Odour and Health Backgrounder

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Executive Summary

This backgrounder aims to build a basic understanding about odour, health, and the relationship between the two, cited in existing studies. As well, limitations of current knowledge about odour and its effects on health and the shortcomings of current research tools used to understand odour and health will be discussed.

The sense of smell is one of the most primal human senses, with a powerful connection to our brains. *Olfaction*, the mechanism that allows people to smell, relies on two essential processes. Volatile chemicals in the air—called *odorants*—bind to *olfactory receptors* on special olfactory neurons in the nasal lining that are sensitive to their specific chemical structures. Those olfactory receptors signal the brain, which then makes associations with a person's surroundings and between the odour and their past experiences. Our noses contain roughly 400 different types of receptor on neurons, each sensitive to a specific type of odorant.

The nasal lining also contains *trigeminal neurons*, which transmit information on temperature, pressure, and pain, and also respond to noxious stimuli. Volatile chemicals can trigger olfactory neurons or trigeminal neurons but odours often trigger both simultaneously. This report will only focus on health effects related to the stimulation of the trigeminal and olfactory neurons.

Stimulation of trigeminal neurons by odorants can cause irritant effects, while stimulation of olfactory neurons by odorants can cause nuisance effects. Some odorants can stimulate both neurons and can cause both irritant and nuisance effects. Irritant effects are a bodily reaction to trigeminal nerve stimulation (e.g. watery eyes). Nuisance effects are tied to the perception of odour, with no mechanistically understood cause (e.g. insomnia). While the reason why certain odours cause nuisance effects is not fully understood, there's no denying the resulting symptoms are real.

Odours can affect a person's health physically (e.g. nausea), psychologically (e.g. stress), and socially (e.g. embarrassment). This report describes many of the different health effects cited in existing studies.

That said, there are challenges in studying the relationship between odour and health. Different people experience odours in different ways—a nuisance smell to one may be undetectable or pleasant to another. It's also difficult to measure odours in an objective way. These two factors make it challenging to assess the health effects caused by odours.

This report details some resulting limitations of current knowledge, problems scientists face in monitoring odours, and shortcomings in current research tools. In order to fully understand the health effects of an odour, many other pieces of knowledge are required including composition and chemical properties. Professionals in this field must continue to do the best they can with the knowledge they have, while also working to contribute better data and research to improve the overall understanding of the issues.

1 Introduction

This backgrounder is intended to build a basic understanding about odour and health. It will also examine what is known (and what is not known) about the relationship between the two.

First, let's look at the definition of health.

> *Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.*
>
> (Constitution of the World Health Organization).

In other words, health is not always something that can be objectively measured. It often involves subjective, intangible judgement—how people *feel.*

Given the unknowns associated with the chemical composition of odours and their interactions within a mixture, one cannot always rely on people's perception of an odour as a direct indicator of other serious health effects. In order to fully understand the health effects of an odour, many other pieces of knowledge are required including composition and chemical properties.

Smelling an *odour*, refers to the sensations people experience when chemical compounds, in the air that they breathe, stimulate receptor neurons in their noses.

On the other hand, when discussing the odour of a substance, people are generally referring to the specific chemical combination that gives that substance its characteristic scent or smell.

In North America, and particularly in the field of air quality, the term *odour* is usually understood to have a negative connotation. Something might be described as smelling nice, or having a pleasant aroma, but it wouldn't be described as having a good odour.

In this report, the relationship between odour and health refers to unwelcome smells and any related negative impact on people's overall wellbeing.

2 Why do people have a sense of smell?

People have senses to collect information about their surroundings, and their brains use this information to construct an image of the world around them. This is only a partial picture, but from an evolutionary perspective it is essential to the survival and reproduction of the human species.

The *olfactory sense*—the sense of smell—is one of the oldest and most primal human senses. It contributes to people's picture of the world by allowing them to detect chemicals in the environment. Human ancestors used smell to evaluate food, select reproductive mates, and identify dangers and enemies. Those instincts remain embedded in people to this day, providing a powerful connection between the olfactory sense and their brains.

Odours are made up of volatile chemicals—called *odorants*—that people can detect through the mechanism called *olfaction*.

Olfaction consists of two essential processes:

1. Odorants binding to *olfactory receptors* that are sensitive to their specific chemical structures.

2. Olfactory receptors signalling the brain, which then makes associations and determines a person's reaction.

2.1 Chemical binding of odorants

The nasal lining (*olfactory epithelium*) contains millions of *olfactory neurons*. People have roughly 400 different types of receptors, each sensitive to a specific type of odorant. When an odorant bonds to a corresponding receptor, it causes that neuron to send a signal to the brain (Malnic et al., 1999).

