Air pollution: a global problem needs local fixes

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People perch on a high building to observe the heavy smog that enveloped Zhengzhou, China, in January 2017.

Air pollution: a global problem needs local fixes

Researchers must find the particles that are most dangerous to health in each place so policies can reduce levels of those pollutants first, urge **Xiangdong Li** and colleagues.

Each year, more than 4 million people die early because of outdoor air pollution, according to the World Health Organization (WHO). The main culprits are fine particles with diameters of 2.5 micrometres or less ($PM_{2.5}$). These can penetrate deep into the lungs, heart and bloodstream, where they cause diseases and cancers.

But global average estimates such as this assume that these particles are the same the world over. They are not: $PM_{2.5}$ is a cocktail of chemicals (hydrocarbons, salts and other compounds given off by vehicles, cooking stoves and industry) and other, natural components such as dust and microorganisms. The mix — and its toxicity — varies from place to place and over time, in ways that are not tracked, understood or managed.

For example, in Asia, soot from residential heating and cooking is the biggest source of $PM_{2.5}$ (ref. 1). In European countries, Russia, Turkey, South Korea, Japan and the eastern United States, agricultural emissions such as ammonia are the leading source. Desert ▶

dust boosts air pollution in northern Africa, the Middle East and central Asia. It is not clear which source is the most dangerous.

Levels of $PM_{2.5}$ alone give only a rough guide to the toxicity of air pollutants in a particular place[2]. Reducing $PM_{2.5}$ by the same amount in different places will not deliver the same health benefits everywhere. To protect millions more lives, scientists need to help governments and municipalities to determine the most hazardous constituents of air pollution and mitigate them first. Researchers and policymakers need to rethink methods for assessing health risks and regulatory measures for reducing those risks.

UNEQUAL TOXICITIES

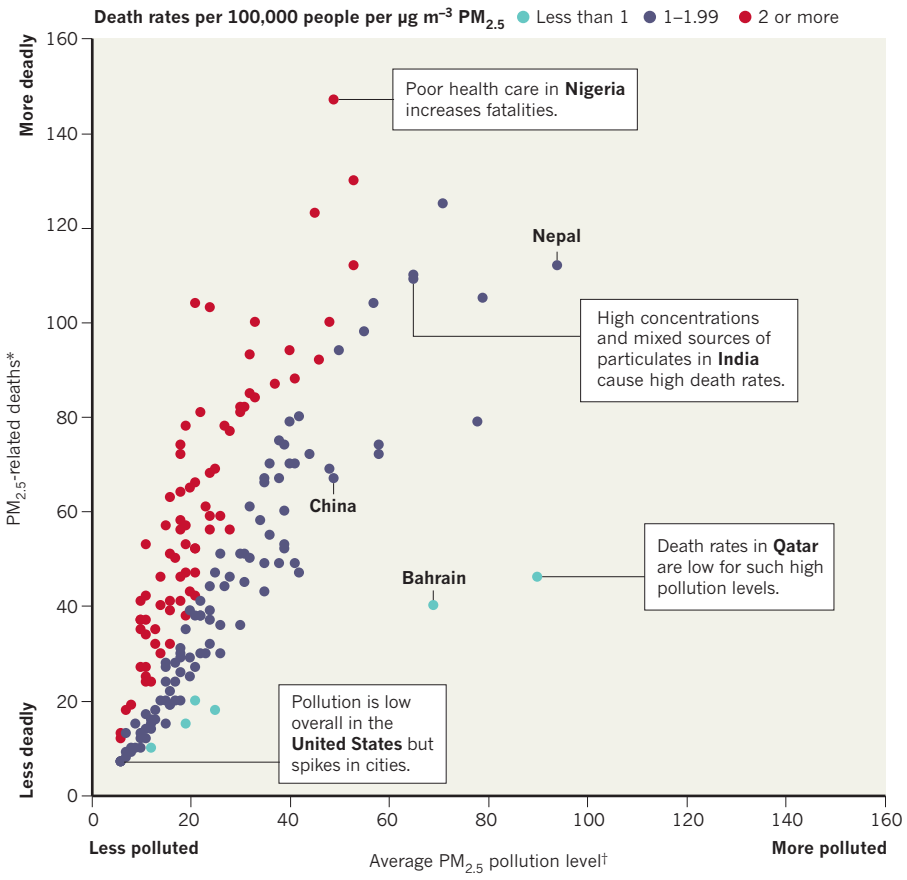
Evidence is mounting of geographical differences in health responses to air pollution (see 'Deadly combinations'). For example, although the associated death tolls are high in China and India — industrializing cities are heavily polluted and lots of people live there — the relative risks to city dwellers in Europe and the United States are greater. Europeans and North Americans are more likely to die from heart disease and from acute respiratory attacks than are people in China, when exposed to similar levels of $PM_{2.5}$ (ref. 3).

