What is spoiling our air?

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I took my first flight in 1976. It was a Mumbai-Delhi flight by the national carrier of that time. Life was relatively simple those days. You could request a 'Non-smoking window seat' and get it without having to pay extra. So, in my very first flight, I got a window seat. Fortunately, it was a day time flight. I got a seat that was not on a wing, and had a clear view of Central India for much of the flight. I could identify various rivers from a height of over 30,000 ft. In addition, the pilot made announcements about the part of the country we were flying over, and monuments that could be seen on the right or left. The visibility of the area below was extraordinary.

Sadly, in recent years, I have not been able to see much except for one or two days in a year.

In those days, while coming downhill from Powai towards Kanjurmarg, one could easily spot the Malang hill near Kalyan, right in front at a distance of about 50-km as the crow flies. The same hill could also be seen from the Mumbra Bypass Road till 2007.

In 1985, I changed jobs and relocated to Badlapur, a village near Kalyan. The job came with a company-provided car that I enjoyed driving on empty roads. To keep me company, I used to pick up any colleague living in Badlapur. Being a village, with very little road traffic and hardly any industrial development, the air quality was really good. We could see the hills in the surroundings quite clearly.

In December 1987, there was a sudden change in air quality. The atmosphere was dusky and distant visibility was lost. The newspapers described it as a "phenomenon." My colleague brought this to my notice. "Yes", I said, "This phenomenon is called air pollution."

Year after year, the air quality

continued to deteriorate with gaseous effluents from industries, sulphur oxides & carbon oxides from diesel vehicles, particulate matter from rapid construction of concrete jungles, and fires from municipal dumps.

Even now, I like to take a window seat in daytime flights. Soon after the rainy season, for a few days of October, the air is indeed clean. But for the rest of the time, there is no visibility of the earth below.

Causes of pollution

The causes for air pollution are not easy to determine. The Central/State Pollution Control Boards, Governments, and Transport Departments in cities have implemented several measures in a bid to improve air quality. The Ministry of Petroleum, Government of India, mandated unleaded gasoline and ultra-low sulphur diesel, which has helped reduce automobile pollution. Catalytic converters and mandates to reduce NOx in diesel vehicles by passing the exhaust through urea solution have also helped.

As is well reported, the situation in Delhi is particularly dire. Heavy fog for as many as three months of the year

