGinley, C. M. (2002) Standardised Odor Measurements Practices for Air Quality Testing.
http://www.fivesenses.com/Documents/Library/38%20Standard%20Odor%20Measure%20for%20Air%20Qual.pdf
[z] Environment Agency; UK (2007). Review of odour character and thresholds
[aa] CPCB (2008). Central Pollution Control Board. Guidelines on Odour Pollution & its Control. Government of India
http://www.cpcb.nic.in/divisionsofheadoffice/pci2/package_odourreport_2.12.08.pdf
[bb] Miedema et al. (2000)
[cc] Netherlands Emission Guidelines for Air (2003)
[dd] Environment Agency: UK (2011) Additional Guidance for H4 Odour Management. How to comply with your environmental permit.

[ee] Xiangzhong Li. Odour impact and Control at a Landfill site in Hong Kong. Odour Research Laboratory,The Hong Kong Polytechnical University, China. http://www.env.go.jp/en/air/odor/eastasia_ws/2-2-3.pdf

[ff] Sang Jin Park (2003)

Table 5-5: Separation Distances

Jurisdiction	Separation Distance (m)	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments
NORTH AMERICA					
Alberta	150 minimum	Residences	Livestock facility	-	Based on odour production, odour objective[a] factor and dispersion factors
Colorado[b]	1 mile	Occupied dwelling; public or private school; incorporated municipality	Land waste application site or waste impoundment used in connection with a housed commercial swine feeding operation	Permit	Applies to new land waste application sites and new waste impoundment since June 1, 1998
Ontario[c,d]	100 (recommended)	Sensitive land uses, such as residential neighbourhoods	Sewage treatment plant with capacity equal to or less than 500 m^3/d	Certificate of Approval for new and expanding sewage treatment facilities	A separation distance of less than 100 m may be permitted
	100 (minimum); 150 (recommended)		Sewage treatment plant with capacity greater than 500 m^3/d but less than 25,000 m^3/d		-
	>150		Sewage treatment plant with capacity greater than 25,000 m^3/d		These plants will be dealt with on an individual basis; a separation distance of greater than 150 m may be required
	Variable		Livestock facilities	-	Dependent on number and type of livestock, manure system and storage and type of encroaching land use
Quebec[e]	148	Dwelling	Liquid manure storage site of 1,000 m^3 capacity located more than 150 m from a livestock facility	-	For solid manure, multiply these distances by 0.8
	295	Protected immoveable			For solid manure, multiply these distances by 0.8
	443	Urbanization perimeter			Also dependent on

Jurisdiction	Separation Distance (m)	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments
	30	Public roadway			additional factors including category of animal, technology in place ect.,
	304	Dwelling	Liquid manure storage site of 10,000 m^3 capacity located more than 150 m from a livestock facility	-	
	607	Protected immoveable			
	911	Urbanization perimeter			
	61	Public roadway			
USA[f]	400 – 800	Domestic dwelling	Livestock facilities	"Desirable distance"	Set by the American Society of Agricultural Engineers (1994)
	1600	Housing development			
	3600 - 7200	-	Larger facilities	Guidance	-
AUSTRALASIA					
New Zealand[f]	50	Residential building on same site	Pig production unit of any size	Code of Practice	-
	45	Milking shed and yard			-
	50	Slaughterhouse			-
	800	Reservoir for domestic water supply			-
	30	Well for domestic water supply			-
	20	Water course			-
	50	Public highway			-
	20	Property boundary			-
	500	Rural dwelling	Pig production unit with up to 2000 pigs		-
	1500	Place of public assembly			-

Jurisdiction	Separation Distance (m)	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments
	2000	Residential area, urban			
	variable	Rural dwelling, place of public assembly, urban residential area	Pig production unit with 2000 or more pigs		Adjustable setback distances depend on the size of operation and a set of correction factors for operational characteristics
Queensland[g]	500	-	Intermittent agricultural activities (e.g. fertiliser spreading, effluent disposal or chemical spraying)	Planning guideline	A buffer should be implemented if odour from intermittent agricultural activities exceed nuisance levels for greater than 1 percent of the time (or 88 h/yr)
South Australia[h]	numerous	-	-	-	-
Western Australia[i]	numerous	-	Each individual industry is listed, along with sub sets. Buffer is assigned base on number of impacts including odour, and varies accordingly	-	-
EUROPE					
Germany[f]	variable	-	Livestock operations	-	Setback distances graph for different numbers of “livestock units” with correction based on points for operational practice and design of the facility
Nordrhein-Westfalen (Germany)	300	Residential area	Composting plants, wastewater treatment plants	Land use planning	-
	500	Residential area	Livestock facilities, slaughterhouses, landfills	-	-

