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Why communicating air quality information in the simplest form gets more people to understand and get involved in the fight against air pollution

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ABSTRACT

Mass communication can enable changes in public behaviors, public awareness, and an effective public-policy dialogue, and simplification of the knowledge, data, and concepts of the problem is the key to mass communication. Globally, according to the State of the Global Air 2020 report, an estimated 6.7 million premature deaths are associated with outdoor and household air pollution. There is a consensus on the level of the problem, there are guidelines for better air quality from the World Health Organization, and there are state-of-the-art analytical systems to support air quality managers and practitioners. Often, especially in the low- and middle-income countries, the path forward to act against the air pollution problem halts because of the "fear of the unknown" driven by lack of data, misconceptions, and complexities of the analytical systems. There is an urgent need to train the next generation of managers, practitioners, and scientists without this fear. This manuscript is an attempt to catalogue examples that simplified the theory of air pollution to benefit public awareness activities for a broader audience and to present resources to bridge their knowledge gaps with the air pollution modeling community.

KEYWORDS

Air Quality; Mass Communications; Public Awareness

1.0 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". Air quality is a common denominator for most of the developing world and gaps in knowledge and communications to support the research community and public awareness activities have been intermittent. There is still a certain "fear of the unknown" about it, despite all the improvements in trying to know more about the problem and finding ways to improve research collaborations in the global south (Garland et al., 2023). Compared to what it used to be in 1990's and early 2000's, there is more awareness on cities and countries with the most pollution (https://iqair.com), more information resources from institutions like NASA and ESA providing open data from their respective satellite and global modeling products (Holloway et al., 2021; Veefkind et al., 2012), more media and academic coverage on the extreme events across the globe covering forest fires, dust storms, winter hazes, and health impacts (Fuller et al., 2022; HEI, 2022; Kok et al., 2021; Wang et al., 2024; Yan et al., 2024), more access

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to the modeling programs at urban, regional, and global scales to study the past and the 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 programs working on making the official and unofficial data accessible to the public (https://openaq.org).

Understanding atmospheric science and air pollution is complex as it is, from the first step of ambient monitoring to emission and pollution estimation to policy making. The process of information generation and usage is well defined, despite the bottlenecks related to the technical, personnel, and computational demands at each of these steps. Yet, the atmospheric science community remains small, especially in the global south and belief in the modeling process is low. For example, the meteorological forecasts of whether or not there will be rain tomorrow and how much. The unending demand for more information, uncertainty in the available data, and a large knowledge gap in understanding the ways in which the data and the models can be used for public awareness and public policy, induces a certain "fear of the unknown" among the users. Today, in the air quality research community, the number of journal articles published using artificial intelligence and machine learning has also increased - further perpetuating the idea that trying to understand more about air pollution is complex, the modeling exercises are complex, and the computational systems necessary to learn about the problem is complex, furthering the fear of pushing a button to understand the available information, make deductions of the patterns, and build consensus on the data. Fear only from thinking, "what-if". What-if the numbers generated or wrong. What-if the theory or the models are not accepted.

One of the important goals of the community is capacity building and nurturing the next generation of atmospheric scientists, meteorologists, air pollution strategists, and air quality information communicators. This is a two-step process. The first comprises of regular courses, lectures, exams, and thesis works at the established Universities and Colleges. The second comprises of the ways to make the knowledge easy to understand for more people to get involved, beyond the scientists and strategists. However, this is a catch-22 phase - to simplify the matter, we need to go through the full circle of learning and to generate more interest in learning we need access to simplified theories and material. Without compromising on science, if there is a way to demystify the material and make the masses understand the problem, we will have more buy-in into the solutions that immediately benefit air quality and health.

This manuscript is an attempt to catalogue 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.

2.0 AMBIENT MONITORING DATA, VIDEOS, AND MASS MEDIA

The journey to understanding a city's air pollution problem starts with ambient monitoring and access to the data. More monitoring is always encouraged, as it provides more data to study the spatial and temporal trends in pollution, it provides more data to validate the inputs to various emissions and outputs from pollution models, and builds confidence in the process of information generation and usage (Brauer et al., 2019; Engel-Cox et al., 2013; Martin et

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al., 2019). Ambient monitoring data is also the basic form of pollution data that any air quality practitioner and manager need to have access to as it provides a temporal baseline as annual, seasonal, monthly, and diurnal variations and a spatial map of pollution hotspots in an airshed.

