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Fear of the Unknown: Communicating Air Quality Information to Public & Practioners

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SIM-air working paper series #51-2024

UrbanEmissions (UEinfo) was founded in 2007 with the vision to be a repository of information, research, and analysis related to air pollution. UEinfo has four objectives: (1) sharing knowledge on air pollution (2) providing science based air quality analysis (3) promoting advocacy and raising awareness on air quality management and (4) building partnerships among local, national, and international air-heads.

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Abstract

Simplifying information and the learning process makes it easier to communicate messages to the public, policymakers, managers, and practitioners. When complex data and concepts are broken down into clear, accessible language, it enhances understanding across all audiences. This approach not only helps the public engage with the issue but also equips decision-makers and practitioners with the knowledge they need to take informed actions and implement effective solutions.

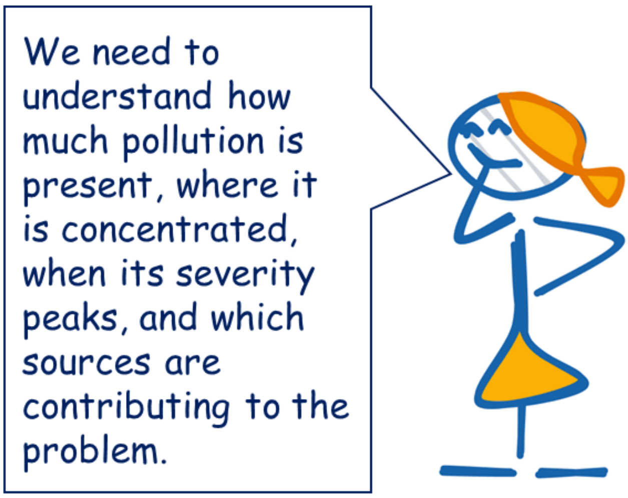
The *State of the Global Air 2024* report estimates that 6.7 million premature deaths worldwide are linked to outdoor and household air pollution. Despite widespread recognition of the issue, clear World Health Organization guidelines, and advanced analytical systems available to support air quality managers, progress often stalls—especially in low- and middle-income countries. This is largely due to the "fear of the unknown," stemming from a lack of data, misconceptions, and the perceived complexity of these systems. Training the next generation of managers, practitioners, and scientists to confidently tackle air pollution challenges is urgently needed.

This working paper catalogs examples that have successfully simplified air pollution theory, making it more accessible for public awareness efforts targeting a broader audience. It also provides resources to help bridge knowledge gaps between the public and the air pollution modeling community. The paper covers communication methods such as videos, photos, comics, doodles, posters, primers, and installations, along with information simplification tools like indexes and calculators[1]. It also explores their practical applications and operational strategies for effectively conveying air pollution data.

[1] The examples presented in this working paper are just a few relevant to the discussion, with many sourced from https://urbanemissions.info. This is not an exhaustive list, and numerous other resources and case studies are available across the internet.

1. Fear of the Unknown

A popular saying goes, "you can't manage what you can't measure", which can be extended to, "you can't manage what you can't communicate to the masses".



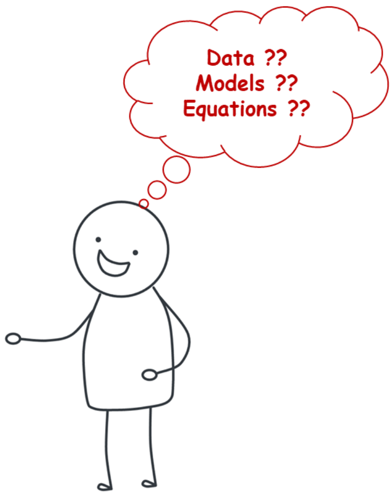
The top challenge in achieving "*clean air for all*" is to eliminate the "fear of the unknown" among both the public and the air quality modeling community - this is *fear of unknown data, science, and technology*. Achieving this requires a multi-faceted approach. (1) Effective communication is key—presenting data in clear, accessible language that breaks down complex concepts into understandable terms. Regular "show and tell" events, such as public demonstrations or interactive workshops, can demystify the science behind air pollution, giving people hands-on experience with the instruments, tools, and models used in the air quality monitoring and modeling community. (2) Operational trainings for practitioners and scientists ensure that those working with air quality data are confident in using the latest technology and methodologies. (3) Additionally, art and creative expressions, such as visualizations, infographics, or public art installations, can engage broader audiences by transforming scientific data into relatable, emotional experiences.

Combining these approaches will not only bridge the knowledge gap but also build trust, encouraging more people to take ownership of the air quality conversation. When people (experts and non-experts) understand the data, they are more likely to engage in advocacy, creating a stronger and unified response to combat air pollution.

Air quality is a shared concern across much of the developing world, yet gaps in knowledge and communication to support research and public awareness remain inconsistent. Despite progress in understanding the issue and improving research collaboration in the Global South, a "fear of the unknown" persists (Garland et al., 2023).

Data: Compared to the 1990s and early 2000s, there is now greater awareness of the most polluted cities and countries (https://iqair.com). Additionally, institutions like NASA and ESA offer more information through open data from their satellite and global modeling products, enhancing access to air quality information (Holloway et al., 2021; Veefkind et al., 2012). Media and academic coverage of extreme events like forest fires, dust storms, winter hazes, and their health impacts has also expanded (Fuller et al., 2022; HEI-SoGA, 2024; Kok et al., 2021; Wang et al., 2024; Yan et al., 2024). Additionally, there is greater access to global air quality modeling programs to study past and future trends in emissions, pollution, and health impacts (Vollset et al., 2024). Comprehensive reviews of past developments in regulations and science (Fowler et al., 2020; Monks et al., 2009) and efforts to make official and unofficial monitoring data accessible to the public (https://openaq.org) have further advanced the field.

Science: Understanding atmospheric science and air pollution is inherently complex, from ambient monitoring to emissions estimation and policy making. While the process of generating and utilizing this information is well-defined, there are bottlenecks at each stage, including technical, personnel, and computational challenges. Despite these advancements, the atmospheric science community remains small, particularly in the Global South, where confidence in the air pollution modeling among practitioners and managers is still low. The constant uncertainty and knowledge gaps in understanding how data and models can be used contribute to "fear of the unknown" among practitioners.