Jurisdiction	Separation Distance (m)	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments
	700	Residential area	Facilities for production of sauerkraut, facilities for production of sugar	-	-
	1000	Residential area	Facilities for the removal of animal cadavers	-	-
	1500	Residential area	Chemical industries with more than 10 production units	-	-
United Kingdom[f]	400	-	-	-	-
The Netherlands[f,j]	100 - 200	-	Composting installation for vegetable waste with frequent turning using special machines	Standards used in permits	Production: 0-5,000 t/yr
	200 - 400	-			Production: 5,001 – 10,000 t/yr
	400 – 600	-			Production: 10,001 – 15,000 t/yr
	600 – 750	-			Production: 15,001 – 20,000 t/yr
	> 750	-			Production >20,000 t/yr
	225 – 300	-	Composting installation for vegetable waste – conventional method of turning using a grab or loader		Production: 0-5,000 t/yr
	300 – 450	-			Production: 5,001 – 10,000 t/yr
	450 – 600	-			Production: 10,001 – 15,000 t/yr
	600 – 750	-			Production: 15,001 – 20,000 t/yr
	>750	-			Production >20,000 t/yr

Jurisdiction	Separation Distance (m)	Land Use	Source Type	Use (Permit, Guidance etc.)	Other Comments
	100	-	Composting installation for vegetable waste – forced aeration		Production < 20,000 t/yr
	200	-			Production > 20,000 t/yr
	variable	-	Pig production	-	Graph relating the required setback distance to the number of animals

[a] Alberta (2014). Agricultural operation practices Act: Standards and Administration regulation
[b] Colorado Air Quality Control Commission (1999)
[c] Ontario, Ministry of Agriculture, Food and Rural Affairs (2013). Minimum Distance Separation (MDS) Formulae: History, Key Elements and Key Changes.
[d] Ontario Ministry of Environment Guideline D-2 (1996)
[e] Quebec (2014). Guidelines respecting odours caused by manure from agricultural activities
[f] Integrated Pollution Prevention and Control (IPPC) (2002. Horizontal Guidance for Odour. Part 1- Regulation and Permitting.
[g] The State of Queensland, Department of Natural Resources and Mines (2001)
[h] South Australia EPA (2001)
[i] Western Australia (2005). Separation Distances between Industrial and Sensitive Land Uses.
[j] Netherlands Emission Guidelines for Air (2003)

Table 5-6: Odour Intensity Scales

Jurisdiction	Related Criteria	Scale	Description	Land Use	Comment
NORTH AMERICA					
New Jersey[a]	-	0	Odour not detectable	-	Used by inspectors in the field. In addition to this scale, inspectors consider such factors as odour frequency and duration to determine whether a nuisance exists.
		1	Very light odour (an odour is sensed or smelled, but its characteristics may not be distinguishable)		
		2	Light (an odour is sensed or smelled, is distinguishable but not necessarily objectionable for short durations, yet may be objectionable during longer periods)		
		3	Moderate (an odour is easily sensed or smelled, is clearly distinguishable, and may be objectionable or irritating)		
		4	Strong (an odour is present that would cause a person to avoid it completely and could produce adverse physiological effects during prolonged exposure)		
		5	Very Strong (an odour is so strong and overpowering, it is intolerable for any length of time and easily could have adverse physiological effects)		
Puget Sound Clear Air Agency (PSCAA)[b]	PSCAA may take enforcement action if Control Officer detects an odour at a level 2 or greater	0	No odour detected	-	-
		1	Odour barely detected		
		2	Odour is distinct and definite, any unpleasant characteristics recognizable		
		3	Odour is objectionable enough or strong enough to cause attempts at avoidance		
		4	Odour is so strong that a person does not want to remain present		

Jurisdiction	Related Criteria	Scale	Description	Land Use	Comment
AUSTRALASIA					
Western Australia[c]	Odour Concentration should be less than or equivalent to an intensity level of 3	0	Not perceptible	-	-
		1	Very weak		
		2	Weak		
		3	Distinct		
		4	Strong		
		5	Very strong		
		6	Extremely strong		
Wellington, NZ	-	0	Not detectable (no odour)	-	Used as basic guidance for Council officers in the field
		1	Very light (detected but not recognizable)		
		2	Light (detected and discernible)		
		3	Moderate (clear & distinctly distinguishable)		
		4	Strong (you want to try to avoid the smell)		
		5	Very strong (overpowering and intolerable)		
EUROPE					
Germany[d]	-	0	Not perceptible	-	-
		1	Very weak		
		2	Weak		
		3	Distinct		
		4	Strong		
		5	Very strong		
		6	Extremely strong		
Switzerland[d]	Long term measures taken when 3 – 5,	1 - 2	Reasonable	-	Thermometer value of annoyance on a scale from 0 to 10
		3 - 5	Medium	-	