With 400 different types of receptors, spread amongst millions of neurons, the olfactory system can detect an endless number of different odours. It can differentiate between odorants of similar structure, and between varying concentrations of a single odorant.

In short, the nose is an extremely sophisticated and sensitive instrument for detecting chemicals in the environment.

The nasal lining also contains *trigeminal neurons,* which transmit information on temperature, pressure, and pain, and also respond to noxious stimuli.

Odours can be caused by a mixture of volatile compounds. These compounds can be classified as pure olfactory, pure trigeminal, or mixed olfactory/ trigeminal, depending on which systems they trigger (Nagata et al., 2005).

A mixture of volatile compounds that has an odour can activate both the olfactory and trigeminal systems. The olfactory and trigeminal processing systems exist independently, but appear to converge and interact during brain processing (Hummel et al., 2009a; Boyle et al., 2007b; Savic, 2001). When both of these systems are triggered (bimodal), they activate more regions of the brain together than they would individually (Boyle et al., 2007a). In other words, some bimodal odorants may directly affect the central nervous system.

2.2 Processing of olfactory signals in the brain

Although scientists have identified the general regions of the brain involved in the sense of smell, it is still not fully understood how human brains decode those smells.

To complicate things further, different areas of the brain may be involved depending on the properties of the odour (e.g., pleasantness or familiarity) or the task at hand (e.g., identifying the odour, or discriminating between smells) (Livermore and Laing, 1998). An odour can also involve brain structures controlling emotion (the limbic system), reflecting the ways in which smell is connected with emotion, memory, and behaviour (Gottfried, 2010; Wilson and Rennaker, 2010; Savic, 2005). People respond to odours differently based on how intense, pleasant, or familiar they seem to us, and based on their past experiences with those odours.

2.3 Factors influencing the sense of smell

Sense of smell can vary greatly from one person to another. Factors such as age, gender, health status, and culture can significantly affect how people perceive odours (Ferdenzi et al., 2011; Doty and Cameron, 2009; Doty et al., 1985).

- The sense of smell generally declines with age. Elderly people are typically less able to detect or identify odours than younger adults.
- Women generally perform better than men on tests of olfactory threshold sensitivity, odour discrimination, and odour identification
- Certain diseases can also reduce or eliminate the sense of smell (e.g., Parkinson’s disease, Alzheimer’s disease, and multiple sclerosis).

Also, when people are consistently exposed to an odour, we may eventually lose our ability to smell it. This is called odour fatigue (Sears, 2013).

3 How do irritant and nuisance effects differ?

Odours can cause two types of health effects: irritant and nuisance effects. These can occur in isolation or simultaneously.

Exposure to odorous compounds can cause long-term health outcomes, but these are caused by the chemical properties of the compound in question, other than the odour itself. Generally, the only long-term outcome associated with odours is *sensitization*, which is addressed in the section on nuisance effects.

3.1 Irritant effects:

Irritant effects result from the stimulation of the trigeminal nerve in the nose (Bromley, 2000). Pressure, pain, temperature, or noxious substances detected by the trigeminal nerve can sometimes trigger a physical response (Bromley, 2000; Boyle et. al., 2007b). For example, when you chop onions your eyes may water.

Different people may react differently to an odorant, even under identical circumstances, depending on their age, gender, lifestyle, health status, and other factors. In relation to irritant effects, some people will react to a smaller concentration of the chemical than the average person; these people are described as having a low response threshold. Common examples are infants, young children, the elderly, and people with medical conditions. On the other hand, some people have high response thresholds, and are less likely to experience irritant effects.

Depending on the properties of the chemical, an irritant effect can occur above, at, or below the threshold of odour perception (the concentration at which one can detect the odour). In other words, just because you can't smell something doesn't mean it isn't a problem.

3.2 Nuisance effects:

Nuisance effects are tied to the *perception of odour*. Some may try to dismiss nuisance effects as 'just' psychological, or as mere 'odour-worry,' but the symptoms are real (Government of New Zealand, 2003). However, compared to irritant effects—where a direct mechanism can be defined—nuisance effects are more complex and more difficult to understand. For example, to continue the onion analogy, a person with an aversion to onions could become nauseated by the smell even before they were chopped. The nausea is real, even if there's no mechanistically understood cause.

