Ambient Air Pollution from Urban Transport in India

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High levels of air pollution from transport systems in urban India pose a severe threat to public health. While long-term challenges remain to curtail pollution sources, immediate measures must be taken to minimise risks to exposed populations.

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The risks from air pollution are greater than previously thought or understood, and reducing pollution is considered critical to improving the health of a population (WHO 2016). Air pollution is the fourth highest risk factor for all deaths globally, and is by far the leading environmental factor for disease. Every year 4.3 million deaths occur due to indoor air pollution, and 3.7 million deaths are attributable to outdoor pollution. More than half of these deaths occur in just two countries, China and India (UBC 2016).

Future of Air

The urban air pollution is predicted to be the top environmental cause of premature mortality worldwide by 2050 (van der Wall 2015; Gouldson et al 2015). The situation in India is already dire. Thirteen of the 20 most polluted cities globally are in India, and the country has the world's highest rate of deaths caused by chronic respiratory diseases (WHO 2014a). The World Bank reports that in 2010, at some point, the entire Indian population was exposed to particulate matter (PM) at levels exceeding the guidelines of the World Health Organization (WHO) (World Bank 2015b). In March 2015, Prakash Javadekar, former minister for environment, forest and climate change stated that the air quality monitoring data for New Delhi provided by the Central Pollution Control Board (CPCB) indicated that the levels of PM exceeded the WHO guidelines by a factor of 7 to 12 (*Economic Times* 2015). New Delhi's pollution levels frequently exceed those of Beijing, conferring on the nation's capital the dubious distinction of sporadically being the most polluted city on earth.

In addition to the enormous disease burden imposed by air pollution, there are outsized external and social costs. In 2013, at the request of Ministry of Environment and Forests, the World Bank conducted its first-ever economic assessment of environmental degradation in India and reported the amount to be 5.7% of the country's gross domestic product (GDP) (World Bank 2013). The highest share of this was from the impact of ambient air pollution. And in another first-of-its-kind study conducted in 2015, the Organisation for Economic Co-operation and Development (OECD) found that the air pollution-related illnesses and mortalities cost $1.7 trillion annually in OECD countries, $1.4 trillion in China, and $0.5 trillion in India (WHO and OECD 2015).

Despite the toll in health and economic costs, it is frequently alleged that most environmental risks are preventable, and that urban air pollution is an avoidable cause of disease and death—there are things people can do to protect themselves, or it can be avoided in the first instance. Certainly, some risk factors can be mitigated by an effective action at street level, and there are ways to protect against the worst health risks, particularly for the most vulnerable—children, the poor, sick and the elderly.

We agree with the assertion by the WHO that reducing the environmental burden of death and disease is entirely possible through cost-effective interventions, and that local action can be a key determinant in shaping the use of resources and management of health determinants. We also agree that municipalities are natural leaders of local environment and health planning, but until there is a change in perception to view the environment as an essential element of health protection, the public health principle that creating and maintaining healthy environments will not be a priority (Prüss-Üstün et al 2016).

At the same time, complex health problems due to urban air pollution are seldom amenable to simple solutions, and macro-level environmental factors are usually outside individual control. Urban transport-related air pollution is only preventable with sufficient time, money and political will. Its structural causes are already in place, and it will require massive, sustained effort to reconfigure cities and their existing transport infrastructure away from the dominance of private motorised vehicles. The banal fact is that infrastructure projects are highly disruptive and expensive in the short term, and even more disruptive and expensive when postponed to the future.

This paper describes some of the immediate actions that should be taken to mitigate health risks faced by exposed and vulnerable populations, as well as steps towards addressing urban transport pollution systemically by going upstream to structures and behaviours that are responsible for harmful emissions in the first instance.

Urban Transport: Private Motorisation Dominates

More people live in cities than in rural settlements, and by 2050, over 60% of the world's population is projected to be urban. India, with 410 million city-dwellers, has the world's second largest urban population, living in some 380 urban agglomerations and three megacities of over 10 million (IIHS 2011). In the next 35 years this urban population is expected to double, with medium-size cities growing faster than the mega-cities, and at higher rates of motorisation (UN 2014). The latter is a troubling prospect, given that Delhi had 7.4 million registered motor vehicles in 2012, a number predicted to increase to over 25 million by 2030 (Kumar et al 2015).