Jurisdiction	Related Criteria	Scale	Description	Land Use	Comment
	immediate measures taken when >5	6 - 10	Strong	-	
ASIA					
Japan[a]	Odour is acceptable if it is less than 2.5 to 3.5	0	No odour	-	-
		1	Barely perceivable (detection threshold)		
		2	Faint but identifiable (recognition threshold)		
		3	Easily perceivable		
		4	Strong		
		5	Repulsive		
Korea[e]	Ambient odour should be less than 2	0	None	Facility boundary	Measured using "Direct Sensory Method"
		1	Threshold		
		2	Moderate		
		3	Strong		
		4	Very Strong		
		5	Excessively Strong		

[a] WEF (2000)
[b] Puget Sound Clean Air Agency Regulation I, Section 9.11 (1999)
[c] Western Australia EPA (2002)
[d] Frechen (1997)
[e] Sang Jin Park (2003)

Table 5-9: Quantitative Odour Emission Criteria

Jurisdiction	Contaminant	Standard	Units	Source or Process Type	Specific Control Technology	Use (Permits, Guidance, Enforcement, Planning)	Other Comments
NORTH AMERICA							
Bay Area Air Quality Management District (California, USA)	Odour	1,000	D/T	Emission release height < 9m	-	Enforceable Regulation 7	General Limit on Odorous Substances. Samples collected and analyzed as prescribed in Section 7-400
		3,000	D/T	Release height 9-18 m			
		9,000	D/T	18-30 m			
		30,000	D/T	30 to 55 m			
		50,000	D/T	> 55 m			
	Dimethylsulfide	0.1	ppm	Type A Emission Point	-	Enforceable Regulation 7	Type A Emission Point: an emission point, having sufficiently regular geometry so that both flow volume and contaminant concentrations can be measured and where the nature and extent of air contaminants do not change substantially between a sampling point and the emission point (i.e., a stack)
		0.05	ppm	Type B Emission Point	-		
	Ammonia	5,000	ppm	Type A	-		
		2,500	ppm	Type B	-		
	Mercaptans calculated as Methylmercaptan	0.2	ppm	Type A	-		
		0.1	ppm	Type B	-		
	Phenolic compounds calculated as phenol	5.0	ppm	Type A	-		
		2.5	ppm	Type B	-		
	Trimethylamine	0.02	ppm	Type A	-		

Jurisdiction	Contaminant	Standard	Units	Source or Process Type	Specific Control Technology	Use (Permits, Guidance, Enforcement, Planning)	Other Comments
		0.02	ppm	Type B	-		Type B Emission Point: an emission point other than a type A emission point (e.g., roof vent)
	Sulphur dioxide	300	ppm	General	-	Regulation 9, Rule 1	Ships and a number of facility types are exempt
		2,000	ppm	Ships	-		Also sulphur content of liquid fuel should be less than or equal to 3.34% by weight
		250	ppm	Sulphur Recovery Plant	-		Plants that emit less than 45 kg/day of SO_2 are exempt
		300	ppm	Sulphuric acid plant	-		-
		1000	ppm	Fluid catalytic cracking unit or fluid coker	-		-
		400	ppm	Coke calcining kiln	-		Or 113 kg per hour, whichever is more restrictive
		22	kg/hr	Catalyst manufacturing plants	-		-
		9.0	kg	Apricot sulphuring operation	-		Per 9.0 metric ton fresh apricots
		10.9	kg	Peach sulphuring operation	-		Per 9.0 metric ton fresh peaches

Jurisdiction	Contaminant	Standard	Units	Source or Process Type	Specific Control Technology	Use (Permits, Guidance, Enforcement, Planning)	Other Comments
		13.6	kg	Pear sulphuring operation	-		Per 9.0 metric ton fresh pears
EUROPE							
Denmark	Odour	100	OU/m3	-	-	-	Measured at the source
Netherlands[a]	Ammonia	5	mg/m^3	Manure processing plant	-	Standard used in permits	-
	Chlorine	6	mg/m^3	Production of chlorine	-		-
	Hydrogen sulphide	10	mg/m^3	Claus plants	-		-
	Ammonia	30	mg/m^3	Production of nitrogen-based fertilizer	-	Permit for new facility	Does not apply to waste gases from urea granulation
		30 to 200	mg/m^3		-	Regulation for existing facility	The status quo must be maintained
	Ammonia	30	mg/m^3	Ammonia plant	-	Standard used in permit	-
Switzerland[b] (Emission standards are set for about 150 substances which can cause odour, this is a sample)	Ammonia	30	mg/m^3	General	-	Federal law	If mass emission rate is ≥300 g/h
	Chlorine	5	mg/m^3	General	-		If mass emission rate ≥ 50 g/h
	Hydrogen sulphide	5	mg/m^3	General	-		If mass emission rate ≥ 50 g/h
	Ethyl acetate	150	mg/m^3	General	-		If mass emission rate ≥ 3.0 kg/h
	Butyl acetate	150	mg/m^3	General	-		If mass emission rate ≥ 3.0 kg/h