Technology: In recent years, the number of journal articles in the air quality research community that incorporate artificial intelligence (AI) and machine learning (ML) has grown significantly. While these technologies offer powerful tools for understanding air pollution, their increasing use has also contributed to the perception that air pollution research is inherently complex. This perception extends to the modeling exercises, computational systems, and data analysis required to study air quality, which can seem daunting to many. As a result, there is a growing fear among users—particularly those unfamiliar with AI and ML and any modeling—about engaging with these tools. This "*fear-of-the-unknown*" is fueled by concerns about pushing a button to generate insights, interpret patterns, or make decisions based on the data. Users often worry: *What if the numbers generated are wrong? What if the theory or models aren't accepted by the scientific community or policy makers?* These uncertainties create hesitation and can impede the use of advanced technologies, preventing researchers and decision-makers from fully embracing the tools available to better understand and address air pollution. In essence, this apprehension stems from a lack of confidence in both the technology and the data, further complicating efforts to build consensus between air quality practitioners and the public with the information.

One of the key goals of the air quality community is capacity building and nurturing the next generation of atmospheric scientists, meteorologists, air pollution strategists, and air quality information communicators, without this *fear-of-the-unknown*. This process involves two key steps. The first step includes regular courses, lectures, exams, and thesis work at established universities and colleges. The second step focuses on making this knowledge accessible and easy to understand for a broader audience, encouraging involvement beyond just scientists and strategists. By simplifying complex concepts, we can engage more people in conversations around air quality and empower them to contribute to the solutions.

This working paper catalogues examples that simplified the theory of air pollution to benefit public awareness activities and to present resources to reduce the "fear of the unknown" associated with the air pollution modeling community. While the examples discussed are Asia centric, all the resources are globally relevant. The resources covered the concepts of simplifying the air quality monitoring information, building emission inventories, and designing communication material.

Most of the examples showcased in this working paper are from https://urbanemissions.info.

2. Mass Communication of Open Data

A picture is worth a thousand words. Videos and pictures are powerful tools of mass communication because they can convey complex information quickly and in an easily digestible format. Visual media also evoke emotional responses, helping to capture attention and engage a wider audience, making the message more memorable and impactful.

The journey to understanding a city's air pollution problem begins with access to reliable monitoring data, which provides a temporal baseline for annual, seasonal, monthly, and diurnal variations, as well as a spatial map of pollution hotspots within an airshed for the air quality practitioners and managers to follow.

One of the most impactful examples of using ambient monitoring data for public awareness comes from China. In 2015, the documentary "*Under the Dome*" highlighted pollution data and health impact estimates of various pollutants. This video sparked a shift in public discourse around air pollution regulations in China, contributing to a significant reduction of up to 30% in $PM_{2.5}$ levels and other pollutants over the past decade (Han et al., 2022; Sicard et al., 2023).

A screenshot from "under the dome"
@ https://www.youtube.com/watch?v=MhIZ50HKIp0

Effective mass communication relies not only on state-of-the-art equipment but also on presenting information in the simplest form possible. A notable example is the use of an MS Excel file on the US Embassy website, wherever an air monitoring station is operational. Open data from Beijing's station inspired innovative public awareness activities, such as the "View from My Window" calendar, which creatively paired real-time pollution data with visuals to engage the public. This project featured daily photos of a fixed location with an open sky, paired with real-time pollution level readings, making air quality data easily relatable and understandable to the public (Nguyen, 2020). These visualizations began in 2008, the year of the Beijing Olympics, and were replicated by air quality advocates in many Chinese cities.

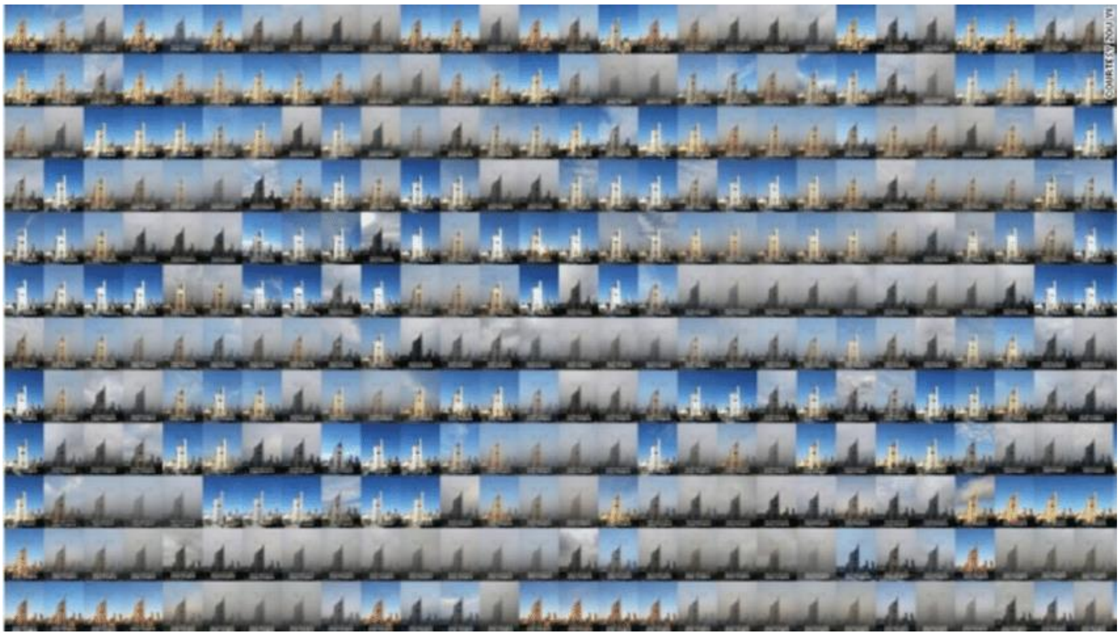


Figure reproduced from (Nguyen, 2020) A mosaic of a year of Beijing's air. Image by Zou Yi, 2016

Following the success in Beijing, the expansion of air quality monitoring networks at US Embassies in 80 countries also contributed to changes in air quality awareness and policies in these nations (Jha & Nauze, 2022). In India, an analysis of print and social media reports indicates that the rise in public complaints about air pollution coincided with the release of open data from US Embassy monitoring stations in Delhi and Mumbai in 2015. This access to transparent data helped drive public awareness and concern over air quality issues (Adhikary et al., 2021; Patel et al., 2022). A significant rate of increase in the total number of monitoring stations operating and reporting information in India, also matched this event. In some Central Asian and African countries, monitoring data from the US Embassy stations continues to be the only official open source of information (as of 2024).

