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Short Introduction to the Summary and Evaluation of the Odour Regulations Worldwide

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When it comes to air pollution complaints, odours are often the most significant contributor. Sources of odour emissions range from natural to anthropogenic. Mitigation of odour can be challenging, multifaceted, site-specific, and is often confounded by its complexity—defined by existing (or non-existing) environmental laws, public ordinances, and socio-economic considerations. The objective of this paper is to review and summarize odour legislation in selected European countries (France, Germany, Austria, Hungary, United Kingdom, Spain, The Netherlands, Italy, Belgium), North America (USA and Canada), South America (Chile and Colombia), as well as Oceania (Australia and New Zealand) and Asia (Japan, China). Many countries have incorporated odour controls into their legislation. However, odour-related assessment criteria tend to be highly variable between countries, individual states, provinces and even counties and towns. Legislation ranges from (1) no specific mention in environmental legislation that regulates pollutants which are known to have an odour impact to (2) extensive details about odour source testing, odour dispersion modeling, ambient odour monitoring, (3) setback distances, (4) process operations, and (5) odour control technologies and procedures. Agricultural operations are one specific source of odour emissions in rural and suburban areas and a model example of such complexities. Management of agricultural odour emissions is important because of the dense consolidation of animal feeding operations and the advance of housing development into rural areas. Overall, there is a need for continued survey, review, development, and adjustment of odour legislation that considers sustainable development, environmental stewardship, and socio-economic realities, all of which are amenable to a just, site-specific, and sector-specific application.

1. Introduction

This paper is a collaborative work by seventeen international odour experts sharing comprehensive summaries and evaluations of odour policy and legislation from seventeen countries/regions: Europe (Austria, Belgium, France, Germany, Hungary, Italy, The Netherlands, Spain, U.K.), Asia (China, including Hong Kong, Japan), Australasia (Australia, New Zealand), North America (U.S., Canada), and South America (Chile, Colombia).

While the authors acknowledge that this paper is only a snapshot in time of current worldwide odour policy, the content of the paper will always maintain historical value (i.e., the status of odour regulatory approaches as of 2019) and will likely remain relevant as a gauge for changes made to regulations in the future and which tend to evolve slowly.

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Odour issues are currently one of the major causes of environmental grievances around the world, and in some countries, are routinely the cause of most environmental complaints to regulatory authorities. There continue to be multiple reasons for the prominence of odour complaints, including an unrelenting urban expansion of residential areas into land-use areas once predominantly agricultural with few largely isolated facilities; increases in facility operations and their size; increasingly higher aesthetic environmental expectations of citizens, who are less familiar and tolerant of odours than in the past; and, concerns over potential health risks from airborne odorous substances.

In most countries, environmental legislation covers most types of common air pollutants, and there is little variation between jurisdictions which have such legislation. However, odour legislation tends to be much more varied and varies across a wide spectrum: from having little to no specific mentioning in environmental legislation to extensive and rigid detailing in odour source testing, odour dispersion modeling, ambient odour monitoring, setback distances, process operations and odour control procedures. Odour legislation can be highly variable from one jurisdiction to the next.

Odour issues are very complex, and, therefore, a very good understanding of the formation of odour released into the atmosphere and exposure is important. The exposure of individuals living in odour prone areas may lead to immediate annoyance, which in the long term may lead to it being defined as a nuisance. In some countries, odour policies are based solely on odour nuisance criteria and so the question arises on how to determine odour nuisance. There are several guidelines for nuisance such as use and loss of enjoyment of the property, interference with the normal conduct of business, damage to animal and plant life, human health and safety, or property damage. Some countries, provinces, or states have also defined odour concentrations at which the odour nuisance could occur, taking into consideration several factors such as frequency and duration of odour episodes. Therefore, a common use of the FIDOL factors (frequency, intensity, duration, offensiveness and location/receptor) is often used by some jurisdictions to determine the likelihood of odour annoyance in the area.