Jurisdiction	Contaminant	Standard	Units	Source or Process Type	Specific Control Technology	Use (Permits, Guidance, Enforcement, Planning)	Other Comments
	Acetone	150	mg/m^3	General	-		If mass emission rate ≥ 3.0 kg/h
	Acetic acid	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Propionic acid	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Ethyl acrylate	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	Alcanes (not methane)	150	mg/m^3	General	-		If mass emission rate ≥ 3.0 kg/h
	Propionic aldehyde	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Alkyl alcohols	150	mg/m^3	General	-		If mass emission rate ≥ 3.0 kg/h
	Aniline	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	Biphenyl	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	Chlorobenzene	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Dimethyl amine	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	2,6-Dimethylheptane-4-one	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Carbon disulphide	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h

Jurisdiction	Contaminant	Standard	Units	Source or Process Type	Specific Control Technology	Use (Permits, Guidance, Enforcement, Planning)	Other Comments
	Diisopropyl ether	150	mg/m^3	General	-		If mass emission rate ≥ 3.0 kg/h
	Ethylbenzene	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	Ethylene glycol	150	mg/m^3	General	-		If mass emission rate ≥ 3.0 kg/h
	Formaldehyde	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	2-Furaldehyde	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	Isopropyl benzene	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Methyl methacrylate	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Methyl amine	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	Naphthalene	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	2-Propenal	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	Pyridine	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	Styrene	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Tetrahydrafurane	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h

Jurisdiction	Contaminant	Standard	Units	Source or Process Type	Specific Control Technology	Use (Permits, Guidance, Enforcement, Planning)	Other Comments
	Thioalcohols	20	mg/m^3	General	-		If mass emission rate ≥ 0.1 kg/h
	Toluene	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Xylenes	100	mg/m^3	General	-		If mass emission rate ≥ 2.0 kg/h
	Chlorine	3	mg/m^3	Chlorine Production Facilities	-		-
		6	mg/m^3	Chlorine production facilities with complete liquefaction	-		-
	Ammonia	5	mg/m^3	Foundries	-		-
	VOCs (as total carbon)	50	mg/m^3	Smoke-house (warm process)	-		If mass emission rate ≥ 50 g/h
		120	mg/m^3	Smoke-house (cold process)	-		If mass emission rate > 50 g/h but < 300 g/h
		50	mg/m^3		-		If mass emission rate >300 g/h
	VOCs (as total carbon)	150	mg/m^3	Coffee roaster	-		Capacity ≤ 750 kg/h
		50	mg/m^3		-		Capacity >750 kg/h
	Ammonia	5	mg/m^3	Incinerator (municipal or special waste)	-		-
ASIA							

Jurisdiction	Contaminant	Standard	Units	Source or Process Type	Specific Control Technology	Use (Permits, Guidance, Enforcement, Planning)	Other Comments
Japan[c]	Hydrogen sulphide	$C_{lm} = k\ C_m$ (see Other Comments for definitions)	mg/L	Liquid effluent standard in terms of concentration of chemical in effluent	-	Regulatory standard used in permits and enforced by local government	k is a constant that depends on the volumetric flow rate of liquid effluent (see Table y) and C_m is the maximum permissible concentration standard selected by the local authority based
	Methyl mercaptan		mg/L				
	Dimethyl sulphide		mg/L				
	Dimethyl disulphide		mg/L				
	Ammonia	$0.108H_e^2\ C_m$ (See Other Comments for definitions)	m^3/h	Stack emission standard in terms of volumetric flow rate of individual chemical	-	Regulatory standard used in permits and enforced by local government	H_e is the effective stack height calculated using specified equations and C_m is the maximum permissible concentration standard selected by the local authority
	Hydrogen sulphide		m^3/h				
	Trimethyl amine		m^3/h				
	Propionaldehyde		m^3/h				
	n-Butyl aldehyde		m^3/h				
	i-Butyl aldehyde		m^3/h				
	n-Valeraldehyde		m^3/h				
	i-Valeraldehyde		m^3/h				
	i-Butanol		m^3/h				
	Ethyl Acetate		m^3/h				
	MIBK		m^3/h				
	Toluene		m^3/h				
	Xylene		m^3/h				

Jurisdiction	Contaminant	Standard	Units	Source or Process Type	Specific Control Technology	Use (Permits, Guidance, Enforcement, Planning)	Other Comments
Korea	Odour	1000	OU	Outlet facilities of atmospheric pollutants (e.g., rubber and plastic product manufacturing plants, leather product manufacturing plants, industrial waste incinerators, painting mills, and petrochemical refinery plants)	-	-	Measured using air dilution sensory test
	Odour	500	OU	Facilities in residential areas (e.g., agricultural product wholesale markets, joint markets, butchery treatment areas, excretion treatment facilities, livestock farming waste treatment facilities, and cleaning facilities)	-	-	Measured using air dilution sensory test

Table y Values of Constant k as a Function of Volumetric Flowrate Q (m^3/s) Used in Calculation of Maximum Permissible Concentration of Odour Substances in Liquid Effluent (www.env.go.jp/en/lar/regulation/odor.html)