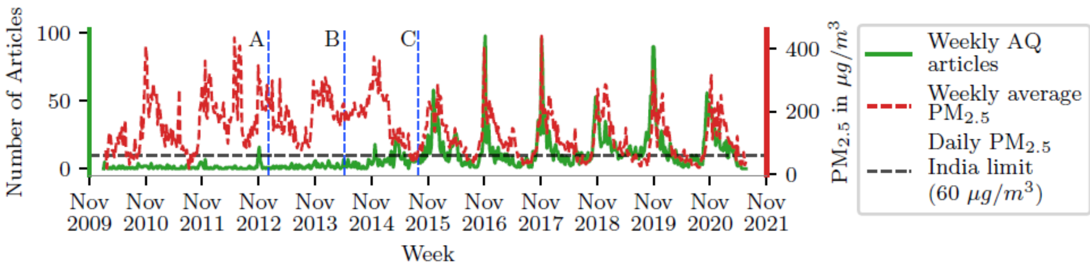


Figure reproduced from (Patel et al., 2022) A: From Jan 2013 onwards, US embassy in India started posting air quality data online; B: In May 2014, Delhi became most polluted city in the world according WHO ambient air pollution guidelines; C: In Sept 2015, OpenAQ website made AQ data of India publicly available. This plot is comparison of AQ articles counts with PM2.5 levels in Delhi over 11 years. News media attention is not persistent throughout the year, whereas air pollution is higher than India limit most of the time. The number of news articles increased comparatively after 2014 due to easily available air pollution data.

The US embassy stations across the world are operated under the USEPA's AirNow international program. Within the US, EPA has made real-time air quality data accessible through its AirNow platform. During wildfire seasons, this data is mass communicated in various forms (on phones and over the internet), informing the public about air quality risks, helping communities take precautionary measures and prompting local governments to issue advisories.

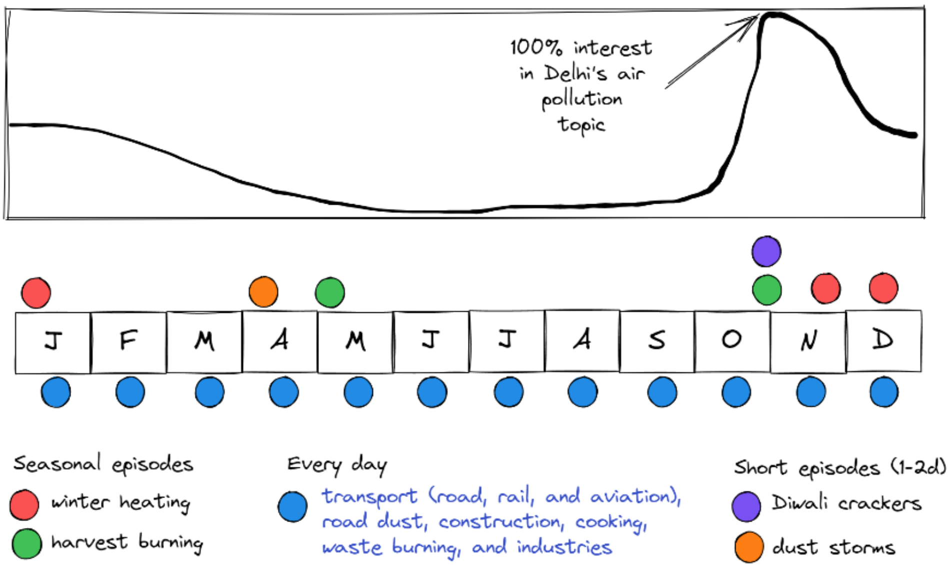
The "*Breathe London*" project uses a network of air quality sensors to provide open access to detailed air quality data across the city. This initiative has sparked numerous public campaigns and policy discussions, contributing to measures like the Ultra Low Emission Zone (ULEZ) to reduce vehicle emissions in the heart of the city. Open data from a wide network of sensors helps garner public support by demonstrating the changes from the intervention as posters at bus stops and large billboards. Following London, the program was implemented in Birmingham with similar rate of success.

In all the examples, access to open data has been key to effective mass communication. Open data empowers the communications community with information, making complex concepts easier to understand and driving accountability. By democratizing air quality data, communities are more engaged in advocating for cleaner air and stronger environmental policies.

Traditionally, most of the monitoring data comes from the big- and medium-size cities, with limited or no representation from the smaller cities and rural areas, where the pollution levels are equally bad (Martin et al., 2019). The emergence of low-cost sensors, which are cheaper than official reference-grade systems, has broken down barriers to self-monitoring and data access (Kumar et al., 2015). While data for regulatory and policy purposes is typically collected from systems that follow established protocols, low-cost sensors—once calibrated and validated—are increasingly filling data gaps. These sensors often contribute to citizen science initiatives, empowering individuals and communities to monitor air quality and raise awareness about local pollution issues (Engel-Cox et al., 2013).

3. Doodles and Comics

In addition to videos, photos, and banners, hand-drawn media has gained momentum as a powerful communication tool. Simple sketches, doodles, and illustrations are being used to break down complex topics like air pollution into more relatable forms. These hand-drawn visuals (sometimes using digital aides) offer a personal touch, making the information feel more approachable. They have been particularly effective in grassroots efforts, local campaigns, and educational settings where formal infographics may not resonate as deeply. By simplifying the message through creative and artistic expression, we can encourage more people to take interest in environmental issues.



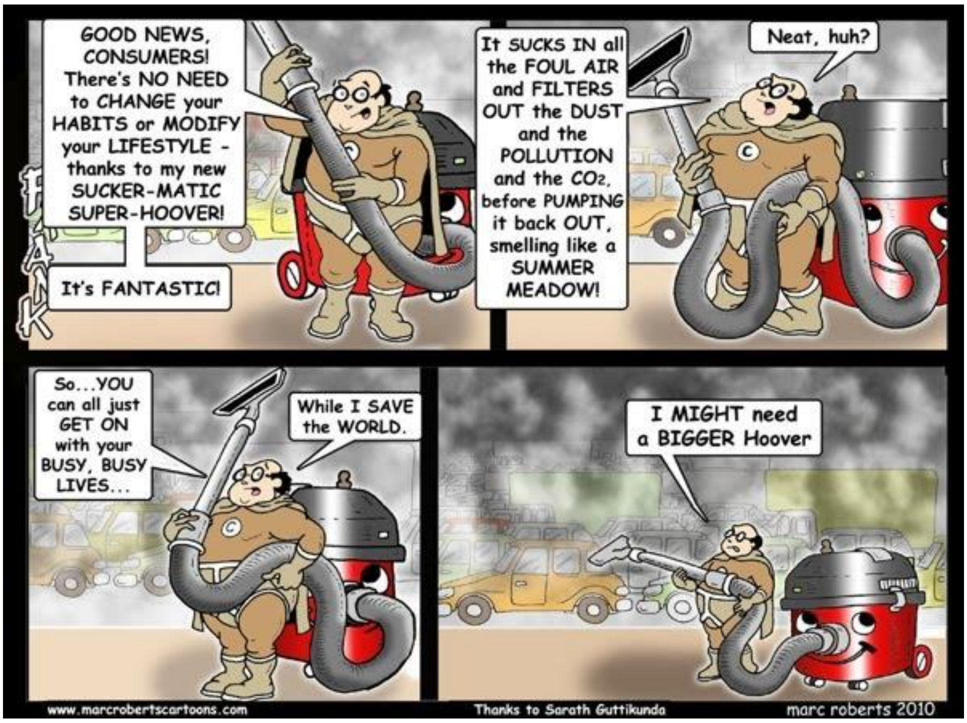
How air pollution problem in Delhi is normalized over a year, using google-trend's interest in the topic of "air pollution in Delhi" data (max on the y-axis scale is 100% interest) and listing the known major sources of air pollution in each month[2].