Nuisance can also be determined based on the validity of odour complaints and odour measurements. The odour measurements are either performed at the sources (CEN 2003), (VDI 2011) or at locations where odour may be present by doing direct odour monitoring (CEN 2016a),(CEN 2016b). Measurements conducted at the sources include estimating odour emission rates at each potential odour source in ou/s and the use of dispersion modeling to establish odour concentrations (in ou or in some countries recorded as in $ou_E \cdot m^{-3}$) at sensitive receptors, at the property line, or at any other affected areas. Some countries set the limit for odour, either based on dispersion modelling criteria at the nearest sensitive receptor, or property boundary (for example, in New Zealand and some states of Australia (Tasmania), or in certain Canadian provinces such as Ontario province) or based on direct odour monitoring at the affected areas (for example in Germany and some American states). The limits are either called the Odour Impact Criteria (OIC) or odour concentration or detection to thresholds (D/T). The OIC is based on odour concentrations and the accepted probability of exceedance of the concentration (i.e., percentile) to define compliance. In some countries where there is no odour control, the odour limit may be determined by some specific and relatively easy-to-measure compounds such as hydrogen sulphide or ammonia. In some European countries such as France, odour exposure limits are also set as ELV (Emission Limit Values in ou/s or ou/h. On the other hand, in several U.S. states, the Dilution to Threshold (D/T) approach is used to set the limits.

Odour nuisance depends on various predictors of odour, which are often summarized with the acronym FIDO (Frequency, Intensity, Duration, and Offensiveness), with factors not presented in any prioritized order (Watts, Sweeten, 1995). In New Zealand and Australia, a fifth factor, 'L', as in FIDOL refers to the location of the odour (NZ MoE 2016). This additional factor refers to the sensitivity of the surrounding residential area. For example, odours near a school may increase concerns for citizens.

Almost all odour policies specify criteria or otherwise reference the intensity component of FIDO: either through a measure of odour strength as odour units per cubic meter ($ou_E \cdot m^{-3}$) from laboratory olfactometry (CEN 2003); as Odour Index Threshold Value through the Triangle Bag Method; as perceived odour intensity (VDI 1992), (ASTM 2010); offensiveness (VDI 1994) (or as Dilution-to-Threshold (D/T) through field olfactometry measurements (Loriato et al., 2012).

The frequency and duration of odour episodes are often taken into consideration through dispersion modelling of odour emission rates to determine odour exposure to receptors and the number of hours in a year with odours present. The OIC limits the number of odour-hours or provides a requirement for percent of year without odours (e.g., 98%). Secondly, frequency and duration are carried through field inspection and documentation of the odours present.

In any investigation of odours, the character of the offending odours is documented to identify their source. Some policies have different criteria or even different approaches for specific odour sources.

Currently, odour policies are highly variable between countries, individual states or provinces and even between counties and towns.

These policies include:
1. No specific mention in environmental legislation;
2. Regulation of pollutants which are known to have an odour impact;
3. Consideration of odour perception as a nuisance;
4. Setting standards for specific odorants or other contaminants such as hydrogen sulfide; and
5. Extensive detail for odour assessments, including odour source testing, dispersion modelling, ambient odour monitoring, setback distances, process operations, and odour control technologies and procedures.
6. Other approaches
While there are differences in the details of these policies, all policies outlined in this paper include one or more of these FIDO factors of odour nuisance. This paper outlines these varying approaches and discusses the advantages and disadvantages of the systems.

2. Discussion and Summary

Odour is based on perception, the chemosensory response to odorants in the air. We experience odours throughout our days around the home and in our communities. The degree of an odour impact is based on five main factors, including the offensiveness and intensity/concentration of the odours, the frequency, and duration that the odours are present, and the location or context of the experience, all together commonly referred to as FIDOR (frequency, intensity, duration, offensiveness, and 'receptor', which is also labeled as 'location' in the alternative FIDOL). The personal experience and biases of the affected citizens have historically complicated the assessment by enforcement officials; however, standardized laboratory and field-based odour assessment protocols have provided the means to objectively quantify a largely subjective experience.
The complex interaction of the five FIDOR elements of odour makes it challenging to 'regulate' odours on a country-level. Different philosophies of control, as well as different regulatory systems, hinder the development of one common approach to policy. However, utilizing various quantification methods, a number of countries and provinces/states have adopted approaches that are suitable or politically feasible to legislate and enforce community odours.
The regulatory approaches outlined throughout this paper provide a foundation for understanding important elements of regulation. Below is a list of questions that may be used for a discussion involving the formulation of odour regulation. This list is not complete, but it is an outline that can be useful.
Planning:
How do the existing local planning and zoning policies impact proposed regulation and its implementation?
Who should be the stakeholders involved in drafting an odour regulation?
What are the costs of regulation (to the facility and the community/agency)?
What are the costs of no regulation (to the facility and the community/agency)?
Choice of regulatory criteria:
In which cases is an air quality regulation suggested, and in which cases is an emission regulation better?
Why are only some industries regulated and not necessarily all types of emissions in a region or country?
Continuous improvement:
Which level of graduality has been reached by countries with a history of odour regulations, and what were the results?
Metrics:
What are the indicators of a successful odour regulation?
How have various methods of current and past regulation been successful?
Is there a link between regulation and accreditation (operating permit, obligatory periodic audit)?
Recommendations:
Is there a list of common recommendations to countries/stakeholders that are considering an odour regulation?
Is there a need for a 'clearinghouse' of best practices that document country-level experiences?
It is a challenge to answer these questions, and the answers could be different depending on the local/state situation.
For most of them, there is not one univocal answer. This paper describes approaches to the different regulations adopted by selected countries and regions within the countries. Table 1 below summarizes approaches categorized by methods, countries where they are adopted, and related pros/cons. Note that the identification of countries is based on the existence of regulatory enforcement. In some cases, an approach may still exist in a specific country based on specific facility permits. For example, while countries such as the USA or Spain may not regulate an odour concentration source emission measurement, a facility permit may be used to instill specific enforcement on one facility.