One of the best examples of the use of ambient monitoring data for public awareness comes from China – a video "Under the Dome" in 2015, documenting the pollution data and the estimates of health impacts of various pollutants. It initiated a change in the course of discussions in China for better air pollution regulations, resulting is a drop of up to 30% of $PM_{2.5}$ pollution (and other pollutants) in the last decade (Han et al., 2022; Sicard et al., 2023).

The barrier to mass communication is not just the availability of state-of-the-art equipment, but also making the information available to the masses in the simplest form possible. For example: an MS-excel file at the US Embassy website. Open data publication from a monitoring station at the US Embassy in Beijing, led to some innovative public awareness activities, like "view from my window" calendar, which includes a picture of a set location from a window with open sky and a reading of pollution levels (Nguyen, 2020). These visualizations started in 2008, the year of the Beijing Olympics, and was replicated by air quality advocates in many Chinese cities. Since Beijing, expansion of the network at the US Embassies in 80 countries also led to some changes in respective countries (Jha and Nauze, 2022). In India, an analysis of the print media and the social media reports suggests that the increase in the public complaints on air pollution coincides with the release of open data from the Embassy stations in 2015 in Delhi and Mumbai (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 2023).

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). With the emergence of sensors, which cost a fraction of official-reference-grade systems, barriers to self-monitor and to access data are broken (Kumar et al., 2015). While for regulatory and policy purposes, the data continues to be collected from systems following established protocols, these low-cost sensors, after calibration and validation, can (and are) helping in filling the knowledge gap, most often in the form of citizen science (Engel-Cox et al., 2013).

3.0 TRENDS IN POLLUTION AND DOODLES

In 2023, Delhi ranked first among the most polluted capital cities in the world and the year before that (https://iqair.com). These rankings are based on data published by the official monitoring networks, some open sensors data, and a combination of data from global model simulations. The annual rankings in its simplest form of "how much", brings the focus back to what the research community and public can (and must) focus on in taking the air quality management conversation forward.

This chronic problem needs a deeper dive into trends in urbanization, consumption patterns, travel demands, and institutional support. A review of Delhi's air pollution from 1990 to 2022 is published in a 30+ page journal article

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(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 into these two doodles (**Figure 1**) to explain the chronic nature of the problem in Delhi and to document who the main contributors are (a) normalizing the problem, year on year, with no real improvements in the overall pollution levels (b) showing interest in the problem only when there is media coverage at the beginning of the extreme events and pollution season. It is a known fact that the winter months record the worst pollution levels in Delhi (and all along the Indo-Gangetic Plain) compared to the summer and monsoonal months. But this doesn't mean that the pollution levels during the summer and monsoonal months are negligible. The problem is normalized against the winter months and not discussed. The problem also lies in the communication methods. The number of media articles, workshops, and discussion forums that spring to action at the beginning of the winter pollution season, invariable leads to a thinking that all the air pollution problem in Delhi is only because of the extreme events like Diwali and agricultural residue burning, while the main culprit is wintertime space heating when the surface temperatures drop to 10ºC. Again, the high winter averages are normalized against the extreme highs and the problem is shrugged off.

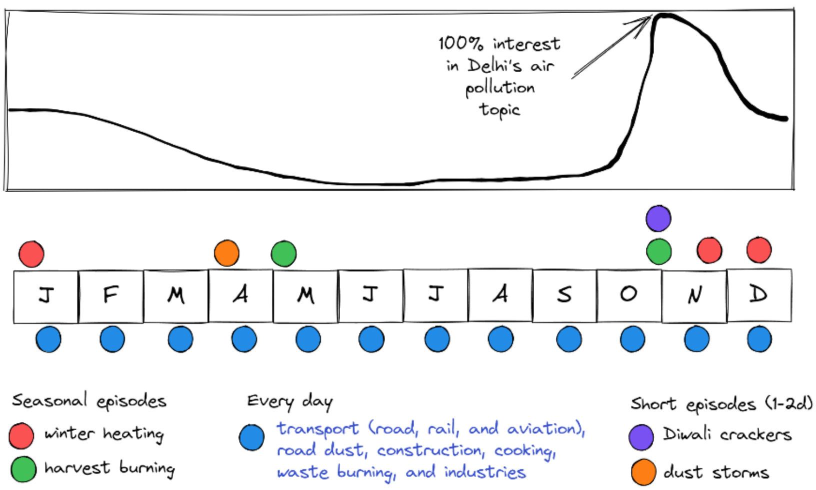

Figure 1: How air pollution problem in Delhi is normalized over a year, using google-trend's interest in the topic of "air pollution in Delhi" data and known sources of air pollution in each month.

