

THE STEEP COST OF DUST

Understanding Air Pollution and Its Economics

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Many years ago, I spent several hours in a basement kitchen in a friend's house in a Himalayan village. Although there was an outlet for smoke, it was nevertheless very smoky in the kitchen and it took some time for my watering eyes and coughing lungs to partially adjust to it. It was only much later that I learnt that prolonged exposure to the smoke from such a wood fire is more than just a nuisance. It raises the chance of getting, and dying of, many deadly diseases.

Health Impacts

The process of burning, whether it's wood in a cooking fire, coal in a power plant, or diesel in a car, produces several gaseous pollutants, as well as small unburnt particles, called soot. These particles drift through the air before settling in a few days or weeks, sometimes in our lungs. Of the particles released, the most damaging are those that are small enough to escape filtration by the cilia (hair and other fibres) in the nose and throat and get lodged in the lungs. The particles provide surfaces that various toxic chemicals adhere to. The finest particles are small enough to enter the bloodstream through the lungs and are carried to other parts of the body.

The coarser particles irritate our eyes, nose, and throat, leading to coughs and aggravating colds and sinus problems. Finer particles, those less than 2.5 microns in diameter, called PM2.5, penetrate our lungs. There, they trigger an immune reaction from the body that causes an inflammation. People who already have lung infections, like pneumonia or other diseases like asthma, find their problems exacerbated when air pollution is high.

The short-term acute effects of air pollution show up in increased hospital visits and a swell in the number of deaths resulting from heart and respiratory diseases on polluted days. The long-term effects show up in decreased lung function in children and adults, and in increased mortality from heart attacks, strokes, respiratory diseases, and lung cancer.

The now large body of evidence from scientific studies showing the deadly nature of air pollution has prompted the World Health Organisation to set an air-quality guideline that the annual average concentration of PM2.5 in the air should not exceed $10 \mu\text{g}/\text{m}^3$. Unfortunately, since India has some of the highest levels of air pollution in the world, 99.9 per cent of the population lives in areas that exceed this limit averaging an exposure of $74 \mu\text{g}/\text{m}^3$ in 2015. The average exposures in the Indo-Gangetic plains exceed $100 \mu\text{g}/\text{m}^3$.

These high exposures have been deadly. The cumulative death toll due to particulate pollution was estimated to be 1.1 million in 2015, or more than 10 per cent of all deaths in the country. Children and the elderly are the most vulnerable to lung infections such as pneumonia. Decreased lung capacity due to air pollution makes them more likely to die from the infection. Older people are also more likely to suffer from so-called chronic obstructive pulmonary disease (COPD), which makes breathing a difficult exercise and air pollution increases the risk of mortality from such diseases.

Other Impacts

There are also regional climatic effects of air pollution, and adverse effects on crop productivity. In the last few years, research in climate science has established that air pollution from these different kinds of combustion results in the formation of aerosols, a complex chemical mixture of solid and liquid particles suspended in the air. Aerosols include carbon particles emitted during combustion (visible smoke), as well as particles formed in the atmosphere from the chemical reactions of gaseous pollutants such as sulphur dioxide, nitrogen oxides, and volatile organic compounds.

Aerosols remain in the atmosphere for a period of days to weeks, being continually replaced by new combustion. Between one monsoon and the next, these aerosols form a three-kilometre deep orange-brown-grey haze that extends for thousands of kilometres over South Asia and the northern Indian Ocean. Anyone who has taken a flight over India will have seen it as the ascending aircraft clears the top of the brown cloud: a perfectly-flat grey-brown haze stretching to the horizon in every direction through which the ground is faintly visible, the bright-blue sky above providing a brilliant contrast.

What are the effects of this haze? First, and most obviously, it reduces sunlight reaching the ground. The bitter cold wave that hit northern India in January 2004 was a direct consequence of the haze. Solar radiation reaching the surface was dramatically reduced and over 800 people who were too poor to afford proper shelter and warmth died. Trains and flights were cancelled and road travel became slow and hazardous. This has now become a routine occurrence every winter. The haze sometimes results in the formation of fog or smog as moisture condenses on the particulate matter in the air. These winter fogs result in travel delays and road and rail accidents. The economic costs of this are hard to quantify.