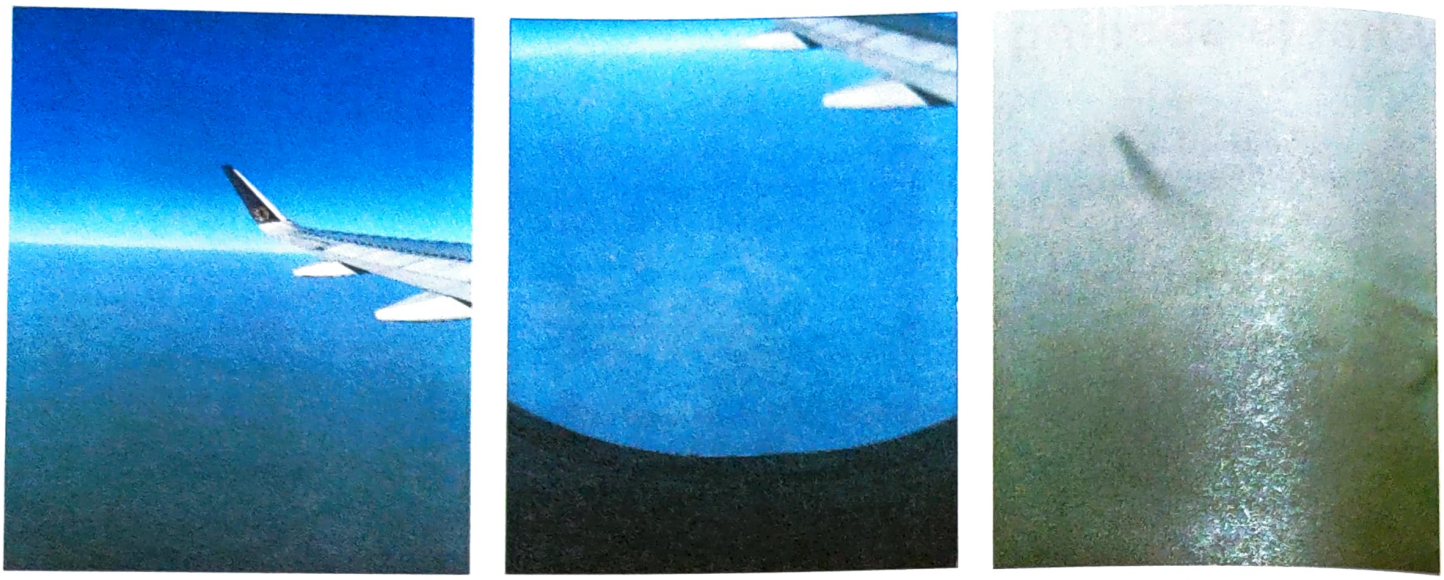

Fig. 1: (L to R) View from an airplane window – After take-off from Mumbai; 200 km from Delhi (some visibility); and just before landing at Delhi

leads to disruption of flights, several road & train accidents, and untold misery from health-related issues, particularly amongst the old and ailing. Haze in the air reduces solar radiation to solar panels, and leads to stunted growth of crops. It is estimated that life expectancy of Delhi's residents has reduced by as much as 8-10 years due to repeated throat and lung problems.

But the air pollution problem is not limited to Delhi; it is all-pervasive. While the air looks dirty when one looks below from a height of 30,000 ft or thereabouts, above this level, the sky is blue and the air clean. The intensity of the sun is so high that most occupants in a plane are often forced to pull down window flaps.

What is causing the problem?

Here are some observations that may be of help to any researcher who wants to investigate the reasons of poor air quality.

One will need to collect samples of the particulate matter suspended in air. This would have to be done by filtering a large, measured quantity of air through a micron filter. The size of the opening may have to be below one micron. The sampling may have to be done long enough to capture all types of particles present. The air may also be scrubbed with a solvent to capture particles covered in organics. The particles so collected may be subjected to analysis using techniques like LC and GC-MS to identify the compounds present. This study may have to be extended to various heights and different parts of the year in different locations. The inorganics can be analysed by microscopy down to nanometer level using techniques like XRF, XRD and EDX. This information could be useful in pinpointing the sources of pollution and recommend remedial measures.

Following activities are primary suspects: Construction, stone quarrying, stone crushing, burning of agro wastes, burning of municipal wastes, faulty automobiles, industrial gaseous effluents, forest fires, activities of recyclers (extracting metals from electrical wires, rubber tires, etc.), road construction, sports activities in dusty sports grounds, and dusty roads.

We saw significant improvement in air quality during the pandemic when clear blue skies, clean air, abundant light, and scorching sun, not seen for many years, were noticed by one and all. This primarily happened due to lower all-round activity. The poor air quality came back as soon as activities resumed.

Some solutions

In the past, when plenty of water was available, city roads were washed every evening to remove dust. As a result, vehicles spewing smoke and raising the dust off the roads spread less pollution. Fresh water is no longer available aplenty, but we do have a source of water not used at all, i.e., used water. The first step would be segregation of effluents. As sewage cannot be easily purified, it will be very risky to use sewage for spreading on roads and trees. However, kitchen waste and bathroom waste can be segregated and treated to lower BOD/COD and then ozonated or chlorinated to disinfect it. This purified water could be used for washing streets, controlling dust on the construction sites and washing trees that otherwise act as a place for dust to settle.

Local bodies should appoint vigilance groups to report any air pollution activity in their vicinity to the police who must take the matter seriously and

try to prevent air pollution by sprinkling water or extinguishing the fires.