In 2023, Delhi ranked as the most polluted capital city in the world, repeating its top position from the previous year (https://iqair.com). A review of Delhi's air pollution from 1990 to 2022 is published in a 30+ page journal article (Guttikunda et al., 2023). While reviews such as this are necessary to document the problem, policies, and knowledge, we also need some simplification of the trends, data, and interest, for the knowledge to reach the masses. Most of the information in the article can be summarized in a single doodle (above) to illustrate the chronic nature of Delhi's air pollution, public perception of the issue, and the primary pollution sources.

Winter months consistently record the worst pollution levels in Delhi and across the Indo-Gangetic Plain, but this doesn't mean that summer and monsoon

[2] Among non-technical tools, Google Trends is a simple yet powerful visualization tool that shows *when* public interest in a topic peaks. Overlaying this data with doodles summarizing modeling results has proven highly effective in communicating the full scope of Delhi's air pollution problem.

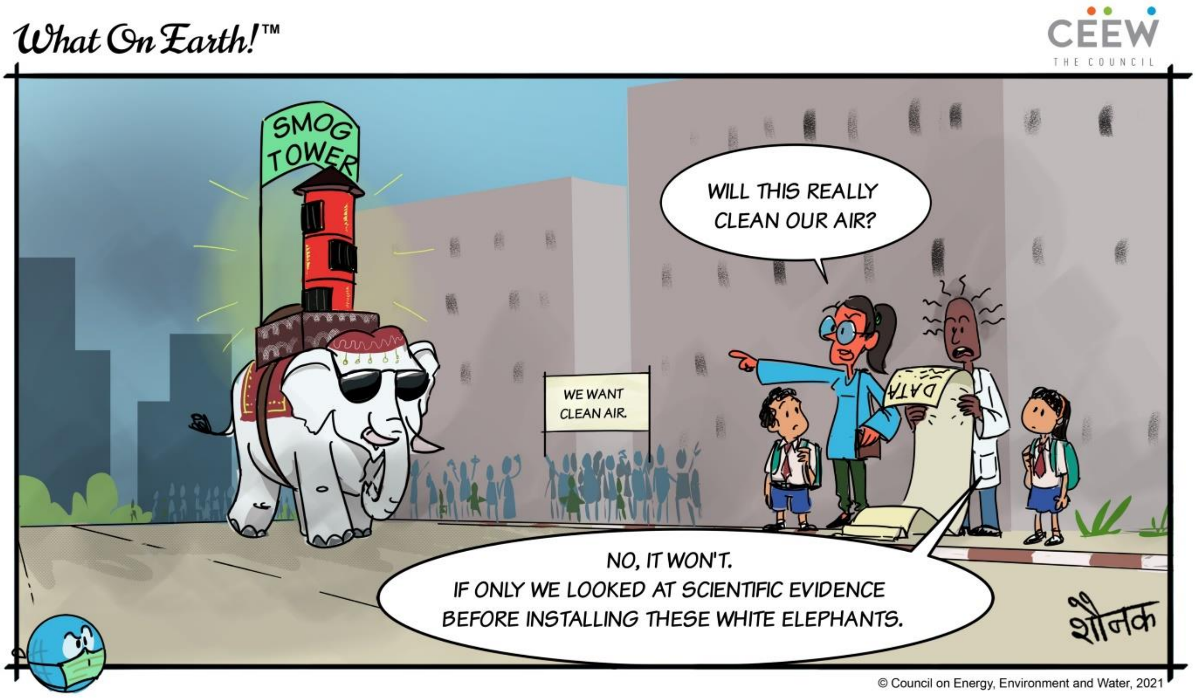
pollution is insignificant. The problem is often overshadowed by pre-winter extremes and is not discussed year-round. Media coverage and discussions spike at the start of winter, creating the impression that events like Diwali and crop burning are the sole causes of Delhi's air pollution. The media's approach to Delhi's air pollution needs to shift, as the problem persists year-round, not just during winter extremes, as illustrated in the doodle. If public interest peaks alongside media coverage, keeping the issue in focus throughout the year could prompt earlier, more proactive discussions, driving a shift toward addressing the root causes before the winter season exacerbates the crisis.



Smog towers are another misguided approach to controlling pollution. As a comic drawn in 2010 (by Marc Roberts) aptly illustrated, these towers are nothing more than glorified vacuum cleaners that fail to reduce ambient air pollution effectively. The cost of building them places an unnecessary financial burden on cities. Similarly, mist-making guns offer no real solution - it's troubling that smog towers and mist-making guns are portrayed in the media as real solutions to air pollution. These costly, temporary fixes distract from the core issue of reducing emissions and mislead the public, delaying more effective and sustainable actions.

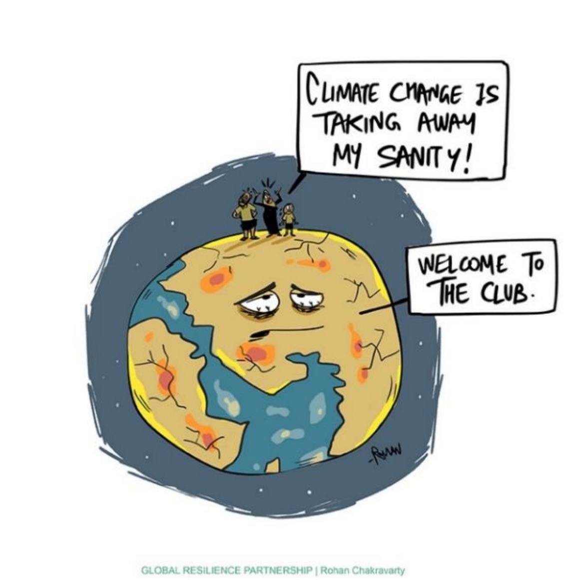
Since 2010, the idea of pollution-sucking machines as a solution resurfaces every pre-winter, with various groups repeatedly attempting to suppress the discussion. However, the media rarely takes a firm stance to clarify that these are not real solutions. Instead, the focus must be on tackling emissions at their sources, which is the only effective way to address air pollution long-term.