The reduction in solar radiation lowers the yield of crops such as wheat. In a study with Ridhima Gupta of Indian Institute of Science Education and Research, Bhopal and Sagnik Dey of Indian Institute of Technology (IIT)-Delhi, we found that wheat yields have been depressed by about five per cent as a result of aerosol pollution.

The aerosol haze affects the climate. Many climate models have suggested that the haze weakens the monsoon, although this is still a subject of some scientific debate. The resulting rainfall deficit has been estimated to reduce rice production and yields by about five per cent. Even larger effects on crop yields due to ozone pollution have been suggested. Ozone is a reactive oxygen molecule formed by chemical reactions involving nitrogen oxides and volatile organic compounds created during combustion. It is also bad for our health when we encounter it at ground level, (although when naturally occurring high up in the stratosphere, it helps protect us from ultra-violet radiation).

While health damages obviously affect the economy by reducing the productivity of workers who fall sick or die, there are other direct economic damages whose magnitudes are hard to estimate. For example, there can be little doubt that the noxious air pollution has reduced foreign tourism in India. Even harder to quantify is air pollution's undoubted role in deterring highly-skilled personnel from returning to work in the country after they have acquired education and experience abroad.

Sources

What are the main sources of air pollution in India? The answer, at a country-wide scale, comes from a large inter-disciplinary study (Global Burden of Disease from Major Air Pollution Sources or GBD-MAPS) whose results were released in January this year. The largest contributor to exposure to PM_{2.5} is residential biomass burning, that is, fires for cooking and heating. It was estimated to account for more than a quarter of a million deaths in 2015. The second-biggest source is the burning of coal – in power plants (that account for about two-thirds of coal consumption in India), and in other industries. Coal burning accounted for over 200,000 deaths, roughly evenly split between power plants and other industries. Open burning (of crop residues and forests), human-caused dust, brick production, transport and non-transport diesel account for most of the remaining deaths. One peculiar feature of the GBD-MAPS study is the way it reports human-caused ‘anthropogenic’ dust. It is reported to cause about 100,000 deaths. However, in an email exchange with Chandra Venkataraman, Professor of Chemical Engineering and Climate Studies at IIT-Mumbai, who is one of the leaders of the study, I learnt that about 30 per cent of the dust is really fly ash from power plants.

Perhaps some similar percentage is fly ash from other sources of coal burning. I mention this because there are several news reports and other studies which find that a high proportion of particulate matter in several cities is dust. It is generally assumed that this dust is from construction and other activities that have nothing to do with combustion. But this assumption is false. The figure I gave for the deaths from coal accounts for the fact that some of the dust comes from coal-burning. Another caveat that must be mentioned is that this study, because of its spatial resolution of 50 km by 50 km, may understate the impact of transport emissions, especially in cities, and thus over-estimate the shares of other sources. It also does not account for small open fires, for example, the burning of rubbish. Some of what is attributed to cooking and heating fires may be coming from this source.

People often think of air pollution as being very local in nature. It isn't. Particles and gases diffuse in the atmosphere. When someone cooks on a wood fire in his or her kitchen, the smoke leaves the house and mingles with that emanating from all the other cooking fires. Every day, the sun warms the ground and causes air to rise. At high altitudes, winds are strong and pollutants rising with air can travel hundreds of kilometres in a single day. Pollution is usually worse in winter since there is less convection as days are shorter and colder. Weakened convection keeps pollution trapped near the ground. In winter, the entire Indo-Gangetic plain between the Himalayas and the Deccan plateau is one big bowl in which the pollution sloshes around. It drifts down the Bay of Bengal across the equator before finally disappearing in the southern Indian Ocean gradually. People living in Delhi who think that if the pollution sources in their city are checked, their problems will be over, are living with false hopes. Pollution has to be tackled on a national scale, although, as we will see, that includes action at the local level.

Residential Emissions

Pollution from residential cooking with solid fuels like wood, crop residues, and dung can be eliminated by switching to cooking with electricity or gas. The transition to gas has already occurred in urban areas to a large extent, supplemented by the use of electric induction stoves in recent years. In rural areas, most households still use solid fuels. The *Pradhan Mantri Ujjwala Yojana* aims to change this by providing a gas connection, stove, and an initial free cylinder to all BPL (below poverty line) households. The scheme is targeted to reach five crore households by March 2019. However, news reports suggest that while the scheme has resulted in some moving away from solid fuels, most of the households continue to use solid fuels and many are not regularly buying gas cylinders at all.

