Elucidating the community health impacts of odours using citizen science and mobile monitoring

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Introduction

Odours from a wide range of sources can affect local air quality at different times and with different intensities. Unlike air pollutants such as fine particulate matter ($PM_{2.5}$) and ground-level ozone (O_3), there is no strong scientific evidence directly linking exposure to odours with specific health effects. Although odours are often characterized as a nuisance rather than a health risk, they can affect how people feel and behave, and studying odours may contribute to our overall understanding of air quality and its public health impacts. Here, we examine the potential effects of odours and introduce Smell Vancouver, a citizen science-based research project to explore Vancouver's evolving smellscape.

Odours can impact health through multiple mechanisms

Odour exposure and odour complaints are an ongoing frustration for many communities. In some regions, they have led to long-term conflicts or have disproportionately impacted racialized and low-income groups (Lowman et al., 2013; Wing et al., 2008). Although different regulatory frameworks have been developed in recent decades, the criteria used for assessing odour impacts in some countries, including Canada, have limited reference to their potential health effects (Brancher et al., 2017). Overall, "annoyance" is easier to quantify via community surveys and it has become a key criterion in odour regulation; however, this approach may also lead to an underappreciation of the mechanisms through which odour can impact health.

Odour annoyance is linked to stress, poor mental health, and decreased well-being

Numerous studies have shown that exposure to unpleasant odours is associated with annoyance, and that the level of annoyance is strongly associated with neurological, respiratory, and gastrointestinal symptoms that impact quality of life and mental health (Aatamila et al., 2011; Baldacci et al., 2015; Blanes-Vidal 2015; Hooiveld et al., 2015; Luginaah et al., 2002). Being exposed to a strongly unpleasant odour can trigger an individual's stress response, as characterized by self-reported anxiety and salivary alpha amylase secretion, a marker of activation of the sympathetic nervous system (Hirasawa et al., 2019). Co-exposure to odour and other stressors, such as noise, light, and vibration, may also have cumulative effects on mental stress (Oiamo et al., 2015). On top of all of this, perception plays a powerful role in modulating the overall strength of the response. The subjective "offensiveness" of the smell, an individual's perceived control over their exposure, or their subjective health status can all affect the stress response. In addition, the stress response can be moderated by perception that an odour producer has broken laws or, conversely, that they are making a genuine effort to reduce disruption (Hayes et al., 2017; Hirasawa et al., 2019; Luginaah et al., 2002).

Odours affect healthy behaviours

In addition to an identifiable stress response, odours may affect healthy behaviours. Residents reporting odours often note that their use of outdoor spaces is curtailed due to annoyance or stress. Examples include not using the backyard, not wishing to go for neighbourhood walks or use active transport, or not being able to leave windows open on warm days (Luginaah et al., 2002). Hindering these healthy behaviours is of particular concern during pandemic conditions, when the ability to get outside and to ventilate one's home are critical health protective actions (Luginaah et al., 2002; Public Health Agency of Canada, 2021).

Odours may contain toxic constituents

Odours are complex and unique mixtures of volatile organic and inorganic compounds, and they are perceived when these compounds interact with receptors on the nasal epithelium. However, some of these substances can also interact with other types of receptors in other organs, potentially leading to toxic effects. For example, Sazakli and Leotsinidis (2021) sampled volatile organic compounds (VOCs) from sites downwind of a

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rendering plant and identified the components that exceeded thresholds for odour detection. Probabilistic human health risk assessment found that the combination of certain malodourous VOCs cumulatively increased a resident's lifetime risk of cancer by more than 10-fold, and they also posed an unacceptably high probability of noncancer health effects over a person's lifetime (Sazakli & Leotsinidis, 2021). Similarly, Zhang et al. (2021) identified 145 VOCs emanating from a municipal landfill and then used dispersion modelling to calculate residents' exposures at various distances and heights. Of the 145 VOCs identified, six increased the lifetime cancer risk to residents at the four closest sites; the same sites were also vulnerable to noncancer health effects from 14 VOCs. These studies highlight the fact that odours are complex and evolving mixtures, and more than a simple "sniff test" is necessary to understand their impacts.

Odourous compounds may contribute to other types of air pollution

Finally, VOCs emitted into the atmosphere can undergo chemical transformation to form secondary pollutants, including ground-level O_3 and $PM_{2.5}$, two pollutants with well-known health effects. Samburova et al. (2019) sampled VOCs emitted from cannabis plants grown at four large cannabis production facilities, which have become important contributors to the smellscapes of municipalities across North America. Emissions rates for the sampled VOCs were used to estimate O_3 formation per plant. The results showed that, depending on the strain of cannabis grown, the growth stage, and the scale of the operation, cannabis cultivation facilities have the potential to increase local concentrations of O_3, which is a tightly regulated pollutant. At the community level, Wang et al. (2019) found that Denver's 600 cannabis facilities made a small contribution to the city's overall VOC emissions, leading to potential enhancements of O_3. Although this work is still in its early days, such a mechanism may underlie the observed association between odour annoyance and chronic diseases such as asthma and chronic obstructive pulmonary disease (Baldacci et al., 2015).