Some interesting comics[3] from "*What on Earth*" campaign by CEEW (New Delhi, India) on air quality and climate change (https://www.ceew.in/what-on-earth).



[3] Not presenting here are some graphic novels and comic books on climate change and air quality.

Some eye-opening comics by Rohan Chakravarty from COP28 meetings (https://greenhumour.substack.com/p/live-cartoons-from-the-cop28-resilience).



There is no distinction between air quality and climate change when it comes to the sources of their emissions—both stem from burning of fossil fuels. While groups and individuals are working on visualizing the problem, we need more hands-on deck to spread the message effectively. Mass communication plays a critical role in raising awareness, engaging the public, and driving action to address these interconnected challenges at their roots, and simple artwork can play a vital role in making these messages more accessible and impactful.

4. Installations and Practice

Cultivating behavior change among communities and individuals is essential for achieving lasting improvements in public health and environmental sustainability. This involves raising awareness, providing education, and creating supportive environments that encourage healthier choices. By fostering a sense of ownership and responsibility, communities can motivate individuals to adopt these habits, leading to benefits for all.

Bogotá's Ciclovía is a remarkable initiative, in this regard, that transforms the city's streets into car-free zones every Sunday and public holiday, promoting walking, cycling, and community engagement. Between 7AM to 2PM, over 100 kilometers of roads are closed to motor vehicles, allowing pedestrians, cyclists, and rollerbladers to take over the streets. Established in the 1970s with less than 10km, Ciclovía provides a safe and vibrant environment for exercise, recreation, and social interaction while also fostering a sense of community. Alongside physical activities, the event often features cultural activities, art installations, and wellness programs, making it a holistic experience that promotes not just physical health, but also social cohesion and environmental awareness. This successful model has inspired similar programs in cities around the world, showcasing how urban spaces can be reimagined for the benefit of their residents[4].

[4] Bogotá's TransMilenio program is also a flagship public transportation system started in 1998, which serves over 2.3 million passengers daily over 12 lines with 112km of dedicated bus rapid transit lanes and has set numerous benchmarks for other cities to emulate.

One installation nicknamed “Lungs Billboard” and “Billboard that breathes” by two Indian organizations (Jhatkaa and Asar) vividly demonstrated through an eye-catching display, the stark difference between breathing clean and polluted air. Under the theme "show, don't tell," this visual art piece personalized the experience for every passerby on the street, offering a powerful reminder of the impact air pollution has on our lungs, highlighting how chronic exposure to polluted environments gradually blacken and damage lung tissues.

The first installation by Jhatkaa took place in Bengaluru in 2018, where the lungs turned black after 25 days of exposure. A subsequent installation in Delhi saw the lungs blacken in just 8 days. Following these impactful displays, Asar and Waatavaran expanded the initiative by installing similar billboards in Mumbai, Nagpur, Pimpri Chinchwad, Pune, Amritsar, Ludhiana, Dhanbad, and Ranchi. In these cities, the rate at which the lungs darkened varied depending on local pollution levels, with the lungs turning black in less than 14 days, starkly illustrating the severe and rapid impact of air pollution on respiratory health.

Along with the installation, these groups also organized awareness raising activities in the community and among the school children, making the abstract science behind health impacts of pollution tangible and real for all who saw it. In various cities, these activities included interactions with doctors, health professionals, scientists, communication specialists, residential welfare associations, and concerned parents.

Lung Installation[5] to demonstrate the impact of air pollution in Delhi in November 2018

[5] An installation depicting human lungs retrofitted with HEPA filters and a fan that mimics breathing was placed at Delhi’s Sir Ganga Ram Hospital as part of a campaign launched by the Help Delhi Breathe Initiative, Lung Care Foundation, and Sir Ganga Ram Hospital from November 3 to 13, 2018. Initially chalk white on Day 1, the installation began turning gray within 24 hours and became completely black by the end of the 10-day period.

AirParif (https://www.airparif.fr), an independent organization, monitors air quality in the Paris region with robust, reliable devices, improves understanding of pollution and its impacts, supports citizens through information and awareness, and fosters innovation to enhance air quality[6]. It gained attention for its innovative Air Quality Index (AQI) balloon (https://www.aerophile.com/en).

The large helium balloon, launched over the city, changes color based on real-time pollution levels, providing a visual representation of air quality for the public. When air quality is good, the balloon appears green, and as pollution worsens, it shifts to yellow, orange, and red. This initiative is designed to raise awareness about air pollution in an easily understandable and visible way, encouraging people to think about their impact on the environment and the importance of cleaner air. The AQI balloon serves as a powerful tool for mass communication, simplifying complex air quality data and making it accessible to everyone in the city.

There are more examples where artists found creative ways to visualize air pollution. Here are some more for browsing[7].

- https://mutualair.org - For six months (2018-19), a network of bells placed in public locations throughout Oakland worked together to sonify global climate data and hyperlocal air-quality fluctuations across neighborhoods.
- https://warwick.ac.uk/research/impact/social-sciences/cim/yellow-dust - Seoul Biennale 2017 - Yellow Dust is an installation that creates a large, yellow cloud of water vapor. As visitors walk through it, the cloud changes

[6] AirParif also gained recognition for actively using AQI forecasts, providing 2- and 3-day advance warnings to help prevent severe pollution outbreaks. By leveraging state-of-the-art forecast models, which consider various factors such as weather patterns, emissions data, and pollutant dispersion, authorities can predict potential spikes in air pollution. These forecasts allow the city officials to implement strict emission control measures, such as restricting vehicle traffic, reducing industrial emissions, or encouraging the use of public transport (like free for 2 days), before pollution reaches those predicted levels. This proactive approach helps mitigate the health impacts of air pollution and demonstrates the importance of integrating scientific forecasting tools into urban air quality management.

[7] All links last accessed on 27th September 2024

in density and humidity in response to changes in air pollution levels in Seoul.