The barrier is cost. Households have to still pay the full market price of a cylinder (well over ₹700) as long as they have not paid off the loan of the first free cylinder. Once they have done so, they can avail the subsidised rate of ₹480. However, in rural areas, it will usually cost something more to fetch the cylinder from the nearest dealer. In any case, if a household cooks mainly or exclusively with gas, it will end up

incurring a monthly expenditure of ₹500/month. More importantly, it will get to that stage only after a year or more of buying cylinders at the unsubsidised price. Most households will never get to that stage. It will be too costly for them.

The other clean option is to use an electric induction stove. This has become a popular option in urban areas in the last few years, since it is cheaper than gas. Induction stoves are being used in rural areas as well, especially in the more affluent states with reliable electricity like Kerala and Himachal Pradesh. They are being purchased even in poor states like Uttar Pradesh, so far still in small numbers. The latest models targeted at the rural market have a maximum power of 1200 watts and sell for under ₹1500. This is affordable even for poor households, so we can expect them to spread. In rural UP, households often pay a flat monthly charge for electricity regardless of how much they use. Thus, using an induction stove is effectively free. Such buyers use the stoves for cooking their main meals (although they typically also do some cooking with solid fuels). This reduces pollution dramatically.

My colleagues and I (we are embarking on a study of induction stoves and air pollution in eastern UP), noticed that in villages where households had their electricity metered, paying rupees three per unit for it, induction stoves were being used only for quick tasks like making tea. Households continued to cook most of their meals with solid fuels.

In order to reduce this source of pollution, electricity should be provided free of charge to poor households up to a reasonable limit. Hundred units per household per month would be sufficient to meet all basic needs for lighting, cooking, a fan, and TV. The average cost of supplying electricity to households is about rupees five per unit. Since around 20 crore households would need to be subsidised for complete coverage of all-but-affluent rural households, this works out to a cost of ₹1.2 lakh crore. Note that since the cooking needs alone can be met for about ₹400 per month, this is a cheaper option than a 100 per cent subsidy to gas, a cylinder of which costs over ₹700 per month.

Of course, the other problem with cooking with electricity is its lack of reliability. The fundamental cause of this is political pressure on the state electricity regulatory commissions to subsidise the price for farmers and residential users. As a result, distribution companies (discoms) prefer to black out households rather than supply them at a loss. This is why the subsidy of ₹1.2 lakh crore that I have proposed above should be paid by the government directly to the discoms so that the latter have no incentive to black out rural households.

Such a policy would solve the problem of the cost barrier, and also, to a large extent, of reliability. This would be enough to eliminate a large part of the pollution from residential sources. In the colder parts of the country, there would still be a problem in winter, as people would need fires for heating. In principle, here too, a larger winter quota of free electricity for heating could help. But the cost would be much higher. Where is the money for the subsidy to come from? Let us turn to pollution from the power sector.

Coal is a Big Culprit

The central government presently imposes a cess on coal of ₹400/tonne. This is a significant amount since the price varies from about ₹1000 to ₹3000/tonne, depending on transport costs and other factors. However, in a study by Dr. Shoibal Chakravarty of the Ashoka Trust for Research in Ecology and Environment (ATREE), the author finds that the economic cost imposed on third parties by coal-fired power plants is more than five times the cess. There is, therefore, a strong case for raising the coal cess. While a large raise would create disruption, a modest increase of ₹150/tonne would raise about ₹1.2 lakh crore, enough to finance the subsidy above. Of course, the money presently being raised from the coal cess could be used too, but it has recently been earmarked for compensation to states for revenue shortfalls due to Goods and Service Tax (GST).

As we saw above, coal burning is responsible for the second-largest share of deaths from air pollution. Two-thirds of Indian coal consumption is by power plants. While Indian power plants are required to have electrostatic precipitators to remove unburnt particles from the exhaust that go up the chimneys, they are not yet required to remove sulphur dioxide (SO₂) and nitrogen oxides (No_x). These gases react in the atmosphere to form sulphate and nitrate particles, resulting in elevated mortality mentioned above.