Citizen science can help to understand complex odour–health interactions

Given that odours are contributing to complex individual- and community-level effects, and these effects can change over seasons and across populations, how can regulators and policy

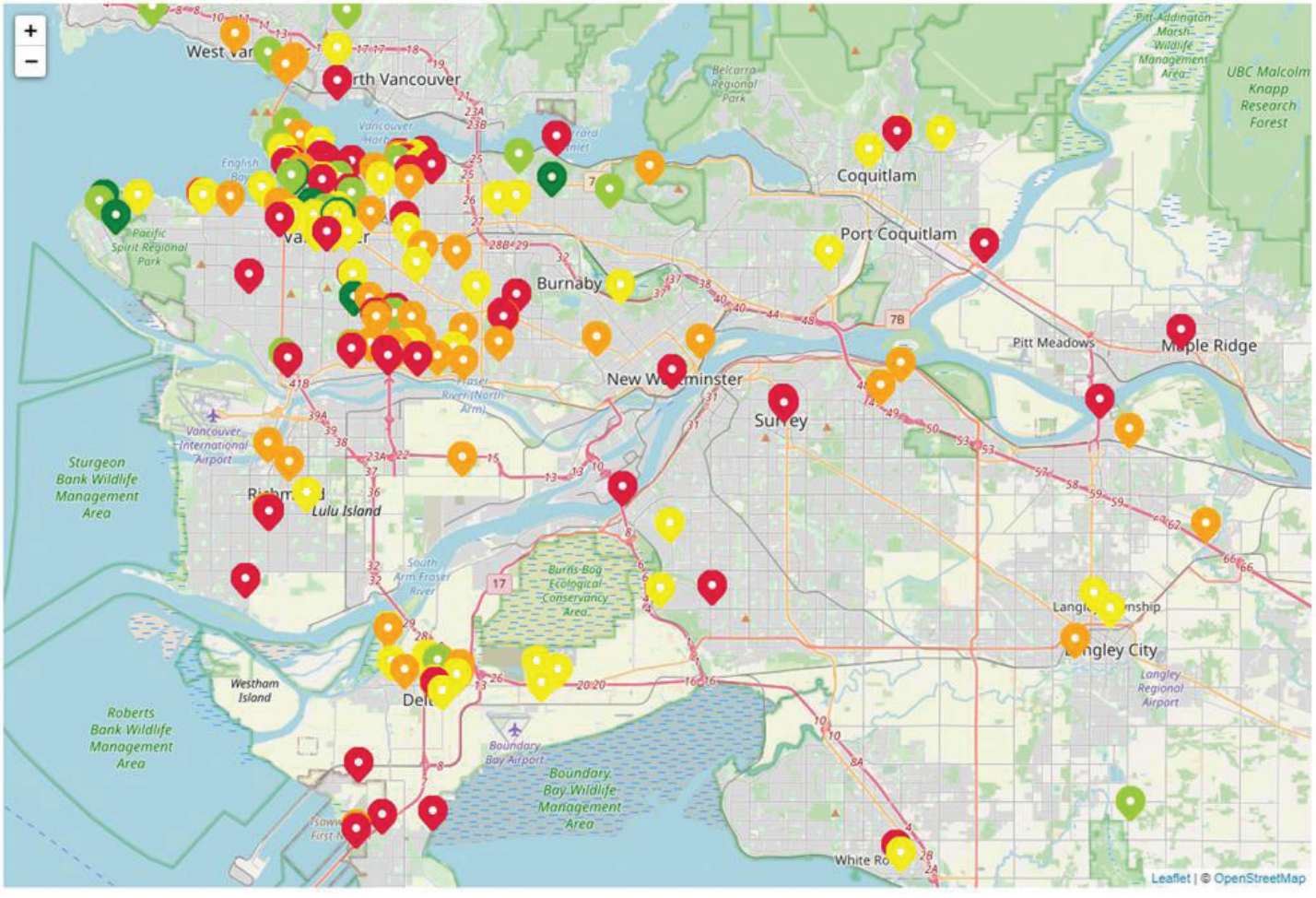

Figure 1. Map of odour reports submitted through the SmellVan web application. Colours indicate the offensiveness of the odour from green (mildly) to red (extremely).

makers make a strategic and targeted response to odour complaints? One increasingly popular approach is citizen science, in which members of the community are engaged in data collection on odour occurrences and their effects. Examples of this approach include the Smell Pittsburgh initiative in the United States (Hsu et al., 2020), and the Distributed Network for Odour Sensing Empowerment and Sustainability (D-NOSES, 2021) in Europe. These initiatives use an online platform to create a community of citizen scientists who log odour reports and associated information, but can also access data and mapping tools to understand how their experience contributes to a larger whole. Beyond simple geospatial displays, the data can be combined with dispersion modelling and other tools to delineate impact zones, disambiguate sources, estimate exposures, and connect those exposures with health impacts. This produces real-world, quantitative data for policy making and enhances transparency among citizens, industry, and regulators.