*Table 1: Examples of approaches to odour regulations in selected countries (*Bokowa et al. 2021).

General Approach	Methods	Country	Pros	Cons
1) Emission measurement	a) Measurement of odour concentration at the source of emissions	Japan (Measurement of odour index), China, Colombia, Canada (Quebec), Germany	Standardized methodology (1)	No direct relationship with odour perception by citizens
	b) Measurement of odour emission rate (at the source of emissions)	Japan, Canada, Germany	Standardized methodology (1) for point sources and active area sources; More related to odour perception than just odour concentration measurement	Not standardized for passive area sources (except for Germany) Hardly achievable in the case of diffuse sources Not applicable to sources with variable emissions over time No direct relationship with odour perception by citizens (meteorological conditions and distance to receptors not considered)
	c) Measurement of the concentration of specific odorants (chemical concentrations, mass/volume, volumetric mixing ratios)	USA (e.g., H_2S), Spain, Canada, Australia, New Zealand	High confidence level in the technique	Not representative of the odour of mixture. No direct relationship with odour perception by citizens
	d) Measurement of the emission rate of specific odorants (chemical mass/time)	Japan, Canada, China	Standardized methodology	Not representative of the odour of mixture. No direct relationship with odour perception by citizens
Fenceline measurement	a) Measurement of odour index at the property line	Japan, China	Standardized methodology (Japan Environment Agency Notification No.63: 1995) Direct relationship with odour perception by citizens	No direct relationship with odour perception by citizens
	b) Measurement of the concentration of specific odorants at the property line	Japan, Canada, China	Standardized methodology (2)	Not representative of the odour of mixture. No direct relationship with odour perception by citizens
Limitation of Impact	a) Separation distances defined based on dispersion modelling	USA, Canada (animal agriculture) Australia and New Zealand separation distances are defined by modelling and empirical equations	Ease of application (Less complex than dispersion models)	Only applicable to new installations. No direct relationship with odour perception by citizens
Exposure assessment (OIC and complementary approaches (e.g., FIDOR factors))	a) Dispersion modelling	Italy (Lombardy, Piemonte, Trento), Canada-Ontario, France (applicable for solvent industries), Germany	Applicability for predictive purposes	No standardization. Different models and settings can be used leading to different results Hardly applicable to complex sources (diffuse or variable over time)
	b) Field inspection	Germany (growing in AU and NZ)	Standardized methodology (European standard EN16841) Direct relationship with odour perception by humans	Long duration, limitations in extreme weather conditions, in not accessible areas unsafe spots.
	c) Field olfactometry	USA (States and Municipalities)	In general, less expensive than other techniques (no sophisticated equipment nor trained assessors needed). Not standardized. Bias can be reduced, and the technique can be very effective if relying on a large number of citizens and if observations are validated	Risk of bias due to the prejudice of involved citizens Might be ineffective in very conflictual situations (e.g., lawsuits) Challenging to verify each specific complaint
	d) Citizen science		In general, less expensive than other techniques (no sophisticated equipment nor trained assessors needed). Not standardized. Bias can be reduced, and the	Risk of bias due to the prejudice of involved citizens Might be ineffective in very conflictual situations (e.g., lawsuits) Challenging to verify each specific complaint

