TAKING ACTION

ODORS IN COURT

In general, odors themselves are not regulated at the federal level in the United States. The Environmental Protection Agency **does** regulate air pollutants via the National Ambient Air Quality Standards, which covers six major pollutants: sulfur dioxide (the only pollutant on this list with a discernible odor), particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide, ozone, nitrogen dioxide, and lead. These regulations apply to a pollutant's toxicity and not its smell. However, using odor identification charts, like the on¬e included in this publication, is one way to use odor as a first step in identifying a regulated pollutant.

It is worth noting that, as of 2019, several of the committees and agencies that are charged with updating and reviewing standards for exposure and testing for toxins listed above have not met or have essentially been disbanded. So, in cases where appealing to federal regulators is unlikely to lead to resolution, it makes sense to explore options available at the state and municipal levels, with organizations that regulate health and safety for workers, nuisance regulations, and civil cases. In nearly all instances, coordinated community efforts have helped move cases and complaints forward by establishing the scope of an issue and monitoring the times and conditions when an odor issue is exacerbated. Below is a short list of some options for pursuing odor complaints in the United States (either via regulation or as a starting point for legal action).

- **State and municipal nuisance laws.** The department handling these will vary from state to state, though most states list odor issues under the departments of health or environment. These generally can be used to address activities that prevent people from enjoyment of public and private spaces, but there are also exceptions for certain industries (such as farming) and areas zoned for industrial or mixed use. It can also fall on the a complainant to demonstrate the degree of exposure to an odor, though some states or municipalities will provide support for this once an initial complaint has been made. The State of Oregon Department of Environmental Quality provides some information about how to use a nuisance report to pursue an issue. Visit **http://bit.ly/ORODOR**
- A helpful overview of how some organizations have pursued action through local nuisance laws can be found at the Center for Disease Control and Prevention (CDC) and their Center for State, Tribal, Local, and Territorial Support. While the CDC provides information about how to conduct a preliminary investigation into an odor issue, options for pursuing regulatory or legal action vary quite a bit from state to state. Visit **http://bit.ly/CDCODOR**
- **Workplace protections.** The National Institute of Occupational Safety and Health (NIOSH) may be helpful if odors are present in places where people are working, particularly with poor indoor air quality. Most of the options here will be focused on proper handling of noxious or toxic air pollutants (such as filtering or venting), especially where employee exposure is a possibility. In cases where an indoor space is also used by customers or the public, reports may be made by non-employees, though in this case (as with the EPA's regulations), the focus is on harmful exposure to toxins and not to the smell itself. Visit **http://bit.ly/NIOSHODOR**
- **Local departments of environmental conservation/protection.** In New York State, the town of Perinton is working with the Department of Environmental Conservation (DEC) to provide residents with tools to report issues coming from a privately owned landfill via a form on the town's website. Visit **http://bit.ly/DECODOR**
- **Agricultural and farming waste.** In cases where the source of an odor is agricultural, nine states (Alabama, Idaho, Missouri, Nebraska, North Dakota, Oklahoma, Oregon, Pennsylvania, and Texas) have specific regulations about odor stemming from CAFOs (concentrated animal feeding operations). Additionally, bacteria seepage or spread as a result of animal waste handling may be considered a regulated toxin in some states, especially E. coli, which is responsible for the odors present in human and animal waste. Visit **http://bit.ly/FARMODOR**

NOVEL METHODS FOR ASSESSING INDUSTRIAL ODOR

Under-resourced communities often experience higher concentrations of air pollution and face greater risks of health problems. Odors from industrial sources is one type of air pollution that affects residents of these often-low-income communities physically and psychologically. North Denver, which is impacted by emitted odors from the surrounding industrial facilities, is one such example. Among North Denver neighborhoods, Globeville and Elyria-Swansea seem to be the most affected communities, where over 70% of their area contains commercial and industrial businesses, including Purina (a pet food factory), Suncor Energy (a major oil refinery), Koppers Inc. (a creosote wood treatment facility), Altogether Recycling, METech Recycling, Owens Corning Denver Roofing Plant, Owens Corning Trumbull Asphalt Plant, Metro Wastewater Reclamation District, Cobitco Inc. (an asphalt emulsion company), and DARPRO Solutions (a meat, grease, and cooking oil recycling facility). In addition to commercial businesses, Globeville and Elyria-Swansea are divided by major highways and railroad tracks.

Between 2004 and 2017, Denver received 1,322 odor complaints. In response to odor and health concerns, the City and County of Denver updated its odor ordinance in 2016, requiring some industries (e.g. pet food factories and marijuana production facilities) to develop Odor Control Plans (OCPs). The ordinance also extends the period in which complaints must be received for the City and County of Denver to trigger enforcement. The ordinance states that a facility that receives five complaints from individuals representing separate households during a period of 30 days will be required to develop an OCP.