- Pollution Pods (https://www.michaelpinsky.com/portfolio/pollution-pods-2) – Five interconnected geodesic domes contain carefully mixed recipes emulating the relative presence of ozone, PM, NO_2, SO_2 and CO which pollute London, New Delhi, San Paolo and Beijing. Starting from a coastal location in Norway, the visitor passes through increasingly polluted cells, from dry and cold locations to hot and humid.

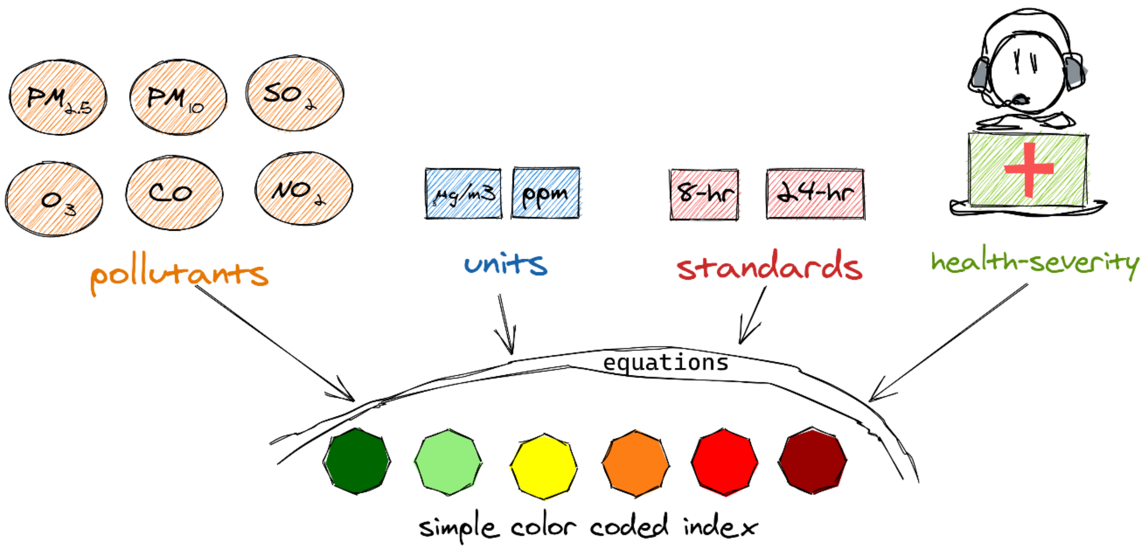
It is important to note that these public installations and art projects, are often initiated by artists, not scientists, though they rely on data provided by scientific and academic groups. These creative public installations and social activities help bring the message to a broader audience, making the complex issue of air pollution more relatable and understandable.

These activities also highlight that: (1) pollution is a serious problem affecting our health and environment, and (2) there are solutions within our grasp.

However, to achieve real change, we need to take two critical steps: (1) we must demand action from policymakers and (2) we must also be ready to make personal and collective changes in our own behaviors and lifestyles. Together, these efforts can lead to meaningful progress in combating air pollution.

5. Common Ground

Air pollution involves complex science—multiple pollutants, units, health thresholds, and standards—which makes communicating it challenging. The Air Quality Index (AQI) simplifies this by unifying the science of pollution into a single, unitless number. This number is then represented with color-coded alerts to indicate good or bad air quality days, making it easier for the public to understand.



While the concept of AQI is universal, what these color codes mean in various countries is while intuitive, not universal. While the absolute concentration numbers of a pollutant can be directly compared between cities and countries, the calculated index is not comparable. For example: $PM_{2.5}$ pollution at 51 mg/m^3 in India is regarded as satisfactory air quality, while the same in the European Union is tagged as very poor air quality[8].

Unlike climate change (addressed through the Kyoto Protocol and Paris Agreement) and ozone layer protection (via the Vienna Convention and Montreal Protocol), the issue of air quality lacks a global treaty. This absence is likely due to varying national standards and differing methods of measuring the health impacts of air pollution. While the World Health Organization's guidelines serve as a global benchmark for healthier air quality, there is still a need for a universal system. Specifically, a standardized methodology for color-coding air pollution alerts could greatly improve mass communication, making it easier for public worldwide to understand and public bodies to respond to air quality warnings, regardless of where they live. Such a unified approach would help bridge the gaps in how air pollution is communicated and addressed globally.

[8] An MS-excel based AQI calculator is available @ https://urbanemissions.info/tools for calculating these index values and color codes and compare results using methodologies from six countries.

6. Simplifying Science

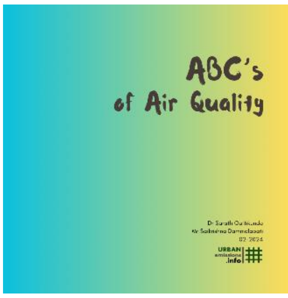
An educated and informed (technical and non-technical) community is a powerful ally for the environment.

Explaining science can be a form of storytelling, much like a comic book uses visuals to simplify complex ideas. By turning scientific concepts into clear, engaging narratives, visual storytelling makes it easier for people to grasp and relate to intricate topics. This method breaks down barriers of understanding, making the science more interesting, engaging, and accessible to a wider audience.