Volumetric Flow Rate Q (m3/s)	Q ≤ 10-3	10-3< Q ≤ 10-1	10-1 < Q
Hydrogen sulphide	5.6	1.2	0.26
Methyl mercaptan	16	34	0.71
Dimethyl sulphide	32	6.9	1.4
Dimethyl disulphide	63	14	2.9

[a] Netherlands Emission Guidelines for Air (2003)
[b] Ordonnance sur la Protection de l'Air (2004)
[c] Japanese Ministry of the Environment Website – page related to Control of Offensive Odour

Table 6-1: Summary of Strengths and Weaknesses of Odour Management Approaches

	Strengths	Weaknesses	Considerations
Avoidance of Nuisance Laws	**Applicable to Pre-existing sources** • Can be applied to already existing facilities. **Acknowledges Receptors** [(a)] • Odour issues are a problem only where there are human receptors. • Focus on sources of concern only (i.e., if a source has not raised concern with receptors, no time or money is invested into an investigation). • Can focus investment in areas (both financial and time) where odour concerns are predominant. **Not Specific to Individual Source** • Can be applied to all sources. **Well established Practices** • Odour regulations in 42 of the 50 states in the United States are of this type (Epstein and Freeman, 2004). • Nuisance laws in Europe date back to late 19th century (Van Harreveld, 2005).	**Contradicting Legislation** • May conflict with Agricultural Operation Practices Act. **Quantification** • Different smells affect different people in different ways. • Each facility would need to be considered as unique. • Legal hearings may increase since "nuissance" and "quality of life" may be interpreted differently by the two parties. **Public Relations** • Once relied on for enforcement, public relations may break down. • Quantifying impacts may lead to receptors being exposed to even longer effects, leading to additional effect on quality of life. **Future Projects** • Hard to determine what is perceived as "quality of life" when in planning stage. • Land use (and thus receptors) may change over time affecting what is considered a nuisance.	**Sources:** • Could be applied to all sources (with the exception of perhaps agricultural). **Combined Application** • Quite often combined with Complaint Criteria Method. **Sample Jurisdictions:** • Ontario, New South Wales Australia. **Enforceability** • A legal test must be established to determine what constitutes a "nuisance". • The steps to enforce with policy and law must be clear. • The time-frame for solving issues must be clear for all parties. **Clarity** • Requires definition of a "nuisance" and "quality of life". • Legislation should be clear with respect to odour. • This would include frequency, intensity, annoyance potential, etc.

	Strengths	Weaknesses	Considerations
Ambient Concentration Criteria for Individual Chemicals	**Quantifiable** • Out of all methods arguably the most quantifiable. • Odour thresholds are known for many compounds. • Ambient concentrations can be measured and quantified. • Concentrations can be predicted with dispersion modelling. **Proactive Management** • Dispersion modelling can be used to predict concentrations and measures can be taken before a facility is built. • Monitoring of multiple compounds can be conducted. As odour thresholds are approached, facilities can take proactive measures to mitigate problems. • Can be used for urban planning, and planning for future facilities. **Temporal Resolution** • Many compounds can be measured continuously leading to multiple measurements over time. • Can study times of day, meteorological conditions, etc. that can lead to odour and proactively manage emissions. **Familiarity to Alberta** • Alberta Ambient Air Quality Objectives currently includes three substances because of odour, including carbon disulphide, ammonia and hydrogen sulphide.	**Capturing Odour** • Odour compounds are not necessarily additive. They can react with each other giving higher or lower odour thresholds than individual chemicals. • Although individual compounds may be below their respective odour threshold, odour may still be present. • Would be hard to quantify (without direct monitoring) for sources that are variable due to organic matter (i.e., landfills, composting, agricultural etc.). • Hard to quantify with monitoring in areas with large number of sources producing similar compounds. **Measurements** • Some chemicals may pose an odour concern even when concentrations are below detection limit of instrumentation. • There are hundreds of compounds that are considered to be odourous (see AIHA, 2012), and not all would be able to be measured (i.e., cost prohibitive). **Consideration of Receptors** • Even if no human receptors are present or receptors report no odours, facilities would still be required to uphold legislation.	**Sources:** • Works well with sources with known emission rates, especially those already reporting to the Government, such as oil and gas facilities, pulp and paper mills, chemical plants, power plants, etc. **Jurisdictions** • Ontario, Quebec, New South Wales Australia. **Sampling Methods** • Cost associated with measurements. • Frequency of sampling period and averaging period must be considered. • Minimum monitoring requirements must be defined. • Preventative monitoring may provide good community relations tool, while reactive monitoring may come under more scrutiny. **Odour Thresholds** • Definition of odour threshold would need to be considered. Reported odour thresholds can range by several orders of magnitude (AISA, 2012). • There are hundreds of odour causing compounds; how would legislation work when it would be impossible to measure/consider all?