Cities are typically more cost-effective than rural settlements in the provision of essential goods and services such as public transport, healthcare, education, housing, electricity and sanitation. Urban dwellers also have access to larger and more diversified labour markets, and have a tendency to enjoy healthier lives overall. But uncontrolled urbanisation and motorisation pose daunting challenges, threatening to undermine the sustainability of many cities. The term "invaded cities" has been applied to those that have been inundated with motor vehicles to such an extent that pedestrians and public life have almost been squeezed out (Gehl 2003).

According to the World Bank, the growth of global road traffic is unprecedented and the number of motor vehicles per person is increasing at a rate "never seen before in human history" (Shotten 2013). By 2050 the number of light duty motor vehicles worldwide is expected to exceed 2.1 billion, with most of the increase in Asian countries, especially China and India. The growing Indian middle class is moving rapidly from two-wheelers to four-wheelers, purchasing 1.9 million cars in 2014–15, slightly more than the 1.8 million sold the previous year.[1] Many upwardly mobile Indians are following the North American model and aspire to transition from one-car to two-car families.

The urban transport sector—consisting predominantly of passenger travel and a smaller proportion of freight—is heavily skewed in favour of private motorisation at the expense of public transit and non-motorised transport (NMT). The dominance of motorcycles, scooters, three-wheelers and cars has negative impacts on the quality of urban life, consumption of fossil fuels, air pollution, climate change and economic growth and prosperity. Traffic congestion is also a chronic by-product of motorisation in cities worldwide, and is a major factor in slowing the movement of people in urban areas, as well as causing enormous public health problems.

Transport Pollution and Externalities

Motorised road transport imposes a massive burden on population health. Deaths attributable to air pollution, to which motor vehicles are an important contributor, grew by 11% over the last two decades. Pollution from vehicles in 2010 was the cause of 1,84,000 deaths globally, including 91,000 deaths from ischemic heart disease, 59,000 deaths from stroke, and 34,000 deaths from lower respiratory infections, chronic obstructive pulmonary disease, and lung cancer (Global Road Safety Facility, World Bank and Institute for Health Metrics and Evaluation 2014). And recently, air pollution has emerged as one of the leading contributors to stroke burden worldwide, accounting for almost a third of stroke-related disability-adjusted life years (Feigin et al 2016).

Transport also accounts for approximately 22% of global energy use, and both carbon dioxide (CO_2) emissions and transport energy have increased nearly 30% since 2000. The share of oil products in the final energy consumption for transport is 93%, consequently the most significant externalities of urban transport affect the environment and human health. A recent study calculated the value of harms caused by gasoline and diesel fuel subsidies worldwide each year. These external costs include $8 billion from CO_2 emissions, $7 billion from local pollutants, $12 billion from traffic congestion, and $17 billion from accidents. Traffic congestion and accidents are rarely mentioned in policy discussions about fuel subsidies, but there is a growing consensus that these are the largest externalities (social costs) of driving (Davis 2016).

In 2015, it was noted for the first time that the average Indian was exposed to more particulate pollution than the average Chinese, and the WHO has well-documented the adverse effects of PM on health (WHO 2013). The international guidelines on the concentration of fine particulates in the air that are dangerous to public health have been set since 2005. The WHO designates airborne particulates, a Group 1 carcinogen. The PM (inhalable coarse particles with a diameter between 2.5 micrometre and 10 micrometre, designated PM 10 and PM 2.5) is the deadliest form of air pollution due to its ability to penetrate deep into the lungs and blood streams unfiltered, causing permanent DNA mutations, heart attacks, and premature death. A study conducted in 2013 has concluded that there was no safe level of particulates, and that for every increase of 10 μg/m3 (microgram per cubic metre of air) in PM 10, the lung cancer rate rose to 22%. The smaller PM 2.5 is particularly deadly (as it can penetrate deeper into the lungs), with a 36% increase in lung cancer per 10 μg/m3 (Raaschou-Nielsen et al 2013).