In 2015, we completed a study specifically on asphalt odors in the Globeville neighborhood. An odor of unknown origin described as a "tar" or "asphalt" smell was reported as unbearable for many residents over the past few years, and caused burning eyes and throat, headaches, skin irritation, and problems sleeping. To identify the potential sources of the odor and the concentrations of air pollutants making up the odor, we collected wind speed and direction data and sampled for a suite of volatile organic compounds (VOCs), sulfur gases, and polycyclic aromatic hydrocarbons (PAHs) in the neighborhood and near suspected sources.

Wind speed and direction data indicated that when the odor was noticed, the neighborhood was directly downwind of a wood preservation facility and an asphalt roofing facility. Air samples collected during short-term, high-intensity odor events revealed strong concentrations of methylene chloride, hexane, toluene, naphthalene, dibenz[a,h]anthracene, benzo[g,h,i]perylene, and indeno[1,2,3-cd] pyrene—each at least two times higher than background concentrations.

Capturing measurements of volatile organic compounds in North Denver

Naphthalene and the other PAHs are emitted from wood treatment processes and have a coal tar odor. Naphthalene was present in a sample collected directly adjacent to the Koppers creosote facility and was not present in any background samples. Single-compound odor and health thresholds, however, were never surpassed during our sampling. To follow up on this work, we conducted two additional studies in 2017 and 2018, in North Denver, and four similar communities in Colorado for comparison. In these studies, we focused on all reported odors and specifically on better understanding the effects on well-being.

Adverse health impacts are hard to investigate for a variety of reasons, including because health effects can be triggered at much lower concentrations than can be sometimes measured with analytical equipment, health data for many odorous compounds is outdated and missing, and impacts of mixtures of odor compounds are not understood.

We also developed a new method to identify the industry that most likely was causing the odors.

The 2017 study assessed the impact of odors from industrial sources on the subjective well-being (SWB). An online survey was sent to participants from Greeley, Fort Collins, Fort Lupton, North Denver, and Pueblo, asking questions about SWB and odors in their areas; 351 people participated. The evaluation of SWB was performed using a novel approach that appraises three aspects and nine measures of SWB.

The results showed that participants who reported that the air is *very fresh* or the odor is *highly acceptable* had higher levels of SWB. This association suggests that residents who live in areas exposed to strong industrial odors had lower levels of SWB. A subset of participants in this study took the survey four times in one year. Both *satisfaction with how life turned out* and *satisfaction with standards of living* slightly increased during the fourth quarter of the year. A comparison between the five communities showed that well-being levels in North Denver and Greeley were not significantly different than those in Fort Collins or Fort Lupton. The comparison, however, showed that Pueblo had the lowest levels of well-being among all communities.

In the 2018 study, a smartphone app was used to collect odor location and type of odor for more than one year. Spatial distributions of the odor data collected by social participation, combined with wind direction collected from local air monitoring stations, were used to identify odor sources in the impacted areas. The majority of odor complaints were reported in North Denver (57%) and Greeley (33%). North Denver analysis showed that a single facility that manufactures pet food was responsible for the pet food odor (the most reported odor: 81 reports). Dead animal and sewage odors were associated with a North Denver meat and grease recycling facility and the Metro Wastewater treatment plant, respectively. Roofing tar odor was probably associated with a facility that treats crossties and utility poles with creosote. Another odor that was often described as a refinery odor was less likely to be associated with the Denver oil refinery and more likely to be associated with one of the four facilities in the northwest of Globeville that uses asphalt and creosote materials. In the Greeley area, most complaints (133 reports) happened in LaSalle, a small town in the southern section. The analysis showed that all complaints from LaSalle described one offensive odor produced by a biogas facility to the east.

In summary, identifying sources of odor can be complex. Adverse health and well-being impacts are reported by many community members and yet quantifying these impacts and addressing them are often not undertaken by local or state officials. Many communities have inadequate odor plans and ordinances. Our studies in Colorado have identified methods that communities can use to collect data on sources of odor, adverse impacts, and odor types. These data, combined with wind data and other important information such as emissions databases, can be used to provide evidence of odor issues within the community. In addition, collecting odor data using methods like social participation is known to have a positive psychological impact on the studied community.

Dr. Shelly Miller *is a professor of Mechanical Engineering at the University of Colorado Boulder and faculty member in the interdisciplinary Environmental Engineering Program at CU. She is currently working on research projects addressing indoor environmental quality, reducing building energy consumption, and identifying sources of air toxins and noxious odors in urban communities. She received M.S. and Ph.D. degrees in Civil and Environmental Engineering from the University of California, Berkeley.*

The Forum area in Barcelona is surrounded by four large waste management facilities, which continue to expose the long time local residents to persistent bad environmental odours.

PUTTING ODOUR ISSUES ON THE MAP

Using citizen science to curb odours in the EU

The human nose is capable of recognising up to a trillion different smells and is by far the best instrument, even scientifically, that we have to detect odours. Not all odours are pleasant however, as many who have spent time near waste management facilities, chemical plants, or even food industries can agree. Our noses are delicate instruments that can detect harmful molecules such as hydrogen sulphur in concentrations as low as 10 parts per billion, protecting us from lethal exposure. When persistently exposed to bad odours, the wonder of the sense of smell can soon turn into a nightmare.