There is a wide range of nuisance effects, and once again they can vary greatly from person to person.

With a nuisance effect, health symptoms occur when odours are detectable but not physically irritating (Government of New Zealand, 2003). It's not fully understood why certain odours can cause adverse health effects. Is it because of a direct biological process, or is it caused by an indirect psychological response based on past experiences? In most cases, when an odour causes health problems there's no straightforward toxicological explanation (Shusterman, 1992).

Odour-induced health effects might be traced to physiological changes, mood changes and stress, cognitive bias and expectations, and learned or conditioned associations (Schiffman and Williams, 2005; Schiffman et al., 2000; Shusterman, 1992). For instance, an odour may cause increased stress, leading to hormonal changes that trigger the body's 'fight or flight response.' Like our ancestors, people may perceive a certain smell as a potential threat to their survival.

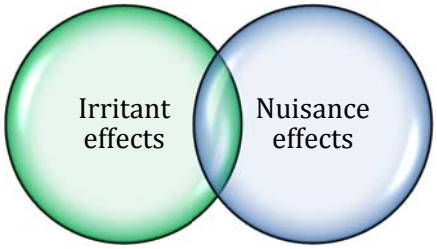
People react to odours very differently, both physiologically and psychologically, because the sense of smell is so heavily connected to past experiences, memories, and emotions. One person's pleasing odour could be another person's perceived health risk.

Generally, nuisance effects only occur when the offensive odour can be perceived. Still, it's once again important to remember that different people have different odour thresholds.

Some people may become sensitized to a specific odour, causing them to suffer adverse effects even when concentrations are so low that others around them can't detect the smell. It's not understood why some people become sensitized to odours while others do not. It's therefore important to remain respectful when dealing with sensitized individuals.

Regardless of people's levels of sensitivity, it is important to remember that nuisance effects cause real health symptoms.

3.3 Combined irritant and nuisance effects



It's also possible for an odour to trigger irritant and nuisance effects simultaneously. For example, you might experience watering eyes from irritation as well as nausea caused by an aversion to the smell.

Most odours result from a mixture of chemicals, so combined nuisance and irritant effects may be expected. The effects of mixtures are poorly understood—a challenge we discuss further in section 5.

4 Reported health effects

Odours can affect your health physically, psychologically, and socially. As discussed previously, different people experience odours in different ways. Age, gender, familiarity with the odour, state of awareness, health status, and sensitivity can all affect your ability to smell odours (Davies, 2013). These factors, combined with the challenge of measuring odours, makes it very difficult to assess the health effects caused by odours. As a result, there have been few scientific reports directly measuring the association between odour and health. Therefore, this report discusses both typically reported symptoms and symptoms measured in scientific studies.

4.1 Effects on physical wellbeing

People complaining about health effects caused by odours report a wide variety of symptoms—nausea, reduced appetite, congestion, sensory and respiratory irritation, headache, dizziness, sleep problems, diarrhea, various respiratory effects, and others. The odours causing these complaints come from a wide range of sources, including petroleum operations, agriculture, hazardous waste sites, landfills, and industrial sites (Dimsdale, 2008; Shusterman, 1992; Shusterman et al., 1991; DeLongis et al., 1988; Davies, 2013; Sears, 2013; Government of Texas, 2007; Government of New Zealand, 2003). In children, odour has been reported to cause language issues, incontinence, eye twitches, nosebleeds, and temper tantrums (Sears, 2013).

The relationship between odour and physiological response is very complex. Epidemiology studies have measured physiological changes in response to odour, including changes in heart rate, heart rate variability, blood pressure, skin conductance response, irritant symptoms, and facial muscle activity. The frequency of symptoms, and their magnitude, differ depending on the characteristics of the odours and the people smelling them. The stress caused by the odour may also contribute to the physiological effects (Laudien et al., 2008; Dalton, 1999; Knasko et al., 1990). And, certain studies indicate that a person's level of annoyance with an odour is a stronger predictor of symptom reporting than proximity to the odour source (Davies, 2013; Claeson et al., 2013; Cavalini, 1994; Cavalini et al., 1991; Lipscomb et al., 1991; Shusterman et al., 1991).

4.2 Effects on psychological wellbeing

Smells can also affect people psychologically. People have reported a wide variety of symptoms, including tension, nervousness, anger, frustration, embarrassment, depression, fatigue, confusion, frustration, annoyance, and general stress (Davies, 2013; Government of New Zealand, 2003; Heaney et al., 2011; Horton et al., 2009; Schiffman et al., 2000; Radon et al., 2004).