The urban air pollution from motorcycles, autorickshaws, cars, trucks, buses and other motor vehicles is understandably found in higher concentrations near major roads. Generally, the more traffic, higher the level of emissions; but congestion and stop-and-go movement can increase emissions of certain pollutants. Two-stroke motors (two- and three-wheelers) and diesel engines have the highest levels of emissions, and congested intersections with many lanes of traffic will be typical "hot spots" for motorised pollution.[2]

NMT and Exposed Populations

Global transport investments are estimated between $1 trillion and $2 trillion per year, yet less than 40% is invested in developing countries, where the vast majority (80%) of the world's population lives, and where NMT is a significant means of mobility in most cities (World Bank 2016). A few countries invest in primary health prevention strategies such as developing active transport networks for walking and biking, and a very limited number of cities are planning public transport systems in a holistic, sustainable manner (UNHSP 2013). In response to congestion, for example, the standard strategy has been to add infrastructures for cars, which only exacerbates greenhouse gas (GHG) emissions, road traffic accidents, noise, air pollution and degraded public health. Some cities are now trying various methods to ration road space and/or limit the number of vehicles entering urban areas, with varying levels of success.

Mirroring the limited transport investment in developing countries is the lack of research on the mobility needs of low income populations who are often dependent on NMT to access employment, education and essential services such as healthcare.[3] In urban India, the combined total modal shares of NMT and public transit are higher than that of motorised—the non-motorised share is approximately 30% in cities with more than one million populations and 60% in smaller cities (Wilbur Smith Associates 2008). This statistic reflects not only economic realities, but a dense, mixed-use urban morphology that enables short trips, and the fact that NMT is a component of public transport—the public transit user is a pedestrian for at least one part of the trip. However, bicycle use throughout India is declining, largely due to inadequate investments in NMT infrastructure, traffic congestion, and accident risk facing cyclists.

Many people who are dependent on NMT have low household incomes, and cannot afford public transport or the cost of a bicycle. They are described as living in transport poverty (UNHSP 2013). Others who can pay the fare choose to avoid public transit because it is uncomfortable or inconvenient (and sometimes unsafe), while still others consider streets dangerous for cycling and take their chances as pedestrians (EPCA 2014). And there are those who cannot drive, such as the young and old, the disabled, the homeless, and the many women who do not own private motorised vehicles.

Pedestrians make up a significant portion of urbanites using the edges of city streets, but they share those spaces with others, and those edges can become very crowded, especially in developing countries. Many sidewalks in India (where they exist) are teeming with food vendors and their regulars, trade and delivery persons, goods and service hawkers, students, business and restaurant patrons, mothers and children, the homeless, and others. And in addition to the itinerant and semi-permanent users of roadsides, are the occupants of near-roadway buildings and spaces within a few hundred metres of the street: homes, offices, bus stops, shops, places of worship, schools, playgrounds, healthcare facilities, markets, and so forth.

Among the millions of people in India travelling on or spending a significant portion of their time in close proximity to a major roadway are those who are more vulnerable to air pollutants than the general population. These "populations of concern" are more susceptible to harm from air pollution due to factors including age, baseline health status, access to healthcare, and socio-economic status (USGCRP 2016). The young, older adults, people with compromised immune systems, and people with heart or lung disease (such as coronary artery disease, congestive heart failure, and asthma) are the most vulnerable to pollution.

Children are at increased risk of pollution-related illness because their lungs are still developing, and because they are more likely to have asthma or acute respiratory diseases that can be aggravated when particulate levels are high. In addition, children tend to spend more time at high activity levels, which even for the healthy, is a risk factor. Exercise and physical activity cause people to breathe faster and more deeply, and to take more pollution particles into their lungs. Numerous studies confirm that ambient traffic-related pollution, with exposure to ambient PM 2.5 and ozone leads to reduced lung capacity has chronic adverse effects on pulmonary function in children (Chen et al 2015; Lee et al 2011; Hwang et al 2015).

The poor can be especially vulnerable if they do not have sufficient resources to deal with adverse health impacts (Awe et al 2015) or if they lack healthcare services within walking distance (Titheridge et al 2014). The poor might also live in lower quality housing and can neither afford to relocate from proximate emission sources or take measures to protect their dwellings from ambient pollution.

It is, therefore, critical to understand urban transportation not only in terms of motorisation as a source of air pollution and other externalities, but also in terms of exposed and vulnerable citizens. The most exposed group includes people who do not drive, those who rely on non-motorised transport, and those who live, work or go to school in close proximity to major roads. The most vulnerable—the populations of concern—include the young, old, those with pre-existing health conditions and the poor.

These populations, along with private and commercial motorists, are the focus of near-roadway research programmes that contribute to the growing body of evidence on how motor vehicle emissions influence air quality, and the relationship between roadway pollution exposure and adverse health effects. The areas of research include identification of impacts, the methods to best monitor them, and protective and mitigation actions to maximise improvements in public health (US EPA, OAR 2016).