Risks from dirty air vary between cities. Londoners and New Yorkers are at greater risk of dying when smog concentrations surge than are inhabitants of Beijing[3]. Each milligram of $PM_{2.5}$ in dirty air in Milan is more likely to generate reactive species of oxygen (free radicals) that stress the body than it is in Lahore or Los Angeles[4]. Residents of cities in eastern China, such as Shanghai, Hangzhou and Nanjing, have a higher death risk per unit increase of $PM_{2.5}$ concentration (despite medium to lower concentrations of total $PM_{2.5}$) than do residents in cities elsewhere in the country (ref. 3). To put it another way, each milligram of $PM_{2.5}$ in these eastern cities is more toxic than it is in the rest of China. And Beijing's winter smog is more deadly than that in Guangzhou — a similarly sized city located much farther south[5].

Cell and animal studies back up these findings (it is unethical to test the toxicity of air pollutants directly on humans). For example, the lungs of mice that had been exposed for 24 hours to $PM_{2.5}$ from California[6] were more inflamed than those of mice exposed to similar concentrations of $PM_{2.5}$ in air from China. The difference could reflect higher levels of organic carbon and copper in Californian traffic fumes, although it is hard to translate findings from animal models to humans.

DEADLY COMBINATIONS

The health impacts of fine particulates ($PM_{2.5}$) in air pollution differ between countries. Toxicity depends on the blend of particles as well as mixing, weather, atmospheric chemistry and pathogens.



*Age-standardized annual deaths per 100,000 people, attributable to outdoor $PM_{2.5}$ exposure. †Population-weighted annual median concentration of $PM_{2.5}$ (μg per m^3).

SOURCE: WHO (HTTPS://GO.NATURE.COM/2WTQPUJ)

Mixtures of air pollutants might also be more harmful than their constituents in isolation. For example, the combined effects of outdoor and indoor air pollution and tobacco smoke could be responsible for 2–3 times the number of premature deaths globally than the WHO currently estimates[2].

Few studies of the health impacts of air pollution consider these variations. Most simply look at masses of $PM_{2.5}$ particles and assume a single recipe. For example, the Global Burden of Disease project captures health risks in one 'exposure-response' function, which the WHO also uses[7]. This derives the likelihood of someone who has inhaled a certain mass of $PM_{2.5}$ dying later from a related disease. It is based on hundreds of epidemiological studies, mostly done in Europe and the United States.

"Researchers should rank sources of $PM_{2.5}$ by how harmful they are."

But we know little about how real smog affects health. Some substances are known to be harmful when inhaled. For example, transition metals, including iron and copper, produce oxygen free radicals. Links between prenatal exposure to free radicals in $PM_{2.5}$ and low birth weight have been reported across 31 cities in Ontario, Canada[8]. By contrast, sulfates, nitrates and ammonium are much more common in smog but are less harmful than metals.