	Strengths	Weaknesses	Considerations
Ambient Concentration Criteria for Odour	**Well Established methods** • Two primary standards have been developed for measurements of odour; 1) ASTM International E679-04: Standard Practice for Determination of Odor and Taste Thresholds by a Forced-Chose Ascending Concentrations Series Method of limits. 2) European Union Standard EN13725:2003: Air Quality Determination of Odour Concentration by Dynamic Olfactometry. **Proactive Measures** • If odour emission rates can be estimated, odour units can be modelled using dispersion modelling similar to contaminant concentrations. • Can aid in urban planning around new or expanded facilities. **Quantifiable** • With use of odour panels, a well-established quantifiable odour can be determined. • Can be used as a tool for reactive responses (i.e., from complaints etc.). **Classifies Odour** • Is applicable to a large range of odorants. • Can be used for complex odours (i.e., more than one odorant). • Related to odour intensity as perceived by human sense of smell.	**Future Planning** • Many times more difficult to determine odour emissions before a facility is built; and thus, to proactively model OU concentrations. **Uniqueness of Samples** • Samples are not always continuous. • Coordination between time of day, meteorological conditions, location etc. can influence if odours are detected or not. • Odours from different facilities with different character of odours may result in odours even when alone they may not. **Costs** • Suitable odour testing facilities (i.e., odour panels) may not exist locally, and must either be established and training programs standardized, or the samples must be sent to other jurisdictions for testing. • Cost to send samples to an odour panel can be high, as the panel usually consists of at least 6 personnel. **Sample Degradation** • Sample can degrade with respect to time, temperature, humidity etc. and are therefore time sensitive. • Window of optimal testing may factor into cost.	**Sources:** • Can be useful for existing and new facilities (in some cases). • Reactive measurements could be used with all types of facilities. **Jurisdictions:** • Saskatchewan, Europe (majority of countries) Australia (all provinces), Korea, Colorado, Connecticut. **Sampling Methods** • Frequency of sampling period and averaging period must be considered. • Minimum monitoring requirements must be defined. • Preventative monitoring may provide good community relations tool, while reactive monitoring may come under more scrutiny. • Coordination of sampling time vs. introducing it to the panel. **Choosing Limits** • 1 OU/m^3 is the point of the detection of an odour, while at approximately 3 OU/m^3 recognition threshold is reached. This differs between the general population. • An acceptable limit must be established, with an appropriate averaging period. • Multiple criteria can be established for different averaging periods as well.

	Strengths	Weaknesses	Considerations
Episode Duration Frequency	**Considers Type of Sources** • Takes into consideration other issues besides intensity that may trigger complaints (i.e., a bakery, although it may emit odours, it would likely not raise as many complaints as other industries). • Considers intensity, duration location and frequency. **Proactive management** • A systematic process for predicting odour impacts on new and/or modified facilities is in place in Germany. • Can be used for future planning of the facility and/or urban planning.	**Quantification** • Some subjective analysis including what is considered. **Labour- intensive** • It can take up to 6 months to take into all considerations. • Would not work for short term complaints. • Costs associated with the method can be expensive. **Uniqueness of protocol** • Only used in Germany, therefore not as well tested in other environments. • Reference material would be only from one country (i.e., harder to determine what works/doesn't work in different environments).	**Sources:** • Could be applied to all sources including oil and gas facilities, pulp and paper mills, chemical plants, refineries and power plants. • Good at distinguishing impact from different types of facilities. **Jurisdictions:** • Germany **Choosing Limits** • Definition of duration, frequency etc., would have to be defined along with what would be termed acceptable. • Length of how long an investigation would last with monitoring would need to be determined, weighing in such factors as cost, exposure, gaining enough time to obtain all measurements it would need. • Germany distinguishes limits for different zones. Zoning may need to be considered (i.e., industrial vs. residential).

	Strengths	Weaknesses	Considerations
Minimum Separation Distances	**Familiarity to Alberta** • Alberta currently has variable minimum distance separation (MDS) for the Agricultural Sector. • Agricultural Operation Practices Act Standards and Administration Regulation (Alberta, 2002). **Future Planning** • Once source is established, urban planning would be straight forward of where and where not to build. • Facilities would be able to quickly decide if expansions could/could not occur.	**Preexisting sources** • Would be hard, if not impossible, to implement for sources and facilities that are already established. **Influence of Surrounding Environment** • Does not take into consideration meteorological conditions that may cause odour issues downwind, while a receptor upwind may not notice an odour. • Complex terrain (such as in the foothills and mountains) may affect the dispersion of odours that would not be estimated with minimum separation distance method. **Source Upgrades** • Would not take into consideration technology investments that a source may implement to reduce odours. **Capturing Odour** • Separation distances would not necessarily alleviate all odour issues. • Over-conservative distances would impede future projects and developments around the sources that may not be necessary.	**Sources:** • Can be applied to new sources. • Used in many jurisdictions for agricultural sources, sewage treatment and composting. • Would not be able to implement for existing sources since source is established. • If separation distance had previously been established, expansion of an existing facility may be limited. **Jurisdictions:** • Alberta (for Agricultural Section), Ontario (for Agricultural Sector), South Australia (most if not all sectors). **Standardizing all Sources:** • In a number of jurisdictions, odour issues related to agriculture are handled by a different department or ministry than other industrial or municipal sources of odour. • Modification to include all sources would have to be taken into account. • Determination how to adjust legislation for all sources would be needed. • Consideration of all types of sources would have to be determined.