In terms of regulation, odour pollution is relatively ignored. In Europe and globally, it is the second largest cause of environmental complaints after noise, and yet there is little effort to harmonise or create regulation at a local or national level. Part of the reason is that detecting and measuring odours can be tricky, and pin-pointing sources or estimating effects even more so. European standards (EN13725:2003) establish how to measure odour concentration, but cannot measure the real impact on people. This is the other part of the problem: odours are assumed to be annoying, but harmless. However, there is growing evidence that persistent exposure to bad odours can have significant effects beyond mere inconvenience. People in affected communities can suffer from headaches, throat and eye irritation, nausea, sleeplessness, anxiety, stress, or even respiratory problems.

The problem is that short term economic interests, inconsistent regulation, and lack of reliable data to demonstrate the severity of the problems usually prevent significant action from taking place. This is why Rosa Arias and the D-NOSES team received funding from the EU to create an alternative, bottom-up approach to odour pollution involving citizens as key actors for change.

Volunteers can register smells in their communities with the new OdourCollect smartphone and web-app, turning the noses of the residents into a sensor array that can report odours in real time. The app uses geolocation to pinpoint where the odour was detected, and the user describes the smell, rating its type, intensity (how strong the smell is) and hedonic tone (how pleasant or unpleasant the smell is). This simplicity hides the complexity of the validation and back tracing process in the background. Reports are fed into a sophisticated retro-trajectory dispersion model, including complete geographical and weather data, to calculate an odour's path to its source. Considering similar reports, this can validate and confirm the source of the odour. Odour experts and citizen scientists can then match observations with industrial processes at the source and co-design ways to minimize the problem.

While that sounds relatively simple, the truth is that scientific data is not enough. For change to happen, communities must mobilise, stakeholders have to agree, and local authorities need to take action. D-NOSES proposes a method, following the quadruple helix model for stakeholder engagement, to bring together communities, local authorities, private enterprises, and research institutions into a constructive dialogue. This will become a platform where effective and balanced solutions can be found, with improved communication and transparency. It uses a highly inclusive approach, where people are encouraged to participate regardless of their literacy and socio-economic levels, cultural background, or gender.

The project will run 10 carefully selected pilots to demonstrate the power of citizen science and the ability to get results in different settings. In some cases, the pilots focus on different types or odour sources. In Barcelona, the affected area has a long history of odour issues from several waste management facilities and wastewater treatment stations concentrated nearby. This has been a growing concern since the municipality tried to revitalise the previously depressed area with new high-rise developments and housing. In Thessaloniki, residents are repeatedly exposed to fumes from a nearby refinery, but it was the population that grew around the refinery over the last 50 years. These cases show how an accommodation needs to take place as communities and industries develop over time. The balance between industry, economic and social development, city planning, and environmental management is one that D-NOSES hopes to achieve.

In São João da Madeira, the pilot will tackle a persistent odour problem from an animal by-product processing plant. There have been previous odour mapping projects that unfortunately did not result in any practical improvement. This case aims to show that beyond data, the positive engagement of all stakeholders is required to find practical solutions.

The D-NOSES method can be used in other contexts. In Sofia, it will help diagnose and explore cost-effective performance improvements for an existing municipal program to eliminate odours from food waste around the city. In Porto, volunteers will help to track odours that may reveal and help stop sources of pollution in the Rio Tinto river, hopefully reversing the environmental damage. These pilots demonstrate the flexibility of the approach to deal with a wider range of issues relating to the impact of odour pollution.

Odor tracking and tracing could help identify and stop sources of pollution in the Rio Tinto River, preventing further environmental damage.

The project findings will go toward creating the International Odour Observatory—a place for anyone who finds themselves a stakeholder in an odour management issue. For residents it will give access to the odour mapping applications and instructions on how to use them effectively. For industry it will describe how they can use the same process to have cheaper and more effective control on their emissions, as well as better relationships with their surrounding communities. For local authorities it will provide a blueprint for an engagement platform that can defuse conflict situations and promote win-win scenarios for all stakeholders. For scientists it will compile state-of-the-art advancements in odour science.

The wind might already be shifting for odour regulation. Recently, Chile approved a legislative proposal that classifies odours as contaminating agents. Portugal and Italy, are working on similar regulations to control odours. New regulations should set a consistent framework that enforces more careful planning of both locations and operations of odorous facilities, both for the safety of the people as well as the investments of the operators.

To find out more about D-NOSES, visit dnoses.org and follow them on Twitter at @dNOSES_EU and Facebook at @dNOSES.EU.