Intervention: First Aid

To many observers, transport-related air pollution in Indian cities is an emergency—a serious and often dangerous situation requiring immediate action. Fortunately, there are appropriate and practical public health interventions that, in the short term, can mitigate risk factors and help to control disease in the community. And accepting the standard convention that municipalities are public bodies operating under statute with a clear responsibility for public health, it is assumed that creating and maintaining healthy environments is a priority of local governments. Health issues should drive decision-making.

As urban planning has shifted its attention to sustainability, cities have begun to integrate public health as a core element of comprehensive plans and policies. In a largely retrospective process of connecting the dots, planners have come to recognise how the impacts of land use, urban design and transportation decisions are inextricably linked to many of today's public health concerns such as obesity, respiratory disease and cancer. The goal of public health is to protect the largest number of people by reducing exposure to risk factors, but health disparities must also be identified and tackled. Consequently, planners are increasingly attentive to inequalities, and seek policies and programmes to maximise both health and equity as a high priority.

Planners working in new cities or urban areas could be responsible for such things as determining if a proposed housing site is near environmental risks, including noise and air pollution, drafting policies to minimise exposure to particulate matter for sensitive land uses such as schools, daycare facilities and playgrounds, or ensuring adequate provision for the NMT modes of walking and cycling. Working in existing cities, planners might be tasked to evaluate local sources of pollution, or define and address "reasonably modifiable" environmental risk factors through such measures as modifying transport infrastructure or creating low emission zones.

In all cases of municipal intervention, inter-sectoral cooperation is essential. City planners must increasingly function collaboratively with their colleagues in health, transportation, housing, and development. Often the general public is not aware of their role in air quality and public health, and they must be both informed and engaged. Planners must also bring school administrators, business associations, non-governmental organisations (NGOs) and others into a process of active participation, not simply consultation (Marsal-Llacuna and Segal 2016). Timely, effective communication with decision-makers, stakeholders and citizens is assumed. Finally, the basic parameters of interventions are that they are sustainable and they should improve the quality of city life, urban access, and fairness.

In addition to planners, experts in epidemiology play an important role in protecting the public's health. Epidemiology—a discipline within public health—focuses on patterns and distributions of disease in order to design preventive measures. Epidemiologists who understand a problem and the population in which it occurs are often in a unique position to recommend appropriate interventions. However, in some of the most highly polluted regions of the world, there is a severe lack of direct epidemiological evidence (WHO 2014b).

Epidemiology is concerned with the collective health of the people in a community or population. In its most condensed form, the aim of epidemiology is to decrease disease burden by reducing exposure to a risk factor, and central to this task is public health surveillance, sometimes called "information for action." This is the systematic collection, analysis, and sharing of health data to help guide public health decision-making and action (US DHHS 2012). Data and their interpretation from health surveys and other information sources are then disseminated so that mitigation and prevention measures can be applied effectively.

Intervention: Sequence and Steps

In epidemiological terms, interventions can be directed at controlling or eliminating the "agent at source of transmission" (that is, shift transport mode, adopt electric vehicles, reduce traffic, prevent congestion), protecting "portals of entry" (that is, provide masks, modify buildings), or increasing "host defences" (that is, health advisories, restrict outdoor exercise, close facilities) (US DHHS 2012). All of these are feasible within relatively short time frames, especially when targeted to small geographic areas.

One short-term intervention is the distribution of certified respirators (masks) to the most exposed and vulnerable populations. Certification of masks (that is, US NIOSH or EU FFP rated) indicate that they have been tested and meet benchmark standards to filter out small airborne particles (Delhi Air 2016). A second high-priority intervention is the establishment of an air quality information system that would provide pollution data, and possibly post health advisories, alerting citizens to take precautionary measures, or administrators to close facilities. Access to accurate and timely information can significantly heighten preventive and healthcare-seeking behaviour. Three traffic management interventions that could also be taken quickly and relatively inexpensively are the designation of low emission zones, time restrictions on movement of high-polluting vehicles, and rerouting busy streets.

Later, city officials could begin medium- and long-term interventions like infrastructure projects to improve urban air such as planting trees and other roadside vegetation. And they should begin creating a network of dedicated pedestrian and cycling lanes, based on equity of use and the safety needs of walkers, bicycle riders and public transport users—a recommendation made in 2014 by the Environment Pollution (Prevention and Control) Authority for the National Capital Region (EPCA 2014).