	Strengths	Weaknesses	Considerations
Odour Intensity Scales	**Introduced to Alberta** • A protocol for internal use only was developed by the AER in 2014; Hydrocarbon Odour Management Protocol for Upstream Oil and Gas Point Source Venting and Fugitive Emissions. • Protocol developed in response to the reflections in April 2014 edition of *Directive 60: Upstream Petroleum Industry Flaring, Incinerating and Venting.* • The Natural Resources Conservation Board has a protocol for inspectors to use when responding to complaints for confined feeding operations. **Simplicity** • Semi-quantitative intensity scale. • Used to assist field personal when investigating an odour complaint. • Allows field staff to make immediate determination regarding intensity of odour. **Cost** • Cost efficient compared to other measuring techniques. • Multiple points can be assessed little time and effort. • Little to no special training. • Does not require taking a sample for further analysis nor will incur associated laboratory costs. **Source Appointment** • In an area of multiple sources, this method may be able to pinpoint odorous source.	**Subjective** • Unique smell to different people, i.e., something strong to someone may be moderate or below odour threshold to another person. • Dependent on time of day location. • If exposed to higher odour intensities earlier, may reduce odour detection of field personnel later in the day. • May be hard to hold up in a court of law. **Distances** • Supporting large areas may be difficult. • Deploying field personnel out in the field as soon as a complaint is issued may be difficult, especially in remote areas. **Uniqueness of Samples** • Samples are not always continuous. • Coordination between time of day, meteorological conditions, location etc. can influence if odours are detected or not.	**Sources:** • Can be applied to all sources. • Good for existing facilities. **Combined application:** • Often used jointly with complaint criteria **Jurisdictions** • Western Australia, New Jersey, Japan, Korea, Wellington NZ, Texas. **Sampling methods** • Preventative monitoring may provide good community relations tool, while reactive monitoring may come under more scrutiny. • Required frequency of measurements would need to be established and/or possible follow up measurements after a complaint is filed. **Streamlining for all Sources** • Since already have procedures for the AER and NRCB would have to consider how to merge methods together or if to leave the procedures different between source type. • There may be situations where one department would oversee odour measurements and pass it to other departments depending on the nature of odour (i.e., a common board may be created to determine odour but may refer to AER or NRCB once the nature of the odour is determined.

	Strengths	Weaknesses	Considerations
Odour Index	**Quantifiable** • With use of odour panels, a well-established quantifiable odour can be determined. • Can be used as a tool for reactive responses (i.e., from complaints etc.). **Locations** • Could be used to quantify odours in locations such as inside buildings. **Classifies odour** • Applicable to large range of odorants. • Can be used for complex odours (i.e., more than one odorant). • Related to odour intensity as perceived by human sense of smell.	**Future Planning** • May not be able to predict odours for future projects and planning. **Uniqueness of Samples** • Samples are not always continuous. • Coordination between time of day, meteorological conditions, location etc. can influence if odours are detected. **Costs** • Suitable odour testing facilities (i.e., odour panels) may not exist locally, and must either be established and training programs standardized, or the samples must be sent to other jurisdictions for testing. • Costs to send samples to an odour panel can be high, as the panel usually consists of at least 6 personnel. **Sample degradation** • Sample can degrade due to time, temperature, humidity etc.; and are therefore, time sensitive. • Window of optimal testing and may factor into cost. **Uniqueness of Method** • Only used in Japan, therefore, not as well tested as other methods in different environments. • Reference material would be only from one country (i.e., harder to determine what works/doesn't work in different environments).	**Sources:** • Can be used for all sources. • Can be used for future planning of different types of sources. **Jurisdictions:** • Japan **Sampling Methods** • Frequency of sampling period and averaging period must be considered. • Preventative monitoring may provide good community relations tool, while reactive monitoring may come under more scrutiny. • Coordination of sampling time vs. introducing it to the panel. **Choosing limits** • What would be considered acceptable vs. threshold detection of the panel? **Training** • Limited globally trained individuals. • Training for odour panel required to adapt to this method.