Rosa Arias *is the D-NOSES project coordinator. She has over 14 years experience as a consultant within environment and innovation projects (with an expertise in odour pollution) and has participated in and coordinated several other European projects. She is passionate about Responsible Research and Innovation (RRI), citizen science, and the role of women in science.*

Nora Salas Seoane *is an experienced psychologist in social intervention and community-based projects within disadvantaged neighbourhoods. She has also worked as a social scientist and coordinated social and international cooperation projects within Gender Studies, Migratory Movements and Interculturalism and Social Anthropology, working with different communities across Europe and Africa.*

Jose Uribe-Echevarria *is the D-NOSES project communications manager. In his regular job he is responsible for strategic projects at the International Solid Waste Association. He has extensive experience as an innovation manager both in the commercial and non-profit sectors.*

COMMUNITY SCIENCE FORUM

PUBLIC LAB COMMUNITY JOURNAL OF ENVIRONMENTAL RESEARCH • SPRING 2019 • ISSUE 16

ODOR LOGGING

How do we measure odors and how do we take action against them?

INTRODUCTION

Airborne odors can quickly go from a nuisance to becoming harmful to one's health; the presence of bad smells can signal the presence of dangerous gases or chemicals, including hydrogen sulfide and methane. Long-term exposure can lead to headaches and dizziness, nausea, and vomiting, skin lesions, cancers, asthma, and developmental impairments. Impacts from factory farming and slaughterhouses, sewage treatment facilities, landfills, oil and gas refineries, manufacturing, and other types of industry threaten the health of communities around the world. So, what can you do about it?

Though tools for measuring smells have existed for years, modern equipment can be expensive and imprecise, making much of it impractical for people outside of the regulation and academic circles. "The most accessible and sophisticated environmental monitoring equipment is made available to most humans in the forms of noses, eyes, tongues, ears, and skin," says Sara Sage, an organizer from Val Verde, California. With homes in her neighborhood as close as 1,000 feet from one of the state's largest landfills, she and other concerned neighbors came together to form Citizens for Chiquita Canyon Landfill Compliance. In recent years, they have worked together to create odorcomplaint.com to document local odor violations, reporting them to the appropriate regulatory agencies. (Sara's brilliant illustrations are also featured in the centerfold of this publication)

Recognizing the need for accessible and affordable ways to monitor airborne pollution, Spanish organizers IMVEC contributed to the creation of Odor Log v.1, a grassroots reporting document for odor events. Building from this, the group recently created Citizen Log, a worldwide online platform for tracking and mapping air, water, soil, and noise pollution (available at citizenlog.ushahidi.io).

Odor logging is a useful way for anyone to get involved, by tracking the frequency, intensity, duration, and offensiveness of odor events. Combining this data with weather and wind conditions, odor logs have been used to document the presence and spread of pollution, track sources, influence legislation and regulation, and even close down troublesome facilities.

In this issue of the Community Science Forum, we collect resources from years of work by community scientists like you—from a lighthearted look at the history of "smelling" tools, the use of odors in court, recent work in the EU to document odor events, studies in Colorado on the effects of industrial odors on quality of life, and a guide on how to describe, record, and report odors so you can investigate their origins, learn about their potential effects on people, and take action.

For online versions of these stories, links to more information, and additional resources, visit publiclab.org/CSF16

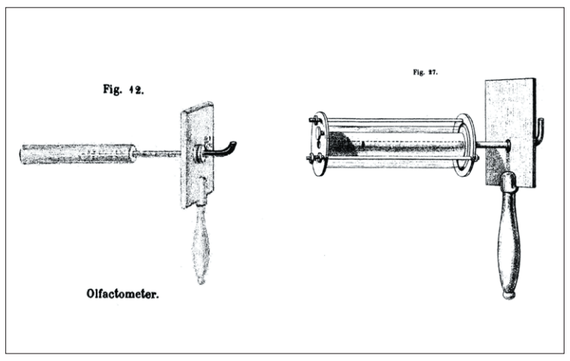
PUBLIC LAB IS MADE POSSIBLE BY *the 11th Hour Project (a program of the Schmidt Family Foundation); Claneil Foundation; Gordon and Betty Moore Foundation; National Academies of Sciences, Engineering, and Medicine's Gulf Research Program; Google; Rails Girls Summer of Code; and all of our individual contributors.*

SMELL AND EVOCATIVE INSTRUMENTATION

THE HISTORY OF MEASURING ODORS

In 2012, I was conducting a literature review of sensitivity and selectivity in olfaction–in machine olfaction and animal olfaction. Although the review itself was rather dry, some of the (humorous) detours that didn't make it in the review are documented here.

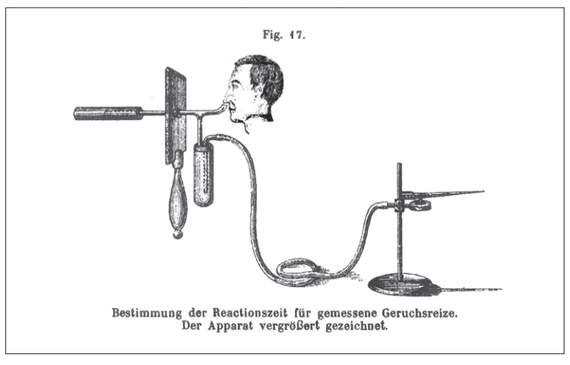
In 1762, Rousseau wrote in *Émile*, or *On Education*, that smell was "the sense of the imagination, as it gives tone to the nerves it must have great effect on the brain." Little did Rousseau know that the olfactory nerve was the only cranial nerve besides the optic nerve that does not route through the brainstem. He continues, "Smells by themselves are weak sensations. They move the imagination more than the sense and affect us not so much by fulfillment as by expectation." Smell as a cue to a memory may draw whimsical or visceral responses. An extremely sensitive reflex may result from these memories, at least in rats; apparently they can smell down to 0.04 parts per trillion of 2,4,5-trimethylthiazoline, which happens to be an odorant exuded from the anal glands of cats and red foxes (Laska et al. 2005).