		technique can be very effective if relying on a large number of citizens and if observations are validated	
e) Collection of complaints (free-form or structured)	USA (municipalities), Colombia, New Zealand, Australia	Easy to implement	Risk of bias due to the prejudice of involved citizens Might be ineffective in very conflictual situations (e.g., lawsuits) Challenging to verify each specific complaint
f) Regulator determination following complaints.	UK, Colombia	No measurements are needed. Regulators need to show permit or consent conditions are not being met.	It can end in a court judgment.
g) IOMS (Instrumental Odour Monitoring Systems)	France	Continuous measurement Possibility to discriminate odour/odorant sources	Not standardized technique It should be connected to odour measurements

Monitoring emissions or rates of emission at the source, either perceived odours or chemical odorants, is a relatively simple approach, but it has the limitation that it doesn't account for the people's exposure and perception downwind.

Chemical analysis for the measurement of odorant concentrations has a lower uncertainty, but it is not always possible to relate chemical composition to odour perception. More research is needed to link specific chemicals with their influence on the overall odour. Chemical analysis alone can miss the impact of strong odorants that are present at low concentrations. Here, the use of an odour activity value (OAV) could be useful, but more data is needed on detection threshold values for important odorants.

Separation distances can be effective in preventing odour problems. However, more research is needed to improve models and/or adopt industrial models for odour regulations.

The most common approaches to odour regulation are those entailing the use of dispersion modelling and field inspections for determining citizens' exposure to odours and compare it with Odour Impact Criteria (OIC). There are two groups of OIC used in various jurisdictions. The first group is common in the Anglo-American countries with high threshold/low exceedance probability; the second group with low threshold/high exceedance is based on investigations in Germany. A more detailed discussion about OIC and their application in different countries in the form of a Table S1 is provided in the Supplementary Material). The more comprehensive review of OIC and the manner in which they are applied is summarized by Brancher et al. 2017.

Dispersion models have the advantage that they usually are less time-intensive and cost-intensive than field inspections. On the other hand, field inspections account for the real impact in the community. Field inspections are now regulated on a European level by EN 16841.

Another possible approach to be considered for assessing odour impacts and regulating odours is advanced psychometry based on citizens' science. Citizen science relies on observations from a large number of citizens. The methodology developed to do so is complex and involves engagement approaches and other aspects such as data plausibility checks and complex meteorological checks. Once this approach is made, there is no risk of personal biases from individual observations as each observation is validated, taking into account different factors. A recent review of assessment techniques in the context of malodour impact on communities was published by Hayes et al. 2014.

Instrumental Odour Monitoring Systems (IOMS) have been developed with a wide range of technologies available. Results from various systems are not easily comparable, making it a challenge to use for regulation while keeping an open market to allow for all technologies. Efforts have been made to regulate environmental odour monitoring with IOMS, but this is a very challenging and heavily debated task. The only regulation concerning IOMSs is in France. In this country, a plant may decrease the frequency of periodical measurements performed by olfactometry if it has an IOMS.

3. Conclusions

While many countries and regions regulate odours with different approaches, there can be agreement among all involved that the regulation of odours can be an immense problem. Odour regulation is a place where science, policy, economics, and public relations are interconnected.

These odours may be quantified based on odorant concentrations as well as human perception. Objective measurements of the odour experience include laboratory and field assessments with olfactometer devices and by direct observations. Air dispersion models and other computer algorithms, such as setback models, further analyze and quantify odour exposure.

More and more countries and communities are regulating odours, and the trend is bound to continue. There is an overall trend towards the measurement of odours instead of chemical odorants, while efforts to standardize odour concentration measurement and field assessments continue around the world.
There is expected to be an increase in approaches based on citizen science. Technology advancements will continue to make it easier to collect data efficiently and analyze the inputs more rapidly.
There are also promising advancements occurring with the standardization of electronic noses and the development of more effective measurement tools. Multiple consensus working groups are currently discussing methods for testing and validation of chemical sensing technologies.
In the end, integrated approaches are often needed to obtain the broadest vision of odour problems. Methods that can take into account all elements of the FIDOR model will go farthest to balance the interests of key stakeholders. Continual review of the various methods in use will provide lessons for countries and regions, creating new or modifying existing regulations.

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