New or ongoing research from a regulatory and public health perspective could include a vastly expanded network of air quality monitoring, as well as intra-urban exposure assessments and health surveys such as the 2008 Delhi study of 36 near-roadway schools in different seasons (CPSB 2008). City officials might also expand studies of health risk factors to include transportation-related noise, or investigate the extent to which differential exposure to air pollution is responsible for health disparities.

Air pollution exposure assessment has evolved from inter-urban to intra-urban studies, resulting in greater accuracy and new information on how differential exposure is driving environmental health disparities. Although the concepts of environmental justice and inequality are understudied in India, it is anticipated that research will find socio-economic disparities in exposure to urban air pollution is having a significant impact on population health (Hajat et al 2015; Cartier 2015).

In any case, municipalities must lead. The first emergency intervention step is to contact and enlist appropriate municipal officials and health authorities that have macro-level or citywide responsibilities in public health. To the extent necessary, the scope and urgency of the crisis will be explained, and the commitment of the appropriate agencies will be secured. An intervention plan will then be drafted, outlining short, medium and long-term activities. The plan will include at a minimum: identification of responsible parties, a prioritised list of interventions, implementation strategies, timelines, benchmarks, and health-oriented metrics to measure and track progress and outcomes.

Exposure Assessment

Mapping locations of high roadway emissions must be done early and quickly. This will be relatively simple for city officials because the busiest roads and most congested intersections in their jurisdiction will already be known. At these locations, subsequent formal exposure assessments can provide much useful data, but under the warrant of a public health crisis, absence of such data should not prevent officials from proceeding with the design and implementation of interventions. In the meantime, traffic counts—hourly, daily and weekly—can be collected by devices or by observation. Observers can also count different vehicle types and the number of people on foot.

As indicated, certain facilities in the vicinity (within 300 metre) of locations with the highest levels of pollution are of particular concern. They include schools, daycare and healthcare facilities, playgrounds and dwellings (including seniors' housing). These facilities must also be plotted and/or geocoded, another task that should not be delayed. It involves trained people using paper and pen, or perhaps technologies such as GPS recorders or smartphones with apps, but special expertise is not required. Buildings and facilities can be located, their use listed, and their occupancy or enrolment recorded. The information is then transmitted to offices of the municipality or health authority, verified and transferred to maps, and used in the planning process.

This project is an opportunity to initiate community-engaged research—collaboration between two or more organisations such as public health authorities, non-governmenal organisations (NGOs), community groups and government agencies. Advocates of community engagement assert that it improves health promotion and health research, and in the present pollution crisis seems well-suited to interventions that involve numerous stakeholders (CTSA Consortium 2011; Nieuwenhuijsen 2016).

An example of community-engaged research on traffic related particle exposure involved 250 students in New York city, who participated in an exercise that monitored and compared diesel particulate exposure levels in two parts of the city and one suburb. The participants also kept symptom diaries. This project produced new data and helped to expand the understanding of the relationships between higher rates of exposures to vehicle-related particles and adverse respiratory symptoms among children living and attending school near heavily-trafficked roadways. The data has helped to produce formal publications, and has offered important evidence to influence policies to reduce acute asthma morbidity (NIH 2015).

Surveying facilities (or counting traffic) could also involve participatory monitoring, whereby research is conducted by amateur or non-professional "citizen scientists." Collecting rudimentary information by scientists is costly, and the internet has increasingly enabled citizens to gather data to be analysed by professionals. Participatory monitoring will also raise local awareness and help build the community expertise needed to address such urgent public health issues as air pollution. Engaged citizens could be invaluable in such areas as communication and outreach, distribution of masks, air quality monitoring and so forth.

Health Surveillance

As emission hotspots are identified and key facilities recorded, formal health surveillance can be started. Locating geographies of vulnerable populations is a fundamental part of health surveillance and disease prevention. Risk factor quantification, particularly for modifiable risk factors, can help to identify emerging threats to population health and opportunities for prevention (Forouzanfar et al 2015).

A health surveillance network, focused on intra- and inter-urban hotspots, should be established. Data on air quality would be regularly collected through standardised monitoring devices, and then linked with the health status of the population living in the catchment areas, where the devices are located. To collect the data on morbidity and mortality, a quarterly survey should be implemented whereby trained interviewers collect information. That epidemiological data of morbidity and mortality could help investigate whether the health status of the population could be attributed to the air quality of that area. Thus, proper cohort studies with health surveillance across different sites in India are the need of the hour.