Some dangerous pollutants remain to be discovered. For example, toxic metals and polycyclic aromatic hydrocarbons accounted for less than 40% of the overall potential of $PM_{2.5}$ to generate oxygen free radicals in Beijing and Guangzhou in January 2014 (ref. 5).What explains the rest?

Possibilities include secondary organic aerosols. These are derived from photochemical reactions of organic compounds such as isoprene (which is produced by plants and animals, and is found in natural rubber). Other 'humic' organics are released from soil and coal. Plasticizers such as bisphenols and phthalates affect the endocrine system[9]. But the toxicities of all of these substances in air breathed by humans remain to be assessed.

Biological components such as bacteria and fungi are rarely considered in health studies. These can be toxic in themselves or can interact with other chemicals to affect health[10]. Pathogens and allergens need to be evaluated. Floating in Beijing's winter smog, for example, is a common bacterium that can cause pneumonia (*Streptococcus pneumoniae*) and a fungal allergen (*Aspergillus fumigatus*) that can invade the airways of people with immune deficiencies[11]. Compounds in the cell walls of bacteria (endotoxins) can induce inflammation, and other products of fungi (mycotoxins) can lead to respiratory conditions and infections.

The list is long. But the most important

DMITRY FEOKTISTOV/TASS/GETTY

Stoves that burn wood create soot, which is a major source of outdoor air pollution.

question is: which pollutants are the most dangerous in a given location and most crucial to mitigate urgently?

NEXT STEPS

First, the focus of air-pollution studies should shift to measuring health effects, not just emissions and atmospheric chemistry[12]. This must involve specialists from fields as diverse as molecular biology, toxicology, health sciences and economics. Researchers should rank sources of $PM_{2.5}$ by how harmful they are, and examine the toxicity of samples of real air.

Next, that knowledge must be translated into local measures to control the most hazardous types of pollution. For example, efforts to reduce emissions from residential energy might be the best way to reduce premature deaths from air pollution in China and India; in that regard, northern China's 2018 shift from using coal for wintertime heating to using natural gas needs to be evaluated. Similarly, clean fuel and energy-efficiency measures might be prioritized in the United States. And inorganic emissions from agriculture should be addressed in rural areas.

To achieve this, WHO data should be used to identify hotspot countries — those where particular health concerns are arising from $PM_{2.5}$ pollution (see 'Deadly combinations'). Niger, India, Egypt and Nepal should be included because they have high levels of particulates and high death rates. $PM_{2.5}$ in Nigeria, Chad, Yemen, Sierra Leone and Cote D'Ivoire might be targeted as being particularly hazardous because of these countries' relatively high baseline death rates, which can be further exacerbated by medium to low concentrations of $PM_{2.5}$.

The WHO, the United Nations Environment Programme and the World Bank should fund a network of flagship stations to monitor the chemistry of air at key locations, starting with these hotspots and expanding to others. *In situ* cell and animal studies should also be conducted across cities. Methodologies will need to be standardized for studies of cells, animals and humans. For cell-based assays, the toxicities of $PM_{2.5}$ mixtures could be quantified relative to the impacts of other chemicals, as is done in water-quality assessments, for example[5].

Data from different locations and seasons should be openly shared and synthesized in a global database of toxicity, similar to the WHO data on global mortality related to air pollution (see go.nature.com/2fiq3tr). A toxicity database could also collect personalized air-quality data, for example from wearable sensors, and determine links between individual exposure to pollutants and health conditions.

More data should be collected on people's behaviours and perceptions, to find out how human activity determines exposure to air pollution[13]. For example, such data could be translated into personalized air-quality and health-management alerts and recommendations. Smart travel warnings could be produced for sensitive individuals to help them to avoid hazardous exposures, such as when traffic emissions are high or weather conditions are likely to form haze.

Upcoming sessions on air pollution at the International Society of Environmental Epidemiology's August conference, the December meeting of the American Geophysical Union and other international scientific events should pave the way for the research collaborations that are needed. ■

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