MANAGING AIR POLLUTION USING EURO 6 FUELS IN VEHICLES

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Abstract –Today, environmental pollution both from the point of view of global warming and presence of high degree of gaseous and particulate matters in the air which are highly injurious to health, is a major concern for the mankind, as possibly even his existence is under threat. Lucknow along with Delhi are among the most polluted cities on earth. The solution probably requires various levels of studies and explorations.

Use of Euro 6 complaint fuels(very Low sulphur content) in Euro 6 complaint and Euro 4 vehicles, has been studied, towards reducing air pollution, particularly what is caused by particulate matters like PM 2.5. It is inferred that considerable benefits can occur through its use in older (Euro 4 complaint) vehicles as well. It is also inferred that worthwhile benefits can occur if retrofitting of Euro 6 like convertors in engine exhausts Euro 4 vehicles is taken up.

KeyWords: Euro 6 fuels, PM 2.5, Retrofitting, Air pollution

I. INTRODUCTION

Global warming and atmospheric air pollution are possibly the two most important issues before the mankind. The two are closely linked, though they require very different approaches and emphasis in their control. While the global warming concentrates on greenhouse gases, particularly CO2, the air pollution control efforts emphasise on oxides of Nitrogen and Sulphur, CO and particulate matters. Also, the global warming sumps up all environment related activities anywhere on earth, in contrast to the air pollution activities and their control which remains mostly local.

Air pollution in many cities of India has been much above the international norms and acceptability and has been in focus in several ways including for having been declared the most polluted cities in the world. Lucknow is one such city. It is a medium size city of around 5 million people and is growing very rapidly being the capital city of the province of Uttar Pradesh and also a declared Smart city. This study dwells on pollution due to vehicular transportation in the city and the emerging ways and means of mitigating it.

Data reveals that the main source of high pollution at Lucknow is due to particulate matters in the city air. The awareness of the consequences of high particulate matter in the city air, particularly PM 2.5 (particulate matter less tha 2.5 microns diameter) has been rising. Today possibly several hundred thousand, both very young and old, are dying every year due to various cardio vascular and respiratory diseases attributed to it. Although, proper statistics is not available, some estimates put it as high as one million. It has now become a political issue and is to be addressed with all resources available. It brings in the comparison with China, where cities are also highly polluted but with a very determined effort in the last five years the pollution has been brought down by 30%. This points to what could be the useful technologies to use to combat it and also gives hope of succeeding as well.

Among the processes that are being tried out globally are the use of less polluting Euro 6 fuels (which have a very low sulphur content) in vehicles, with or without euro 6 complaint engines, a switch towards the use of hybrid or electrically driven vehicles, filtering out of pollutants through Roosegaarde type towers besides the roads, and active monitoring of pollution at known places of traffic concentration and regulating the traffic and pollution in real time through information networks (of smart cities).The switch to Euro 6 fuels has been chosen for further deliberations and evaluating it's efficacy, as it cuts out the pollutants significantly through the modified fuel itself and also by filtering and modifying others close to the production source.

The whole world, with the introduction Euro 6 fuels and then Euro 6 vehicles, believed that vehicular pollution has become manageable including the pollution from diesel engines. But this hope seems to have been shattered with the wide spread reporting of cheating by the firm Volkswagen and subsequently practically every automobile manufacturer has been caught in the net. The reason seems to be the fact that the diesel engines, in spite of their on the road performance, are becoming undesirable due to bulky and in convenient contraptions that are needed for the emission control, particularly the ones based on urea injection in the exhaust of the engines. Apparently that has lead to the desire of under reporting the real emissions by the vehicular monitoring systems and doing less than the possible control. This makes the exhaust injectables lost longer and improves the mileage as well.

It is big source of worry as nearly half the vehicles in most countries are diesel driven. Organisations have worked out as to how many deaths have been caused by the VW's cheating alone. No wonder huge fines have been imposed.

It becomes obvious that by using any one particular means of pollution control the whole problem can't be solved as it is multi-faceted and complex.