Indore has created exemplary infrastructure to treat solid wastes generated by residents, and has claimed the status of 'Cleanest City in India' seven times in a row. It did not happen just like that; a lot of planning and hard work, and a change in the attitude of citizens towards cleanliness are all responsible. The segregated dry and wet waste has also improved incomes for the municipal corporation. All large and small municipalities should be taught the 'Indore Model', and the Central Government should fund these projects. Besides earning revenue, these actions will save the governments large sums of money that they currently spend on health and treatment of the citizens in hospitals.

Are CNTs to blame for Delhi's problems?

In the past, Delhi did not have problems of severe fog for long periods. Residents confirm that the problem has become critical in the last 25 years. So what has changed?

One significant change is in the fuel used in three wheelers – from petrol to Compressed Natural Gas (CNG). CNG was introduced as an automobile fuel in Delhi in the late 1990s as part of measures to reduce severe air pollution. Large-scale mandatory use started in 2001. Soon, Delhi had tens of thousands of CNG vehicles and became one of the first major cities in the world with a predominantly CNG-based public transport fleet.

Incomplete combustion of natural gas (mostly methane) can produce soot, and within soot there can be graphitic nanostructures, including carbon nanotubes (CNTs) under certain conditions (high temperature, catalytic metals, flame synthesis). Conditions required for CNT formation are: temperature of 900-1,400°C; and presence of metal catalysts like Fe, Ni, and Co (often from engine walls and other parts in contact with gases). All these are present inside an internal combustion engine. The sizes of the CNTs are fairly well studied in flame-grown CNT research. Typical size of single-walled CNTs (SWCNT) from CNG is 0.7-3 nm, while multi-walled CNTs (MWCNT) have 0.5-80 nm length, typically 0.5-20 nm.

A CNT particle containing or coated with water can contribute to opacity in air, while the carbon structure continues to strongly absorb light. Larger particles can settle down or get captured by moving objects like fan blades, window screens, etc.

Another coincidental factor is increase in flood irrigation in the rice fields around Delhi from October to January. As a result, the humidity of Delhi NCR in winter is comparable to that of Mumbai, in spite of Delhi's longer distance from the sea and much lower temperature (Table 1). This would cause super-saturation of the atmosphere during low temperature during nights and early mornings. The super-saturation disappears as temperature rises as the day progresses.

Table 1
Average monthly Relative Humidity

Month	Mumbai	Delhi NCR
January	65-70%	65-70%
February	65-70%	50-55%
March	70-72%	35-40%
September	82-85%	60-65%
October	75-80%	45-50%
November	70-72%	40-45%
December	65-68%	60-65%

In addition, the difference in day and night temperatures in Delhi NCR can be as much as 25°C.

All these factors can combine to promote condensation of water inside the CNTs. The size of CNTs is so small that they will remain afloat in the air for a long time. With increased viscosity of air at lower temperature and higher density, settling of CNTs filled with water can lead to opacity in the air. The fact that the fog disappears as the air temperature increases with the progress of the day points towards a strong possibility of condensation of water in hollow particles.

Interestingly, several locations in Uttar Pradesh and Punjab with similar altitude and longitude do not suffer from as much fog as Delhi NCR. Mumbai does not see fog for two reasons: it gets fresh air from the sea; and the day & night temperature difference is small.

What is the remedy?

What I have pointed out is a possibility. It would need detailed investigation of the gaseous effluents from automobiles using CNG. This should not be difficult, though it would require high quality electron microscopy to see the very fine particles.

If CNG based three – and four-wheelers are really found to emit CNTs, the entire CNG programme may have to be revised. A cleaner option will be electric vehicles, or those running on hydrogen and/or dimethyl ether (DME). Facilities to convert natural gas to hydrogen or DME may have to be created, but this would be a better long term option. It will take time, effort and courage to do.

The other aspect needing attention is flood irrigation of crops. This can be easily replaced by drip irrigation. An area of up to 100 km radius from Delhi NCR should be shifted to drip irrigation.

Both these actions could solve the problem of fog in Delhi NCR.

The problems in the rest of the country need further research and, possibly, other actions.