In December 2020, the University of British Columbia, the BC Centre for Disease Control, and the National Collaborating Centre for Environmental Health launched a citizen science project to explore Vancouver's evolving smellscape. Smell Vancouver (https://smell-vancouver.ca/) provides a web-based application that allows people in the Metro Vancouver region to submit odour logs that describe the location, the smell, and their personal experience, including their annoyance, physical symptoms, behavioural changes, and demographic information. Since the launch, hundreds of reports have been collected (Figure 1), which has been extremely useful in both confirming known problem areas and in identifying regions where engagement is lacking or where unknown odour sources may be affecting air quality. Respondents are also prompted to provide their own description of smells experienced, which demonstrates the variety of natural and human-derived odours that people encounter and which odours generate enough annoyance to lead to a report (Figure 2).

What comes next?

Mapping these reports over space and time allows the research team to connect those reports to odour sources in the landscape. Mathematical models can be used to estimate where odours emitted by a source may end up given local weather conditions or, conversely, work backwards from where smells are experienced to understand where the odourous parcel of air has been in the preceding hours. These models are useful screening tools to estimate how/whether an odour report is likely to be connected with a known source or to infer whether a previously unidentified source is present in the landscape.

The smellscape illuminated by the app will be further explored using the Portable Laboratory for Understanding human-Made Emissions (PLUME) van, which has been equipped to measure odour-causing compounds in the air around selected locations. Although currently grounded due to the COVID-19 pandemic, the PLUME van will collect the data necessary to quantify VOC emissions and estimate their contributions to the formation of pollutants such as O_3 and $PM_{2.5}$.

Summary

Smell Vancouver is a unique initiative that combines citizen science and dispersion modelling with "ground-truthing" by the

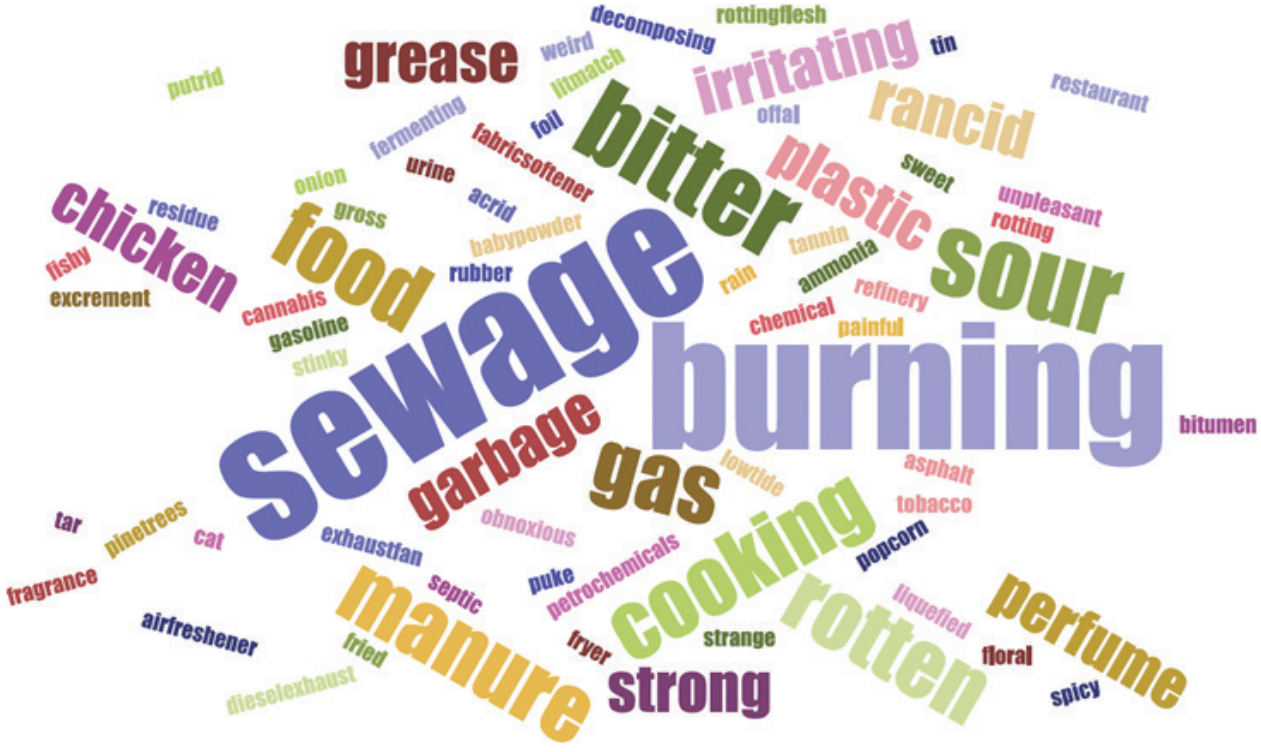

Figure 2. Word cloud created from free text submitted to describe odours reported through the SmellVan web application.

PLUME van. This will provide a richly detailed description of Vancouver's smellscape and will facilitate the communication about and understanding of odours and their impacts. It will also help to elucidate the complex interactions between odours and health. Overall, we hope that this project with bring value to the many stakeholders currently engaged in odour management in the Metro Vancouver region.

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