Among the non-technical tools, "google-trends" is a simple visualization tool for displaying the rate of "when is the interest" in a topic. Overlaying this information in a doodle form with summaries from emission inventories, source apportionment studies, and other modeling works, has been very effective at communicating the breadth of the air pollution problem in Delhi.

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4.0 INDEX AND COMMON GOALS

What constitutes air pollution is plenty of science. There are at least six health criteria pollutants which are routinely monitored across the globe – particulate matter (PM) in two size bins (everything under the aerodynamic diameter of 2.5µm and 10µm), sulfur dioxide (SO_2), nitrogen oxides (NO_x as NO and NO_2), carbon monoxide (CO), and ozone and tens of volatile organic compounds (VOCs), all with varying degrees of health exposure-response functions (Aunan, 1996; HEI, 2022). These pollutants do not have a common or linearized standard - CO and ozone are pollutants which can manifest health effects over short periods of exposure and others are chronic in nature slowly aggravating various human health conditions. These pollutants are also measured in different units - aerosol forms are often reported in mass units like µg/m^3 and gaseous forms are reported in volume units like ppm. None of this makes communicating air quality information simple or easy. Hence, the air quality index (AQI), a unit less number which unifies all the complicated science of pollution composition, exposure rate-based health severity, ambient standards, and measurement and standard protocols, and presented as simple color-coded alerts to represent good or bad air quality days.

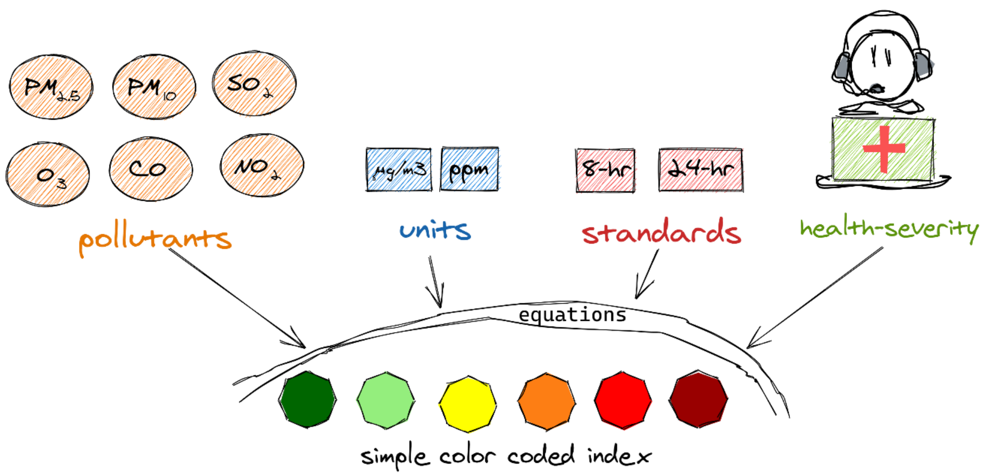

Figure 2: What air quality index (AQI) represents.

While the concept of AQI is universal, what these color codes mean in various countries is 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 µg/m^3 in India is regarded as satisfactory air quality, while the same in the European Union is tagged as very poor air quality. An MS-excel based AQI calculator is available @ https://urbanemissions.info/tools for calculating these index values and color codes and compare results using six methodologies.

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Unlike towards climate change (via Kyoto Protocol and Paris Agreement) and the ozone layer protection (via Vienna Convention and Montreal Protocol), air quality problems lack a global treaty, likely because countries follow different standards and measure the health effects of air pollution in different scales. Like the World Health Organization's guidelines, which act as the benchmarks for universal better air quality, we also need a global methodology for color coding the air pollution alert system for mass communication.