While this problem in emission control will eventually be solved in most of the countries using Euro 6 fuels and with the large fraction of vehicles on the road with Euro 6 complaint engines, it remains a big problem in India. It has been announced that very soon all new vehicles sold in India will have to be Euro 6 complaint and Euro 6 fuel will be available in cities starting with Delhi where it is already available and being used.

Knowing fully well that full benefits of Euro 6 fuels can be realised only in Euro 6 complaint vehicles, Delhi city has decided to insist on the use of Euro 6 fuel in all vehicles, as some reduction in pollution is expected to occur as this fuel is used in Euro 4 or even Euro 3 vehicles.

It is proposed that, as the pollution is very heavy at Lucknow as well, this solution should be tried here also without waiting for the results from Delhi. The proposition here tries to evaluate the possible benefits and the desirability of next steps like retrofitting pollution control devices on older engines to make a larger overall difference.

II. THE REVIEW OF LITERATURE

A. Urgency due to health related concerns

The World Health Organisation (WHO) has estimated that around 4.2 million premature deaths globally are linked to ambient air pollution. This could be mainly from heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and acute respiratory infections in children [1]. A quarter of these may be in the Indian subcontinent

They have further estimated that air pollution is responsible for 29% of all deaths due to lung cancer, 24% of deaths from strokes and43% of all deaths and disease from chronic obstructive pulmonary disease etc.. This shows the gravity of the situation and the need for the urgency in responding.

Chinese evidence further shows that ozone in pollutants may become very important and deadly as other constituents are taken care off [2]. It has been further estimated that in Chinese cities it may be reducing life spans of individuals as much as by 2 years [3].

While specific data may not be available, the nature of problems is no different in India. As an example study shows that children are the worst sufferers at Hyderabad [4].

B. The measurement parameters

Typically, air pollution consists of both gases and particulate matters. Traditionally many constituents of both gases and particulate matters have been measured to get the right picture of air pollution in different countries. There is no universally acceptable classification of the pollution. However, with local experience the National Air Quality Index (India),2014 specifies eight parameters, their values and ranges, as given in Fig 1. Out of these the commonly reported parameters are only five. They are PM 10 and 2.5, NO2 ,CO, and SO2 and sometimes O3 may also be included. The Air Quality Index is calculated based on these values which may be hourly, two hourly, eight hourly or 24 hours averages.

NATIONAL AIR QUALITY INDEX RANGES (INDIA)								
AQI Category (Range)	**PM_{10} 24-hr**	**$PM_{2.5}$ 24-hr**	**NO_2 24-hr**	**O_3 8-hr**	**CO 8-hr (mg/m^3)**	**SO_2 24-hr**	**NH_3 24-hr**	**Pb 24-hr**
Good (0-50)	**0-50**	**0-30**	**0-40**	**0-50**	**0-1.0**	**0-40**	**0-200**	**0-0.5**
Satisfactory (51-100)	**51-100**	**31-60**	**41-80**	**51-100**	**1.1-2.0**	**41-80**	**201-400**	**0.5 – 1.0**
Moderately polluted (101-200)	**101-250**	**61-90**	**81-180**	**101-168**	**2.1- 10**	**81-380**	**401-800**	**1.1-2.0**
Poor (201-300)	**251-350**	**91-120**	**181-280**	**169-208**	**10-17**	**381-800**	**801-1200**	**2.1-3.0**
Very poor (301-400)	**351-430**	**121-250**	**281-400**	**209-748***	**17-34**	**801-1600**	**1200-1800**	**3.1-3.5**
Severe (401-500)	**430 +**	**250+**	**400+**	**748+***	**34+**	**1600+**	**1800+**	**3.5+**

Fig 1 Air Quality Index, India

C. Control of pollution across the globe

Pollution is one problem that has been shared round the globe, be it in cities in U.S., China or Europe. All the major cities in U.S. have been under severe pollution categarisation due to PM and ozone components. However, recent literature reports a degree of success in controlling it. While CO has been brought under control some time ago, PM 2.5 along with NOx and SO2 are in focus now. Towards conrolling the pollution, U.S. requires working at the source for each of the parameters. This poses problems as air pollutants may easily come from crosses the state boundaries.

Literature suggests that it takes considerable time, requires community efforts, suitable legislative norms and state of art technologies [5] to achieve it, as the U.S. agency EPA (Environmental Protection Agency) has done it.