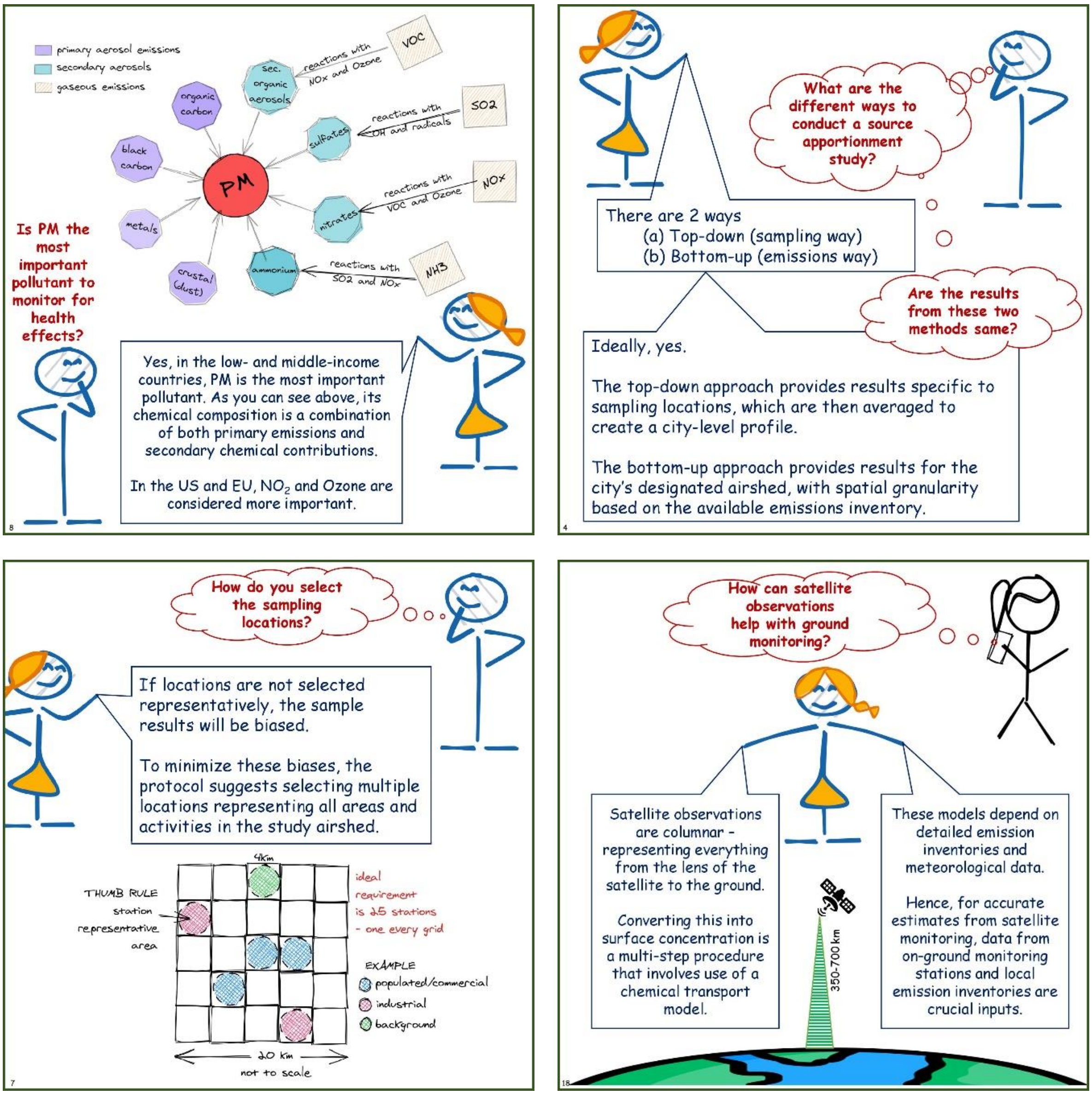
Air quality management involves several key steps: identifying pollution sources, documenting their emission intensities, studying the movement and chemical interactions of these emissions within complex meteorological conditions, and assessing various emission control measures for their costs and benefits. In scientific terms, this process is rooted in atmospheric chemistry and physics (Fowler et al., 2020; Monks & Williams, 2020).

The history of air quality management from the United States, the European Union, and other regions highlight the long journey of gathering the necessary data to conduct analysis at each step. Equally challenging is bringing together various stakeholders, a crucial effort that involves explaining pollution concepts (*aka. science*) to both technical and non-technical audiences. Achieving consensus among these groups is essential for taking collective action.

The main challenge lies in explaining air quality concepts to stakeholders with varying levels of technical understanding (or lack there-off). These concepts can range from basic questions like "*what are the key pollutants?*" to more complex ideas such as "*what is source apportionment?*" and "*what is air quality management?*" If the problem and solutions are presented in an overly texted or complex or convoluted way, the likelihood of most of the stakeholders disengaging increases fast. Therefore, simplifying not only the presentation of data but also the explanation of the problem and its solutions (*aka. simplifying science*) is crucial for fostering action and collaboration.



UrbanEmissions' illustrated primers on air quality management concepts are designed to appeal to various learning levels, from high school students to graduate students, technical and non-technical managers, as well as governmental and non-governmental practitioners. By simplifying complex ideas, these primers serve as valuable tools to accelerate learning, especially for those who may feel overwhelmed by dense textual explanations, thereby broadening the reach of educational content. The aim of these primers to eliminate the "*fear-of-the-unknown*" and encourage engagement with the subject.



This material only aims to complement, rather than replace, traditional learning methods and practical experience on the ground.

7. Small Tools for Big Problems

Air pollution analysis is a numbers game. An increase in total emissions typically correlates with higher pollution levels, and conversely, a decrease in emissions can lead to lower pollution levels. Weather conditions such as rain or strong winds can significantly reduce pollution levels in an airshed, regardless of emission intensities. During winter months, lower mixing layer heights contribute to elevated pollution levels. Additionally, when surface temperatures drop below 12°C, the demand for fuel for space heating rises. While these statements are grounded in logic, they also rely on scientific principles and models, providing practitioners, managers, and researchers with critical insights for assessments.

Established models are essential for comprehending the complex dynamics of emissions, meteorology, and pollution. However, these models are often computationally demanding and require personnel with advanced technical training. In many regions of the global south, progress is hindered by these high demands and lengthy data prescriptions, which often overlook existing knowledge gaps (Garland et al., 2023). These demands contribute to the "*fear-of-the-unknown*" among the next generation of researchers, especially without the necessary basic (operational) training.

We must avoid analysis-paralysis at all costs. Without compromising on the science or the data needs, is there a way to build this capacity to crunch numbers, while there is a waiting period on advanced modeling systems? Should we wait for a flawless dataset, or is a 90-95% representation of the problem sufficient to kick-start our data journey?

The goal of this inquiry is only to focus on building the capacity of the next generation of researchers and emphasizing the importance of operational training and experience. Establishing baselines with readily available data can highlight past knowledge gaps and pave the way for future learning opportunities. By initiating the analytical journey with a representative set of inputs, we can begin to address pressing air quality issues sooner rather than later. We need to foster a culture of proactive analysis and continuous improvement, allowing researchers to adapt and refine their approaches as more accurate data becomes available.

At UrbanEmissions, we advocate for using small models to address big problems, without compromising on scientific integrity or discouraging the use of advanced models. Our aim is to empower managers and practitioners to grasp the fundamentals of air pollution analysis, allowing them to engage in more complex data analysis as their understanding grows and additional data becomes available to enhance the models.

SIM-air family of tools

The SIM-air (Simple Interactive Models for Better Air Quality) model was initially developed in 2000 to analyze SO_2 emissions from coal-fired thermal power plants. Since then, the SIM-air family of tools has evolved to enable users to conduct emissions and pollution modeling in a multi-pollutant environment using MS Excel, including cost-benefit optimization of various emission control options. Some tools and modules even feature instructional videos to facilitate a plug-and-play experience. These resources are designed to clarify data requirements, guide users on modeling approaches in data-scarce regions, and integrate inputs from multiple sectors for comprehensive assessments. One of the key advantages of these tools is their accessibility: built on MS Excel, there's no need for additional software. Users can easily reopen files if they crash, trace errors in calculations, and explore all equations to foster understanding and innovation.