Analytical instrumentation pales in comparison, only managing to detect odorants at parts per billion levels at best (with ideal sample presentation, slow analysis, and no masking odorants present).

Even now, smell experiments (e.g. for determining permissible odour levels around landfills) are often conducted with panels of experts instead of with instrumentation alone. In fact, some legislation around smell is based on number of complaints reported, because detecting the smell levels directly is deemed too complicated and expensive. TSA dogs are sniffing your bags for bombs or apples. But to be able to measure things like how long it takes to detect the smell or where the smell is stronger, people have been inventing funny machines at least since the early 19th century.

In 1895, Henrik Zwaardemaker, a professor at Utrecht University, published *Physiologie des Geruchs*, a treatise on olfaction and odorants. In it, he details different methods of presenting odorants to subjects in a controlled fashion.



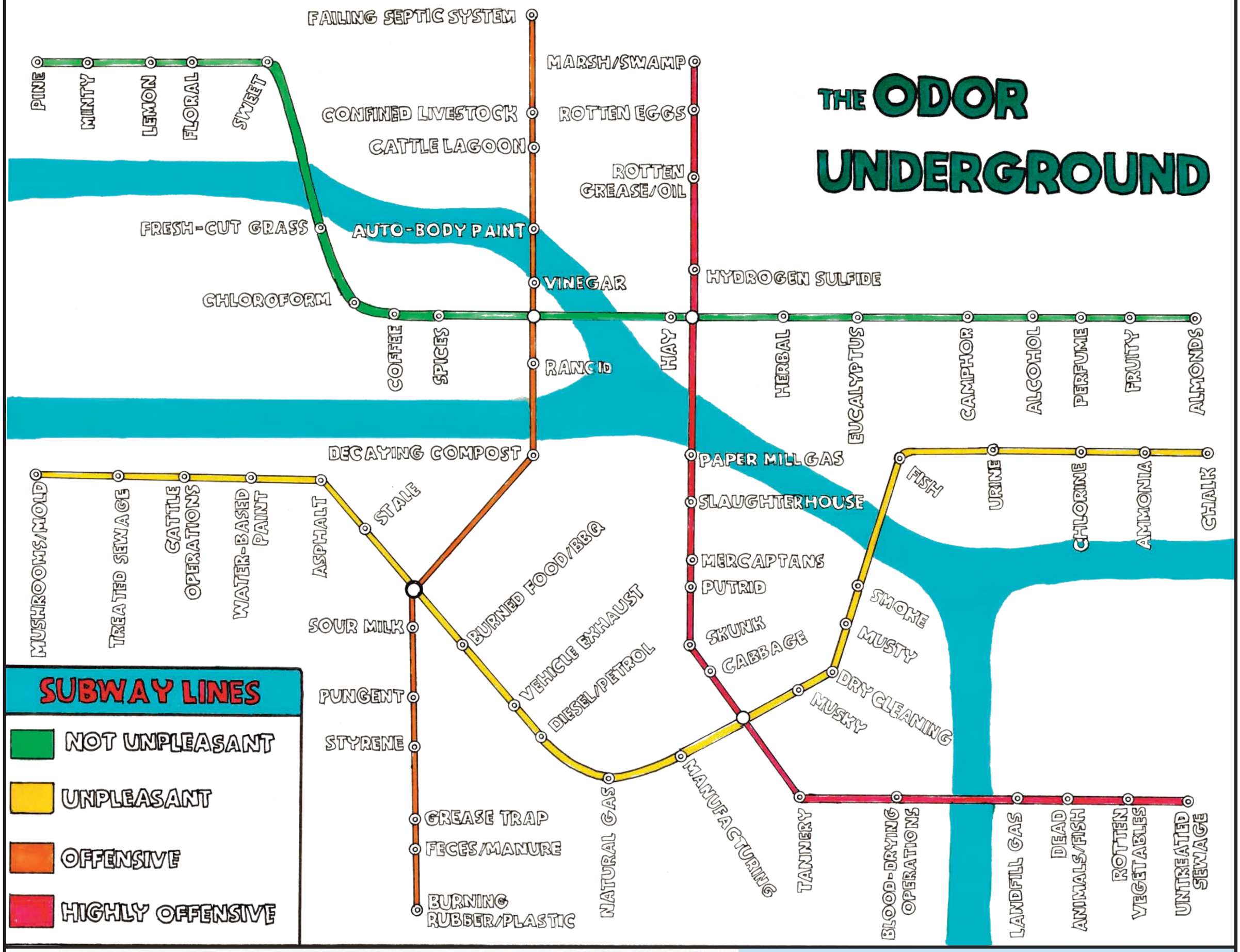
But the funniest man-chine is preserved for the present day! Might I share the NASAL RANGER™. Look at how SCIENTIFIC these people look! The Nasal Ranger™ does nothing more than provide some ratio of active carbon filtered and non-filtered air. So you can smell just the air, or smell nothing, or something in between. You can decide if there is a big difference between filtered and not-filtered air. It's not that fancy. Yet it evokes TECHNONOSE, or a BETTER-THAN-YOURS nose. Here they even describe it as a "mobile artificial nose," even though the nose part actually belongs to the person holding the retro-futuristic contraption.