	Strengths	Weaknesses	Considerations
Complaint Criteria	**Familiarity to Alberta** • City of Edmonton "Gold Bar Odour Complaint Hotline" 780-412-3414 or 311 for sewer odour issues. • Natural Resources Conservation Board (NRCB) 866-383-6722. Once a complaint/concern is registered, a regional NRCB inspector will initiate an investigation. • NRCB can issue an odour report form that is completed by complainants and tracks frequency, duration and intensity of odours. **Applicable to Existing sources** • Can be applied to already existing facilities. **Acknowledges Receptors** • Gives power to public. • Focuses on areas where receptors are located. • Focus on sources of concern only (i.e., if a source has not raised concern with receptors, no time or money is invested into an investigation). • Can focus investment in areas (both financial and time) where odour concerns are predominant. **Not Specific to Individual Source** • Can be applied to all sources. **Well Established Practice** • Most jurisdictions have a system in place for responding to odour complaints. • Many jurisdictions can be reviewed for how best to approach in Alberta.	**Quantifiable** • Different people react to odours at different thresholds. • Hard to distinguish what is acceptable/not acceptable for different people. **Public Relations** • Once relied on for enforcement, receptors may become hostile towards source owner. • Verifying impacts may lead to receptors being exposed to even longer effects. • Legal lawsuits may follow suit if disagreement between what consists of an odour occurs between complainant and source owner. **Preventative Legislation** • This method focuses on what to do to deal with a problem not how to prevent one. • May be seen as "band-aid' solution which doesn't solve the initial problem.	**Sources:** • Applied to all sources, quite often industry based. • Usually combined with other methods to quantify. **Jurisdictions:** • Many cities have by-laws associated with odour complaints. (i.e., Metro Vancouver). • Alberta for agricultural sources (NRCB). **Involvement and Method of Reporting** • Some jurisdictions use an odour diary for public receptors to record details over a certain amount of time. Others use online reporting forms and/or toll free numbers. • Once a complaint is issued, the next step must be identified. • Some jurisdictions respond to each complaint, others require all complaints to be logged, but not necessarily be acted upon. • Some require a minimum threshold of complaints required before an investigation is launched. **Streamlining for all Industries** • Since there are already procedures for the NRCB with respect to odour complaints, it is important to decide how to implement for all sources. • There may be situations where one department would oversee odour measurements and pass it to other departments depending on the nature of odour.

	Strengths	Weaknesses	Considerations
Quantitative Emission Criteria	**Measurements** • Stack testing is common for a number of contaminants presently in Alberta and adding additional testing for odour standards could be included. **Future Planning** • Facilities would know what standards they would need before building and would be able design to or implement so that the facilities follow guidelines. • Dispersion modelling based on measurements could be used to determine possible odour issues surrounding the facility before they occur.	**Capturing Odour** • Emission rates do not necessarily equal odour issues. • Although high emissions may be recorded, meteorological conditions, temperatures, surrounding terrain etc., can influence the dispersion of the emissions. • Does not take into account where receptors are located or if an odour issue would occur in public places. **Inclusion of all Sources** • Would be hard to do for an individual complaint or for an agricultural operation where emissions may be more spread out in both area and time. • Emission rates may be difficult to measure from non-point sources (i.e. agricultural sources). • Would be hard to quantify for sources that are variable due to organic matter (i.e., landfills, composting, agricultural etc.). • Hard to quantify with monitoring in areas with large number of sources producing similar compounds.	**Sources:** • Would be limited to facilities that have point source emissions. For example, electricity generation, pulp and paper mills, chemical industry, transportation. • Would be more beneficial in new facilities. **Jurisdictions:** • Japan, Korea, Switzerland, Bay Area Air Quality Management District (California, USA). **Sampling Methods** • Frequency of sampling period and averaging period must be considered. • Preventative monitoring may provide good community relations tool, while reactive monitoring may come under more scrutiny. • Averaging time would need to be considered. **Odour Thresholds** • Some jurisdictions measure directly OU or D/T, others measure compound concentration. • There are hundreds of odour causing compounds. Would need to know how legislation would prioritize them when it is impossible to measure/consider all of them. • Measurements must relate back to odour detection at the public receptors.

	Strengths	Weaknesses	Considerations
Technology Criteria	**Proactive** • Allows for best practices to occur on site. • Minimizes potential for odour complaints by addressing emissions on site and at the source. **Clear Direction** • Industry would know minimum standards before the planning stages.	**Capturing Odour** • Even with precautions, odour may still be an issue. • Additional technology may not affect potential for odour issues, but will likely have financial impact to companies. • Meteorological conditions, temperatures, surrounding terrain etc., can influence the dispersion of the emissions. • Does not take into account where receptors are located or if an odour issue would occur in public places.	**Sources:** • Large facilities (due to cost to individual facilities). • Easier to implement for common facilities where multiple technology measurements already exist. • Easier to implement for new facilities **Jurisdictions:** • Netherlands, Colorado, Wellington New Zealand. **Definitions** • What is considered best control technology? • How would this change over time? **Defining Limits** • Measurement of technology criteria would need to be defined. • Cost / benefit analysis required. • Some form of change management required as odour criteria evolve, or new technology comes on-line.

(a) Receptors = locations where general public would notice a smell