Some example tools to start emissions analysis for the transport sector in a data scarce region are:

1. VAPIS 2.1 (Vehicular Air Pollution Information System) – a vehicular exhaust emissions calculator to estimate and compare total emissions by vehicle-age and run scenarios (requires user to activate macros)
2. Demonstration of 4 approaches to estimate total fleet average vehicle exhaust emissions using information on (a) vehicle km travelled (b) fuel sales (c) modal shares and (d) meteorology
3. Demonstration of fundamental equation in building fleet average emissions, with and without age-mix information
4. Demonstration of a method to convert fleet average speeds into vehicle km travelled
5. Demonstration of a method to calculate how many additional buses are required to support odd-even or an equivalent scheme (with and without fuel mix exemptions)
6. Demonstration of a method to calculate total fuel wasted from idling in the city
7. Demonstration of a method to calculate benefits of shifting % of 2-wheeler and 4-wheeler trips to buses and non-motorized transport
8. Demonstration of a method to estimate vehicle exhaust emission factors using emission standards and deterioration rates
9. Example set of survival rates based on vehicle age for nine vehicle categories (to convert yearly registered vehicle numbers into in-use vehicle numbers) and

10. Demonstration of a method to grid the total vehicle exhaust emissions using multiple grid-level proxies as weights (requires user to activate macros).

These tools were used in various forms to assess air quality in 60 Indian cities and 10 non-Indian cities (UEinfo, 2024). The goal remains to be able to use these simplified tools to learn about the data needs, improve on the data gaps, and ultimately use the techniques to establish state-of-the-art emissions and pollution modeling systems for the cities.

The missing piece is training—not just theoretical knowledge, which managers and practitioners can obtain from books, lectures, or university courses, but practical, operational training that equips them to effectively use these scientific equations of emissions and pollution modeling. This includes guidance on where to find necessary data, how to conduct surveys in the absence of available information and understanding the appropriate extent of modeling needed for specific contexts. Without this hands-on training, the gap between theoretical knowledge and practical application remains unaddressed, hindering effective air quality management.

Scientists must play their role in: (a) developing a curriculum for the next generation that emphasizes operational knowledge of emissions and pollution modeling systems, (b) organizing training events that provide hands-on experience with monitoring equipment and its maintenance, and (c) creating analytical platforms that help non-technical practitioners navigate air quality data and concepts.

Meanwhile, communicators should focus on: (a) simplifying data trends through effective visualizations, and (b) identifying technical and non-technical knowledge gaps within the broader audience that can be addressed through hands-on training and open workshops.

8. Way Forward

Worldwide, air quality management, modeling, and building emission inventories are never-ending jobs. In the United States and the European Union, it took over 40 years of coordinated efforts to unify databases and establish consensus on modeling methods. One effective visualization that has consistently worked across various contexts is a simple *pollution trendline (going up and how much it exceeds the standards)*, regardless of whether the data originates from monitoring stations, networks, or modeling exercises. These measurement and modeling approaches must be replicated and expanded globally to enhance air quality management efforts.

Building consensus among technical and non-technical stakeholders is essential for the success of air quality management plans. Although these plans often contain complex scientific and technical details, integrating audio, video, and infographic tools can help simplify the concepts of air pollution and management for a broader audience.

There is a challenge to bring forth the next generation of atmospheric scientists, meteorologists, air quality managers, and practitioners and to convince them that while there is a lot of ground to cover, there is a way to boost confidence in emissions and pollution modeling by keeping data needs and knowledge gaps in perspective. Use the simplest method that suits the local needs first and then complicate the analytical systems to advance science.

Scientists must actively develop a curriculum for the next generation that emphasizes operational knowledge of emissions and pollution modeling systems. They must organize training events that provide hands-on experience with monitoring equipment and its maintenance. Additionally, they must create analytical platforms to help non-technical practitioners navigate air quality data and concepts.

Meanwhile, communicators must focus on simplifying data trends through effective visualizations and identifying technical and non-technical knowledge gaps within the broader audience to address these gaps through hands-on training and open workshops.

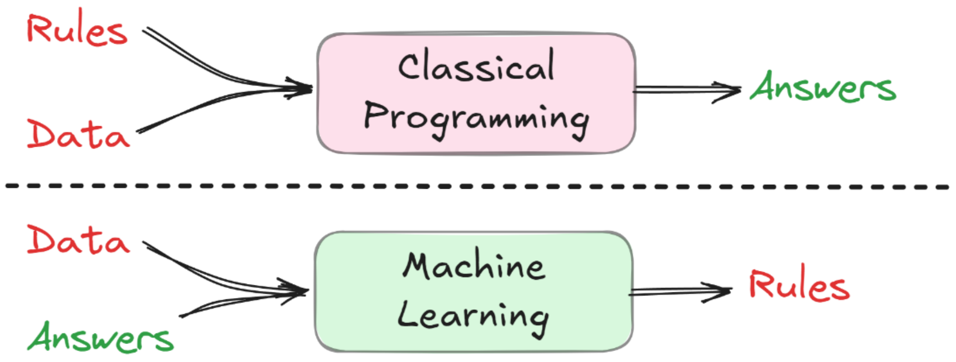
We must collaborate to ensure a seamless flow of information from academia to media to policy, facilitating effective mass communication and enhancing public awareness initiatives.

9. Annexure: Role of AI/ML

There is a growing body of research emerging on the applications of artificial intelligence and machine learning (AI/ML) for analyzing air pollution, particularly in integrating multiple datasets (ground measurements, model results, geospatial information, and satellite retrievals) to predict trends and future outcomes. This surge in interest is accompanied by increasing funding opportunities for researchers exploring this promising avenue.

As an emerging science, **will AI/ML simplify our problem or complicate it further?**

AI/ML and machine learning have the potential to simplify our problems by processing vast amounts of data quickly, identifying patterns, and providing insights that can inform decision-making. However, they can also complicate matters if the models are not transparent or the data feeding these models to generate the patterns is faulty, or if stakeholders lack the understanding needed to interpret the results effectively.



These systems require data and known answers to generate informed predictions, and we are still struggling to obtain this data to know the answers to classical questions – How much is my pollution? Where is my pollution? When is my pollution? and Who is contributing to my pollution problem?

We must exercise caution in using these systems until we have a clearer understanding and clean answers on the ground.

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