Another silly instrument, another day. Next thing you know, they'll be measuring odorant levels in degrees Brix.

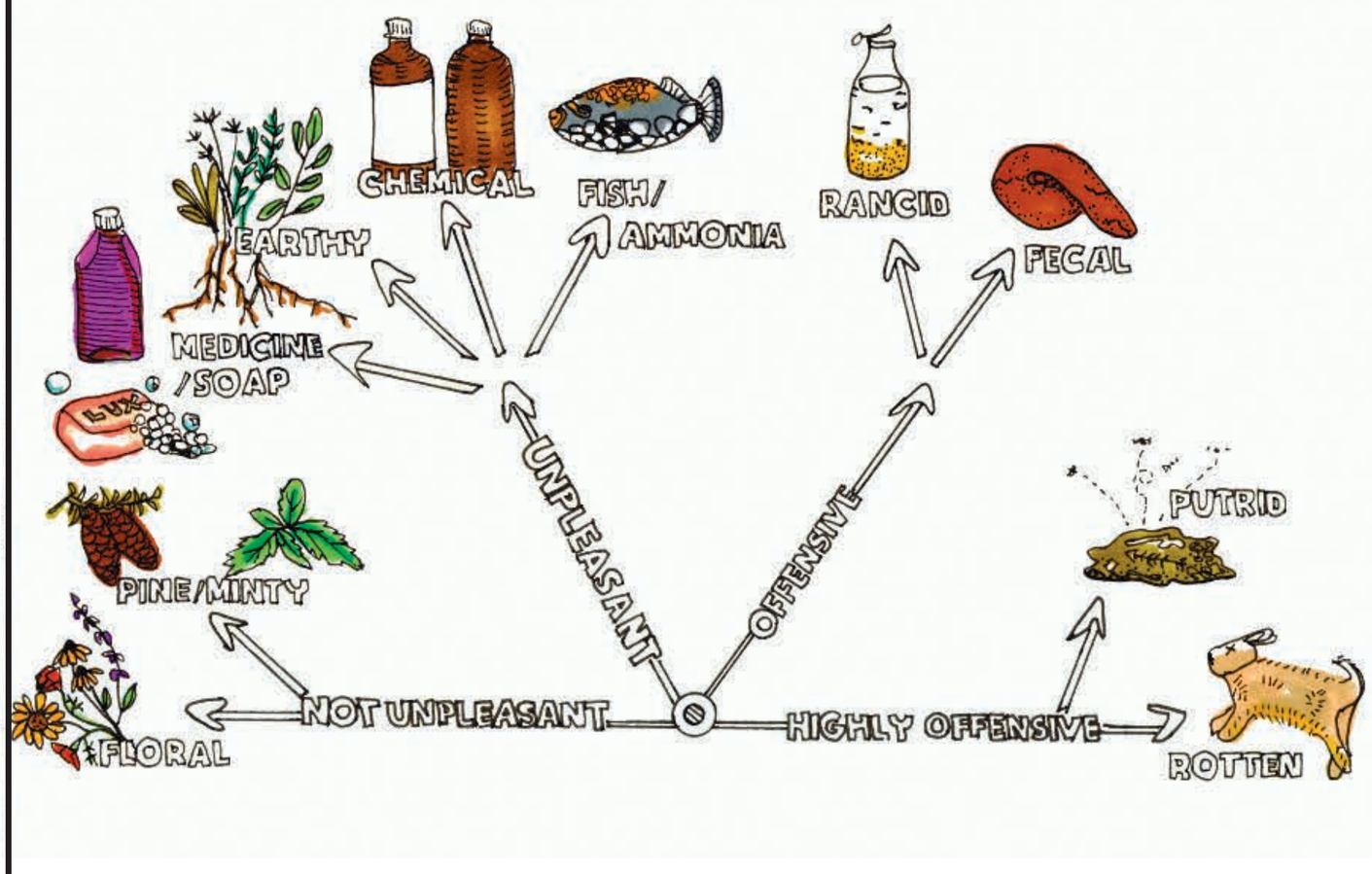
Top: Zwaardemaker's olfactometers, or *Riechmesser*. The second is an improvement upon the first, with an interchangable odorant chamber. From *Physiologie des Geruchs*. **Middle:** A set up for measuring time taken to detect a smell? Not sure where the big pointy thing goes to... *From Physiologie des Geruchs*. **Botto:**: Image courtesy of Nasal Ranger™