The Central Pollution Control Board (CPCB) issued regulations to control these pollutants in December 2015, to be implemented by December 2017. However, the implementation was not carried out and the Ministry of Environment, Forests, and Climate Change, now says it will be done by 2022. India has come late to the party, when it comes to the regulation of these gaseous pollutants. A recent study found that between 2005 and 2016, China's coal consumption increased by 50 per cent but SO₂ emissions fell by 75 per cent due to the implementation of regulations.

One fact that raises a question mark over whether the regulations will be successfully implemented is the limited capacity of the central and state pollution control boards. The US Environmental Protection Agency has about 18,000 employees, many of whom are highly qualified scientists, engineers, and public health professionals. The CPCB in India has only a few hundred employees, and the number of scientific staff is smaller still. Implementing a whole new set of regulations on a few hundred power plants will take a lot of new equipment and qualified and trained staff.

Financing a large increase in the monitoring capacity of central and state PCBs would cost only a few hundred crores. This would be a good use of a small fraction of additional revenues from the coal cess. Another opportunity that the coal cess offers is to induce the power plants and other coal burners to implement pollution controls in return for rebates on the cess. These rebates could be in proportion to the pollution reduction from implementation. Monitoring this will, of course, be crucial, so capacity improvement in the pollution control boards is of the highest importance.

Power demand in India is growing at about five to six per cent per year. At the moment, owing to a boom in coal power plant construction between 2005 and 2015, there is excess capacity in the system. In addition, renewable electricity from pollution-free solar PV (Photovoltaic) and wind energy has been growing rapidly and, owing to the government policy of procurement by auction, has become very cheap. Electricity generated from these sources will, by the end of the coming year, be sold to discoms at just ₹2.50/KWh. Coal-fired electricity, meanwhile, costs anywhere from ₹1.50 to ₹8.50/KWh. As a result, in 2017, for the first time, more renewable capacity was added than coal capacity. Since electricity from new coal plants is the most expensive, (as such plants have to pay off their capital costs), it is now clear that no new coal plants will be built for the next several years.

However, electricity from older plants is cheaper and discoms already have contracts with existing coal plants. Therefore, as electricity demand increases with economic growth, discoms may continue to buy power from them rather than from cleaner new renewables. This will increase and prolong our pollution problem. An increase in the coal cess will help to move discoms power purchases away from coal and towards non-polluting renewables.

The Central Electricity Authority projects that after about 2026, India's peak power demand will have caught up with our capacity, and new coal plants will then be needed to meet it. Solar PV and wind are variable sources of electricity and cannot be relied upon to be available to meet demand peaks. However, the last few months have seen sharp price declines in the western United States for solar PV and wind electricity with battery storage. Battery storage increases the ability of these renewables to meet peak demand. Moreover, a new source of renewable electricity that can be stored overnight is now also seeing rapid cost declines like solar PV and wind before it. This is Concentrated Solar Power with storage. Contracts have been signed in Australia and Dubai for electricity with overnight storage to be commissioned in 2020 and 2022 for the equivalent of less than ₹5/KWh. While direct solar irradiance here is not quite as high as in those countries, it is almost as good in Rajasthan and parts of central India. Thus, it is to be expected that such prices can be achieved in India as well by the time new capacity is needed. A programme to procure CSP with storage by auction is needed. This will drive down its cost in India, just like the solar PV procurement programme did for that technology.

We will then be free of the need for polluting the environment by using coal for our electricity generation. This is important, even if we succeed in implementing controls on SO₂ and NO_x. The US has had these controls for decades. Yet, a study published in 2011 found that the external costs of the pollution from coal-fired power in the US exceeded the value of the electricity produced by those plants. The residual pollution emitted even after the installation of flue-gas desulfurisation and other pollution-control technologies is still great enough to do enormous damage.

Coal is also consumed by various industries, including brick kilns. An increase in the coal cess, by raising the cost of fuel, will encourage all such industries to move towards more energy-efficient technologies that burn less coal, and thus, produce less pollution. The same kind of pollution rebates offered to coal power plants could also be offered to other industries.