Such a health surveillance network is conceptually similar to the nationwide health tracking network proposed by the Pew Environmental Health Commission in the United States (US). This proposal was in response to what was deemed an environmental health gap, a lack of basic information that would document links between hazards and disease, and provide communities and public health professionals the critical data needed to reduce and prevent health problems. The comprehensive tracking network would enhance ability of localities to:

- Identify populations at risk and respond to outbreaks, clusters and emerging threats;
- Guide intervention and prevention strategies, including lifestyle improvements;
- Improve the public health basis for policymaking;
- Enable the public's right to know about health and the environment; and
- Track progress towards achieving a healthier city or region (Environmental Health Tracking Project Team 2000).

There is also an urgency to determine the scope of the population at the highest exposure risk because an intervention such as distribution of respirators requires the quantity of supplies to be estimated with reasonable accuracy. (Alternately, stockpiles can be assembled ahead of time in anticipation of need.) Epidemiologists will also document vulnerabilities of exposed populations (co-morbidities, age, or socio-economic status) and their time-activity patterns.

Air Quality Monitoring

Air quality monitoring should also begin in the areas around the identified hotspots, where only rough estimates of pollution levels have been identified. Monitoring air quality more accurately is critical in predicting and documenting health effects, especially in vulnerable populations and ecosystems. Small-area and site-specific monitoring will support better protection of public health and the environment by providing communities with detailed and finer-grained data on pollution and exposure in their neighbourhoods, information that is unaccounted for in metro and regional scale modelling (Borrego et al 2016).

The type of vehicles and fuel used, traffic activity, and wind speed and direction all have significant effects on pollutant levels near major roadways. Urban roads flanked on both sides by high buildings ("street canyons") also give rise to very high air pollution levels, and individual buildings and groupings have a significant impact on local wind flow patterns. Collected data will include types, quantities and times of emissions, and sites can be differentiated based on such local factors as dispersion patterns and load levels at various times of the day, week or season.

Air quality monitoring networks have typically used expensive, stationary equipment that provides accurate data, but only in a few locations. Despite the importance of location to assess environmental outcomes, a global data set of air pollution in cities has been lacking, and data in many countries and at the citizen level are scarce (Brezzi and Sanchez–Serra 2014). However, this is changing with the emergence of lower-cost, easy-to-use, portable air pollution monitors (sensors) that provide high resolution data in near real time (US EPA, ORD 2016; Piedrahita et al 2014; Borrego et al 2015). Lower cost sensors can supplement existing networks and reduce the costs of pollution monitoring for public agencies, and researchers. New sensor devices are continually being introduced and are proving effective, particularly in urban areas that often have high spatial variability of air pollutants (Snyder et al 2013). Recently the United Nations Environment Programme unveiled an affordable national air quality monitoring network based on inexpensive sensors, and is publishing the blueprint for the monitors as a global public good (UNEP 2016).

Air quality monitors tied to advances in computing and communication also make data more readily available, increasingly via internet portals and air quality dashboards.[4] These can serve as both public information interfaces for civilians and visualisation/control systems for air quality experts as well as city officials in support of pollution management and policy development. Web-based dashboards that present public health information based on daily air quality data can also be the sites of advisories and warnings.

Publishing high-resolution maps and data increase public awareness, helping citizens understand the air quality in their local area. Informing citizens with the most accurate and detailed air quality information is essential to building public support for ambitious air quality management programmes. At the same time, targeted source-specific studies along roadways and in the vicinity of congested intersections are critical tools for fast and effective interventions.

As data from exposure assessments, health surveys, and air quality monitoring is collected and analysed, intervention priorities might change. In census terms, there will be a more accurate tally of how many people are affected, especially those in the most vulnerable populations. Differential exposures and potential health disparities can be revealed at a fine-grained, neighbourhood level. This information allows comparison between locations, and can confirm early targeting or reveal unanticipated patterns, all of which supports ongoing planning and decision-making.

As soon as masks are procured and ready for distribution, a campaign of outreach and public health education should be launched, targeting the most exposed and vulnerable populations. The goal is to inform and educate these populations about pollution exposure risk, and ways that individuals can mitigate those risks. But telling people that there is a way to improve their health is not often sufficient to change behaviour.