Nadya Peek *develops unconventional digital fabrication tools, small scale automation, networked controls, and advanced manufacturing systems. Spanning electronics, firmware, software, and mechanics, her research focuses on harnessing the precision of machines for the creativity of individuals. Nadya directs the Machine Agency at the University of Washington where she is an assistant professor in Human-Centered Design and Engineering.*

THE ODOR UNDERGROUND



FROM YUM TO YUCK



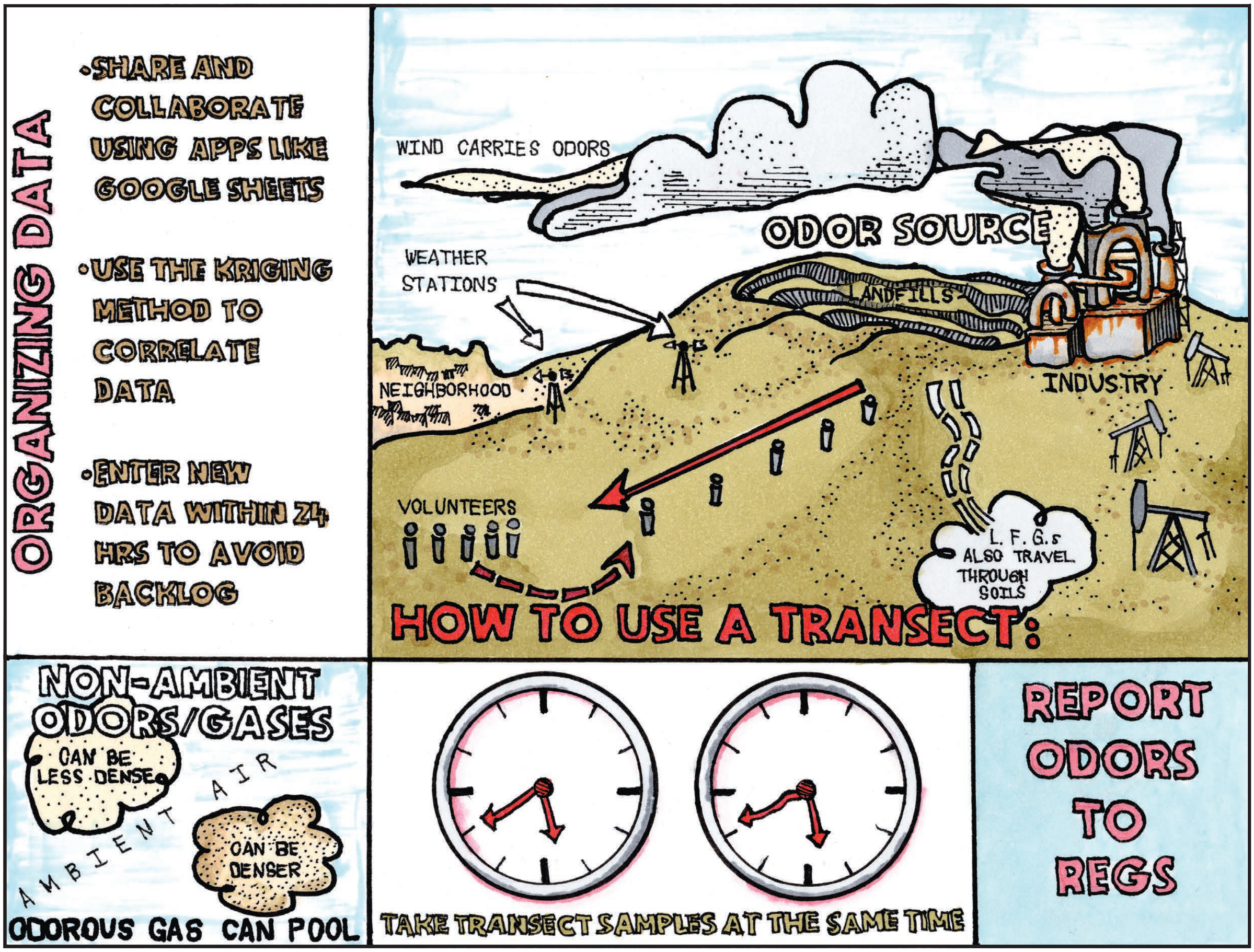
An odor log can help you keep a record of the environmental odors you smell in your neighborhood so you can report your findings to suspected offenders, community groups, health officials, and/or code enforcement officials.

The Agency for Toxic Substances and Disease Registry (ATSDR) recommends collecting "FIDO" characteristics when keeping an odor log: information about the odor's **frequency**, **intensity**, **duration**, and **offensiveness**.