Some of these psychological responses may be caused by the health worries people have when they smell a bad odour (Sears, 2013). People may also feel stress if they feel their odour concerns are not being heard (Davies, 2013). Studies have shown that odour annoyance (an emotional response to a smell) is correlated with frequency (Aatamila et

al., 2010) and intensity of odour (Luginaah et al., 2000; Taylor et al., 1997; Jonsson et al., 1975; Axelsson et al., 2013; Claeson et al., 2013; De Feo et al., 2013; Aatamila et al., 2010; Steinheider, 1999; Steinheider et al., 1998; Steinheider and Winneke, 1993; Bruvold et al., 1983; Sucker et al., 2008; Both et al., 2004).

Psychological effects can also contribute to physiological effects (Bosma et al., 1997). Stress experienced by workers has been linked to higher blood pressure and other cardiovascular symptoms (Bosma et al., 1997).

4.3 Effects on social wellbeing

People's social and economic environment can contribute to 50 percent of the health effects they experience with odour complaints (O'Hara, 2005). Epidemiological studies suggest that odours may decrease quality of life (Heaney et al., 2011; Tajik et al., 2008; Wing et al., 2008; Wing and Wolf, 2000; Miedema and Ham, 1988; Bruvold et al., 1983). These studies looked at different ways odour problems affect people's lives—decreased outdoor activities, having to keep the windows down, being forced to leave home when the smell is bad, and decreased property values (Davies, 2013). Some people report feeling embarrassed about their bad-smelling neighbourhoods, making it harder for them to interact socially (Davies, 2013).

5 Limitations and challenges

There are still have gaps in the knowledge and understanding of the relationship between odour and health.

As discussed earlier, researchers haven't been able to fully determine why some people experience health effects from odorants even at concentrations lower than the irritant levels (Shusterman, 1992).

It is recognized that odours are made up of many chemicals that may or may not have specific health effects and risks, but it's not always known what chemicals make up an odour. As a result, odour perception cannot be reliably used as a direct indicator of any other serious health effects. Researchers need to address this limitation of knowledge on a chemical-by-chemical basis.

At the same time, researchers have struggled to arrive at a standard way to assess odour, or to assess the level of people's exposures. Studies in this field have come up against problems in reporting, sample and selection biases, personal influences, emotional responses, etc. The Odour Assessment Task Group must grapple with the overall challenges faced in monitoring practices.

5.1 Limitations and research gaps

Research studies on health effects associated with exposure to odorants fall into two main categories: epidemiological and toxicological. Although these two approaches have shed light on many other areas of human health, they have inherent limitations when it comes to building understanding about the effects of exposure to odours.

Epidemiological studies of odour and health are hampered by the application of weak exposure assessments (Lowman et al., 2013), and by the use of subjective measures for exposures and/or outcomes (Sucker et al., 2009, 2008; Luginaah et al., 2002, 2000; Ames and Stratton, 1991; Shusterman et al., 1991, Laudien et al., 2008; Dalton, 1999; Knasko et al., 1990).

On the other hand, toxicological research is limited by the lack of standardized exposure methods (Steinheider and Winneke 1993), difficulty in carrying out blinded studies (Cavalini, 1994; Cavalini et al., 1991; Shusterman et al., 1991), the subjects' personal biases (Cavalini, 1994; Cavalini et al., 1991; Shusterman et al., 1991), and the influence on odour-induced responses caused by personal factors such as predilections and past experiences (Seubert et al., 2009; Inoue et al., 2003; Vernet-Maury et al., 1999; Alaoui-Ismaïli et al., 1997a).

It's also often difficult to compare one study with another. For instance, different studies use different durations of exposure—and people respond differently to odour depending on how long they're exposed. Studies looking at short exposures to odour (Cavalini, 1994 and Cavalini et al., 1991) might not provide meaningful information about how people respond to chronic exposures.

One direct issue of concern is the fact that data is not typically collected with the intention of applying it to questions of health. Most epidemiological studies look for the effect of chronic exposures, rather than acute exposures. Instead, samples are collected from short-term exposures and then an algorithm is used to approximate long-term chronic exposures. The data might not convert as consistently as hoped, in which case the results may not be fully reliable.