A successful campaign should tell people that a change in their behaviour will improve their health; demonstrate and model the behaviour; reduce barriers to its adoption; create a system for supporting people who choose to adopt it; provide the materials necessary to begin adoption (that is, masks), and provide a background of support through in-person, print, radio, television, and other approaches (World Bank 2015a). Masks will be distributed free as part of this information/outreach campaign, and individuals will be advised on how to use them and when to replace them.

Concurrently, the city can experiment with methods to reduce traffic on the busiest roads and at the most congested intersections. This is both feasible and cost-effective because the actions are source-specific and intra-urban, not indiscriminate and citywide. Locations of high population exposure plus high emissions are the immediate targets of traffic reduction interventions. Using risk exposure data from the mapping exercise, officials can determine where to create—either provisional or permanent—low emission zones, and where and when to reroute or limit traffic near vulnerable populations and high-risk facilities such as schools, health facilities, daycares and parks.

Behaviour Change

The final and most difficult intervention will be to make the public aware of the role they play in the air quality problem, as well as in its solution. This ambitious, long-term project has two interdependent objectives, the first is to convince Indians to reduce their motorised travel, and the second is to make the case for government intervention. The project will involve local public conversations and national debates about sustainable transport and the quality of city life, set within a framework of urban planning and public health. It will include government, the media, the scientific community, civil society, academia and business.

The intent is to go upstream to the source of most roadway pollution—private motorised vehicles—and create a starting point for social change. The project also hopes to create the political space for policy intervention. Municipal governments are trapped in a cycle of inertia, but low public awareness means they feel little pressure to intervene. Public dialogue will hopefully prepare the ground for the longer-term reforms needed in Indian cities. And while awareness-raising alone will not be sufficient to achieve sustainable transport, it will be necessary for the success of government policies and strategies that are implemented. In a reciprocal manner, well-planned and executed strategies send a powerful signal to citizens that sustainable transport is beneficial and that government takes the issue seriously.

Conclusions

We argue that a proper response to the pollution emergency in India must deal first and foremost with public health risk and what can be done to mitigate it at the individual and population levels. Guided by an explicit framework of prevention and protection, action must include: exposure assessment, health surveillance; air quality monitoring and data mapping of pollution sources and the proximate most vulnerable groups; collecting and reporting daily air quality data; and, disseminating health information such as what effects may be experienced as a result of pollution exposure, and measures citizens can take to reduce their risk. Wearing proper respirators—provided by the city or NGO—is one of those measures.

Using the surveillance data of vulnerable populations, municipal transport planners must then play a complementary role within the preventive and protective health framework. They must apply the mechanisms available to them to immediately address the worst sources of emissions in proximity to the largest clusters of the most vulnerable. Responses include creating temporary or permanent low emission zones as required by monitored levels of daily emissions data. Such actions will be targeted, based on an accurate mapped data, and implemented in collaboration with health officials. The results of municipal actions will be measured, evaluated in terms of health prevention and protection, and communicated to citizens. Surveillance and response will be continuous and flexible as transport patterns change and climatic conditions shift.

We also recommend a public dialogue—still within a preventive and protective health framework—focused on private motorised transport and what individuals can do to reduce urban congestion, pollution and health risk to themselves and others. This dialogue involves government communication, mass and social media, public and private discourse and behaviour change. The broad objective is to "go upstream" to the primary source of urban ambient air pollution, namely, the private auto, and to engage citizens to learn about the interconnectedness of urban access, environmental/climate justice, active transport, and urban livability. The key message is simple: we must drive less. Although a daunting agenda, there are many immediate actions possible for citizens, such as foregoing a second car, carpooling, car sharing, and walking or cycling when possible and safe to do so.

NOTES

1 "Overview of the Indian Auto Industry," 2016, available at: http://www.knowindia.net/auto.html, accessed on 9 May.

2 Studies have shown in excess of a 20-fold increase in particle number concentrations at traffic lights during decelerating, accelerating or idling conditions compared with free flowing traffic conditions (Kumar et al 2015).

3 "Social Inclusion in EU Public Transport," Report prepared by European Parliament, Directorate-General for Internal Policies of the Union, Ludovica Samek Lodovici, Nicoletta Torchio, available at http://dx.publications.europa.eu/10.2861/75342.

4 "AIR-Portal—Air Quality Dashboard for European Cities: ESA's ARTES Applications," 2016, available in https://artes-apps.esa.int/projects/air-portal, accessed on 16 May; "Atmosys—Home" 2016, accessed on 20 May, http://www.atmosys.eu/faces/index.jsp.

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