5.0 CONCEPTS OF POLLUTION AND PRIMERS

Air quality management means many steps - identifying the sources that are contributing to the problem, documenting emission intensities of these sources, studying the movement of these emissions along with their chemical interactions in a maze of meteorological fields, and evaluating a range of emission control measures for costs and benefits (Fowler et al., 2020; Monks and Williams, 2020). The history and case studies from the United States and the European Union, point to the long journey in putting together not only the information to conduct the necessary analysis at each of these steps, but also the struggles in getting various stakeholders together. The later effort is crucial as it involves explaining the concepts of pollution to technical and non-technical stakeholders and getting their consensus to act with combined understanding of the problem. The main challenge is in explaining the concepts to these stakeholders with varying degrees of technical understanding. These concepts can range from as basic as "what are the pollutants" that we need to focus on, to "what is source apportionment" and "what is air quality management". If the presentation of the problem is complex and what needs to be done is convoluted, the probability of the community to put hands up and not do anything is higher.

An image is worth 1000 words - illustrated media (graphic novels) has emerged as a powerful medium for mass communicating complex and technical concepts, bridging the gap between traditional textual explanations and visual storytelling, and addressing a broader audience. Examples in **Figure 3** are illustrated booklets on various concepts of air quality management, simplified to appeal to a range of learning levels (from high school students, graduate students, to governmental and non-governmental practitioners) and enable common understanding of the concepts. These new tools can fast forward learning, especially among the readers who might be intimidated by dense textual explanations, thus broadening the reach of educational content. The goal is to remove the "fear of the unknown" and get the learning started. The material should not be considered as an alternative to traditional learning methods nor to the practical experience on the ground.

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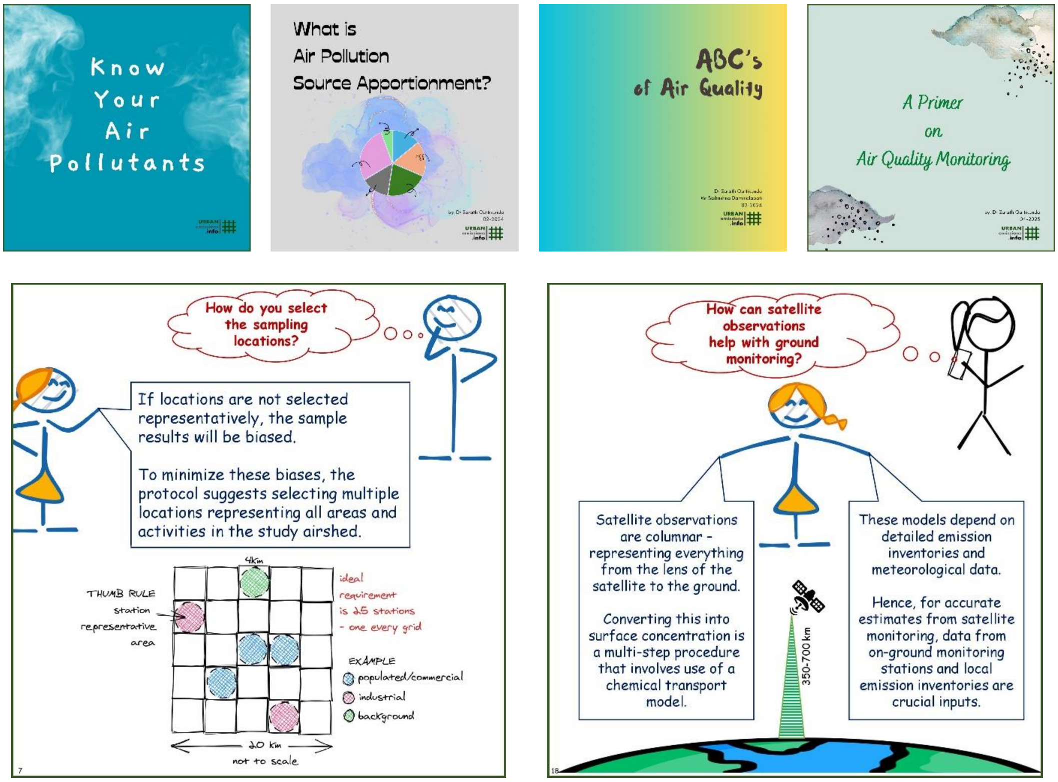