Normally, people are exposed to mixtures of odorous air pollutants and non-odorous co-pollutants such as nitrogen dioxide and fine particulate matter respectively. This makes it difficult to know whether the observed health effects are caused by the substances people smell or the ones they don't smell. So far, no toxicological study has been able to separate the health effects of odours from that of the co-pollutants in the mixtures (Schiffman et al, 2005). As well, no toxicological research has been conducted to understand the health effects caused by complex mixtures of environmental odours.

An odorant may be just one component in a mixture of chemicals, and only one of the chemicals may be toxic (Schiffman and Williams, 2005). Depending on the mixture, odorants and non-odorants can interact chemically, either reducing or increasing the adverse health effects (Azocar, 2002; Davies 2013).

Studies based on single odorants might not explain how people react when they're exposed to chemical mixtures in the environment. One chemical in the mixture may prevent the body from eliminating another chemical, or two chemicals in the mixture may affect the same body system but in different ways (Roth and Goodwin, 2003; Sears 2013).

Current research approaches have not determined the mechanisms by which odours adversely affect human health. In general, classic toxicological mechanisms are not helpful in understanding the human health effects associated with exposure to odours (Schiffman et al., 2005), unless the chemical composition is known.

Based on current research, toxicological mechanisms can probably explain the way people respond to odorants above the irritants threshold limits (Schiffman and Williams, 2005; Shusterman, 2001; Schiffman et al., 2000). However, researchers don't completely understand the toxicological mechanisms for exposure to odorants below the irritant threshold levels (Shusterman, 1992).

Likewise, current research hasn't found consistent ways in which the brain responds to odours. Therefore, it is not possible to compare and contrast the studies or confidently make any conclusions on impacts of odours on the brain (Royet and Plailly, 2004; Sobel et al., 2000).

Traditional risk-assessment research looks at human exposures to a single pollutant in a mixture, but this methodology may not adequately protect sensitive or vulnerable individuals. Moreover, combining the risks of all pollutants in a particular mixture in order to estimate an overall risk will end up increasing the level of uncertainty in a study (Lanphear et al., 2005; Ciesielski et al., 2012; Trasande et al., 2005).

Going forward, there is a need to better account for these nuances when designing monitoring programs and research studies.

5.2 Challenges of linking odours and health effects

Some of the evidence linking odours with symptoms has been discussed. It is difficult to accurately define and measure those links, because studies focus on subjective variables—namely, odours and symptoms. When something is smelled, most people aren't able to even start identifying or quantifying the chemicals involved. Likewise, different people experience and describe symptoms in different ways—symptoms that don't always point to specific medical conditions.

People who complain about being frequently exposed to bad odours are more likely to report health effects. However, because the parameters are so subjective, it's very difficult to draw confident scientific conclusions about the connection between odours and human health (Sucker et al., 2009, 2008; Luginaah et al., 2000, 2002; Ames and Stratton, 1991; Shusterman et al., 1991).

Current knowledge of chemical toxicity is based on chemical-by-chemical assessment—and, as discussed, the chemicals mixed together in an odour may interact in unexpected ways. Until the ways chemical mixtures affect human health are better understood, it's important to respond to odour complaints by assessing the presence of chemicals in the environment to identify potential health effects.

6 Conclusion

The relationship between odour and health remains a major ongoing concern, despite gaps in technical understanding, challenges in collecting standardized data, and shortcomings in research approaches.

Given the unknowns associated with the chemical composition of odours and their interactions within a mixture, one cannot always rely on people's perception of an odour as a direct indicator of other serious health effects.

Professionals dealing with real-life air-quality issues, must continue to do the best work possible with the approaches and knowledge available to them, while at the same time contributing to the data and research needed to improve the overall grasp of the issues.

Glossary

Irritant effect	The bodily response to trigeminal nerve stimulation caused by an odorant.
Nuisance effect	An effect tied to the perception of odour, with no mechanistically understood cause. Sometimes referred to as an annoyance effect.
Odorant	A volatile chemical in the air that stimulates our sense of smell.
Odour	An *odour* refers to the sensations people experience when chemical compounds, in the air they breathe, stimulate receptor neurons in their noses. The odour of a substance refers to the specific chemical combination that gives that substance its characteristic scent or smell.
Odour threshold	The concentration at which one can detect an odour.
Olfaction	The scientific term for the processes involved in our sense of smell.
Olfactory epithelium	The nasal lining.
Olfactory neuron	A specialized receptor neuron in the nasal lining which bonds with a specific type of odorant.
Response threshold	The concentration at which one experiences an effect.
Trigeminal neuron	Neurons that transmit information on temperature, pressure, and pain, and also respond to noxious stimuli.

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