- First determine how **offensive** the odor is. Would you rate it: not unpleasant, unpleasant, offensive, or highly offensive? Use the diagram to the left to help determine the rating. Use the chart above for ideas on how to describe the specific smells or types of odors you notice.
- Next, determine the **duration**. How long does the odor last? One minute, ten minutes, one hour, four hours, more than 12 hours?
- Then choose the **intensity** level. Describe how strong the odor is: very strong (VS: makes you feel sick), strong (S: can't go outside), moderate (M: you can smell it, but it doesn't affect normal life), or light (L: barely noticeable).
- Choose the **frequency** of the odor. How often do you smell it? Once, daily, weekly, monthly, every few months?

For further reading from the ATSDR on odor logs, their uses, how to determine if an odor is considered a nuisance, and other resources, visit bit.ly/ATSDRODOR.

Building on previous work by Sara Sage and other organizers around the world, community group IMVEC created Odor Log 1.0, PDF odor logs that can be printed and filled in by hand. They suggest collecting data about **date**, **time**, and **location**, as well as **type of odor**, **intensity**, **temperature**, **wind** (speed and direction), **effects on people**, and **other observations** (including weather conditions). Learn more about their history and download the logs at bit.ly/ODORLOG.



KRIGING FOR BEGINNERS

(kree-ging) $Z(s) = \mu(s) + \varepsilon(s)$

ILLUSTRATED BY
SARA SAGE

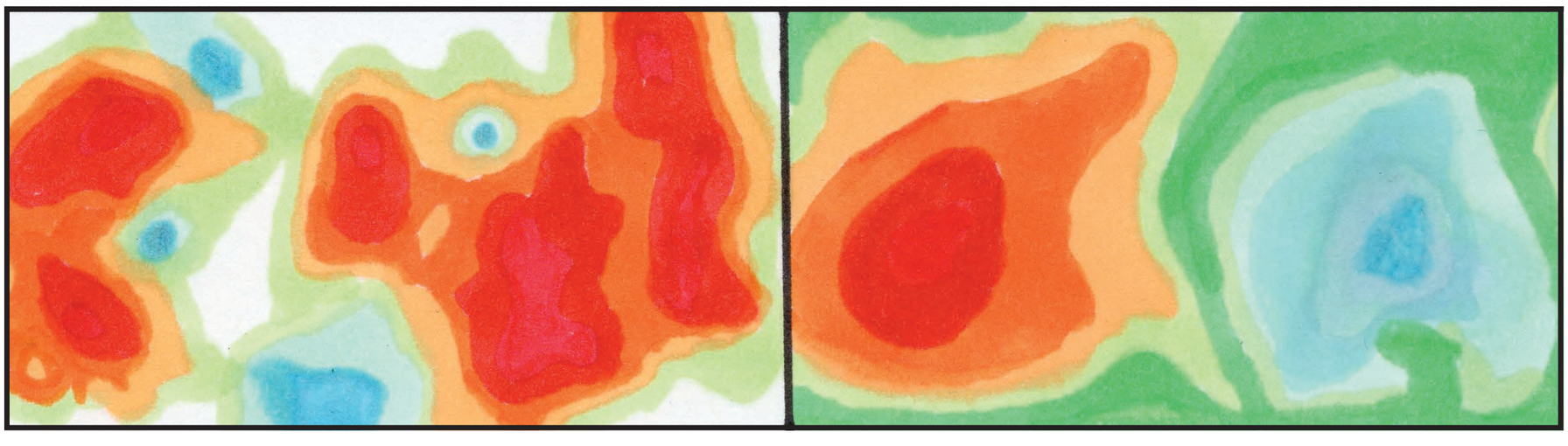
Do you have odor data you would like analyzed? Want to see a visual-spatial representation of your data? If so, Kriging might work for you, as it is a detailed way to predict values for locations. Used frequently in environmental science, it is a method to determine spatial variability using large-scale and small-scale correlations. Kriging is frequently used in soil sampling and odor monitoring.

How does it work? Take as many observations as you can and be sure about your location. You will need source data to import into software. Your source data will consist of 3 metrics: latitude; longitude; and a value. For odor monitoring, you can use either air-monitoring equipment for values, such as ppb for VOCs, or you can task volunteers with smelling a location.

If you do not have air-monitoring equipment, you can still use Kriging. Volunteers at each sampling location report whether or not they detect an odor. Convert your results into binary values: no odor=0; odor present=1. Next, calculate the percentage an odor was detected and that percentage becomes your "value" for each sampling location.

Not good with math? Don't worry, you won't need to do any advanced math. ArcGIS and the free software, QGIS can do this for you. There are many GIS tutorials online.

The downside of Kriging is that it is a very time-consuming endeavor, since many data points are required to get more reliable values. The upside is that it is a terrific tool to quantify large data and can be completed by volunteers.



Sara Sage *is an organizer for Public Lab and Program Director for the Val Verde Air Monitoring Program (VVAMP), a community-led 501(c)3. Val Verde is in Los Angeles County, sited near the Chiquita Canyon Landfill. She is an illustrator and artist, and a graduate of California Institute of the Arts. You can find her on Instagram: @inkukase*