Figure 3: Examples of Illustrated primers for air quality management @ https://urbanemissions.info

6.0 TOOLS TO UNDERSTAND NUMBERS

Air pollution analysis is a numbers game. If there is an increase in total emissions, there will be an increase in the pollution levels and vice versa. If there is rain or strong winds over an airshed, irrespective of the emission intensities, we can expect a drop in the pollution levels. In the winter months, the mixing layer heights are low, which means higher pollution levels. If the surface temperatures are under a threshold of 12ºC, we can expect higher demand in the fuel for space heating. These statements, while logical, are also based on science, which helps the practitioners, managers, and researchers with rapid assessment of pollution sources of an airshed. Eventually, established models must be utilized to fully understand the dynamics of emissions, meteorology, and pollution, which is often computationally demanding, requiring personnel with advanced technical training. A consensus among the global south is that most of the necessary work is halted because of this high demand and long data prescriptions without taking into consideration the knowledge gaps of the regions (Garland et al., 2023). Again, without compromising on the science or the data needs, is there a way to build the capacity of the next generation of researchers to crunch numbers, while there is a waiting period on advanced modeling systems. The goal of this question is only to simplify the modeling data requirements, to build capacity instead of idling for perfect fits, to establish baselines that can reveal

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the knowledge gaps of the past, and to pave the way for future learnings. The idea is to start the analysis journey with a representative set of inputs. Do we need to wait for 100% perfect dataset or is 90-95% representation of the problem good enough to start the data journey?

The SIM-air (Simple Interactive Models for better air quality) model was first put together in 2000 to analyze one pollutant from one sector – SO_2 emissions from coal-fired thermal power plants. The SIM-air family of tools now allows users to conduct emissions and pollution modeling in a multi-pollutant MS-excel based environment (https://urbanemissions.info/tools), including cost-benefits optimization of a set of emission control options. Some of the tools and modules also include instructional videos to support plug and play. The tools are further broken down to also understand the data needs, to explain how to approach modeling in an open data scarce region, and to collate inputs from multiple sectors for an integrated assessment. The only unintimidating part of the tools is the fact that everything is based on MS-excel; no new software to buy; if the file crashes, reopen and redo; if there is a mistake, follow the numbers to see where the error is; and all the equations are open to explore, expand, and innovate.

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, 2019). 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.

7.0 WAY FORWARD

Air quality management, air quality modeling, and building emission inventory are never ending jobs. It took more than 40 years of coordinated efforts in the United States and the European Union to unify databases and to build a consensus on modeling methods. The simplest visualization that worked in all the cases is the pollution trendline, whether the data is coming from a monitoring station, monitoring network, and a modeling exercise. These measurement and modeling methods must be replicated and expanded across the globe.

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Building consensus among the technical and non-technical stakeholders is crucial for the success of air quality management plans. While the plans are heavy on science and technical details, integrating audio, video, and infographic tools must be encouraged to simplify the concepts of air pollution and management to 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.

Work together to make the transition of information flow from academia to media to policy a smooth sail for mass communications and support public awareness activities. The role of the scientists must include (a) building a curriculum for the next generation which encourages operational knowledge of the emissions and pollution modeling systems (b) building training events which include hands-on operations and (especially) maintenance experience on monitoring equipment and (c) building analytical platforms for the non-technical practitioners to navigate air quality data and concepts. The role of the communicators must include (a) finding ways to simplify the data trends with visualizations (b) detecting technical and non-technical knowledge gaps among the broader audience, which can be addressed through hands-on trainings and open workshops.

SUPPLEMENT AND DATA AVAILABILITY

All the databases, tools, and primers discussed in this manuscript are available for open access and use @ https://urbanemissions.info

COMPETING INTERESTS

The author has declared that there are no competing interests.

ETHICAL STATEMENT

As this was a desk-based literature review, no ethical approval was required for this study. This study referred to data and news available only in the open feeds. The research conducted in this study represents the authors' perspectives and does not involve any intent to cause harm to others.

FINANCIAL STATEMENT

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