Environmental Cost of Transport

Diesel consumption in India is several times as high as petrol. This is partly owing to diesel being more suitable for long-distance trucks that carry freight. However, it is also because for many decades, we followed a deliberate policy of keeping the diesel price lower than that of petrol. It was also believed that petrol was the rich man's fuel, used in private cars, while diesel helped to carry goods used by the poor. Unfortunately, diesel is many times more polluting than petrol. Diesel engines produce much more fine particles, SO₂, and NO_x, than petrol engines. After economic liberalisation in the 1990s, as restrictions on private car manufacture were removed, the number of private cars exploded. Since diesel was artificially kept cheaper than petrol, (by taxing petrol more), manufacturers started selling private cars and SUVs with diesel engines. This has resulted in huge pollution from the transport sector in cities and on highways.

A lack of public awareness about air pollution and successful lobbying from the auto and oil industries also resulted in the postponement of regulations on new car engines and fuel quality. Only recently, the government has accelerated the timetable for India to match up to European pollution standards. We will reach Euro 6 standards for new cars in 2020, many years after Europe. A very simple fix for the problem is to reverse the tax penalty on petrol. The petrol tax should be lowered and the diesel tax raised until the price differential is reversed. This will immediately stop manufacturers from selling more diesel cars. This will cause a gradual decline in pollution on the roads. A more immediate effect could be obtained by identifying the most polluting vehicles, and removing them from the road. Since a small percentage of the most polluting vehicles tend to account for a significant share of the total vehicular pollution, this can have a great impact quickly.

Finally, no policy to curb transport pollution can ignore the fact that a poor public-transport system, combined with a high population density, and increasing affluence, has resulted in the explosion of new cars on roads across the country. So even if our policies to make each vehicle less polluting work, this will be offset by the growth in the number of vehicles. The nightmarish state of traffic on our roads, that has forced cyclists and pedestrians off the streets, is a huge environmental problem in itself, quite apart from the air pollution it generates.

So, What Are the Long-Term Solutions?

There is really only one solution to this problem. It is to make road use expensive. As long as road use is free, any improvement in congestion brought about by new roads or flyovers will only induce more vehicles onto temporarily less-crowded roads. Higher diesel and petrol taxes will accomplish this, and are probably needed. But by themselves they are not enough, because they apply equally on less and more crowded roads, and at less and more crowded times. To reduce congestion, we need to be able to price the more-crowded roads and times higher than the less crowded roads and times. A congestion pricing scheme can do exactly that. Such schemes have been implemented in Singapore, Stockholm, and London. However, they use obsolete and expensive technologies. Nowadays, every logistics company from Uber and Ola to your local trucking company, uses GPS and the mobile network to track its fleet. The government can do the same by requiring every car to have the technology. It will then know where every vehicle is, and the vehicles can be charged according to place, time of day, and vehicle size.

The congestion charges will have to be sizeable to have the desired effect. They will, therefore, generate huge revenue that can be used to massively upgrade the public transport systems and pavements. Buses and metro services are of little use if one has to risk one's life walking on the streets to avail them. Revenue from the charge can also be used to compensate particularly-vulnerable groups like auto drivers who will lose their livelihoods.

How will this happen?

As noted above, there are other sources of pollution. But I would like to close with some more fundamental reflections. First, a reader who has got this far will have noticed that I have not said anything about individual actions to reduce pollution. The reason is that such actions don't work in the long run. If I drive my car less because I am a good citizen and want to reduce pollution, someone else will occupy that bit of slightly-less crowded road space. Pollution problems are fundamentally social issues and require collective action. It doesn't have to be by a government. Rather, it can be by civil society groups. However, such actions work for problems at very local scales, whereas air pollution issues mostly operate at large spatial scales. This isn't entirely true, of course. There are things we can do in our neighborhoods to reduce air pollution – such as stopping the burning of rubbish. But these actions are quite limited in their scope.

Nonetheless, there is an enormously important role for the citizen. It is to participate in political life, to demand that our elected representatives tackle these problems in serious ways rather than posing for photo-ops and indulging in gimmickry and campaigns. It means talking to one's fellow citizens so that they develop a better understanding and also make the same demands. It means engaging with the media to advocate for good policies and to point out hypocrisies and fallacies that are all too prevalent.

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