Due to rather rapid economic development in China, increased and un-acceptable level of pollution has become a big issue [6]. It has evolved into a national commitment to bring it down by 25% in 5 years time [7] Towards this very serious efforts have been made, including closure of coal burning power plants, shifting of polluting industries,

regulating the construction sites, implementing new vehicle and fuel norms and construction of air filtering towers etc.

Most European countries rely on 'The Climate and the Clean Air Coalition' in Europe. They are committed to half the pollution related deaths by the year 2030 [8] . They are proposing stricter norms for the five pollutants which are a little different from elsewhere. The specified pollutants are the fine particulate matter or PM 2.5, Sulphur dioxide (SO2), Ammonia (NH3) ,Nitrogen oxides (NOx) and Volatile organic compounds.

Many of the pollution control programs are mixed with the global warming efforts as well like Methane emissions, which is a dangerous green house gas. Also, the emphasis is on involving public in policy making and implementation [9].

C. Air pollution at Lucknow

For quite some time Lucknow is in the list of most polluted cities in the world. Several studies have tried to explore the causes. The main causes [10] have been brought out. They are the vehicular emissions from rapidly increasing population of vehicles , rapid urbanisation, burning wood for fuel and burning garbage etc.

Some estimates show that vehiclar population has gone up several times in Lucknow in the last ten years and the city population has also risen by 25%. No. strong measures have yet been evolved towards controlling the pollution.

However, the agencies of the State Government are trying to tackle it through traffic control, road widening, removing encroachment on the roads etc. and evolving a PPP (Public Private, Participation) methodology [11] for it.
The dominant component of pollution at Lucknow, in the worst period of the year, continues to be PM 2.5, as typical pollution figures of a specific day from the monitoring agencies show [12], in Fig 2. They also say that the break up of PM 2.5 compnents varies significantly across the year. Basically it consists of primary carbon particles from combustion, dust particles from the road, and secondary components as aerosols created with the reactions of SO2, NOx, VOC with carbon particles, sunlight, moisture etc. In a broader way it includes domestic cooking emissions, jungle fires, crop residue burning etc.

Studies [13, 14] show that much of the complexity in estimating PM2.5 comes from the role of SO2 and NOx gases condensing into particulate matters (particularly aerosols) in presence of other exhaust components, carbon particles, water vapour and VOC (Volatile Organic Compounds). In the presence of sunlight Ozone may also be produced which is a significant health hazard.

AIR MONITORING STATIONS
Central School, Lucknow - CPCB
Significant Pollutant is **PM2.5**
292
0
AQI
500

Poor

Pollutant	Avg	Min	Max
PM2.5 (µg/m3)	292	94	480
NO2 (µg/m3)	66	25	132
SO2 (µg/m3)	6	3	11
CO (mg/m3)	60	10	128
OZONE (µg/m3)	7	2	35

Fig 2: Typical pollution figures as published at a monitoring station at Lucknow

A general study of literature leads to the thinking that a major step in controlling the pollution in cities can be an early switch to Euro VI fuels and vehicles as has done in the National Capital Region Delhi, rather than wait for the year 2020 which was the specified schedule earlier. The same strategy may be adopted for Lucknow as well.

It has been reported that Euro 6 complaint fuel (essentially very low sulphur fuel) has been developed by Indian oil companies with significant R&D efforts and can be made available at slight extra cost over the normal fuels. There are already over 400 filling stations supplying this fuel in Delhi.

It can also be seen from the review of literature that most countries hope to get over PM 2.5 particulate pollution and NOx through strict implementation of vehicles emissions norms with increasing proportion of Euro VI complaint engines. However, the degree of reduction in pollutants when Euro VI complaint fuel is burnt in Euro IV complaint engines which form the bulk of the vehicles, is not established.

It can also be seen that while various constituents of pollution remain important, the city air pollution in the worst polluted cities remains the creature of PM 2.5 and NOx gases which add to it by creating atmospheric haze or aerosol as well.

D. The most important source of pollution :The diesel engine

While much energy has been spent in understanding pollution due to crop residue burning, industrial pollution etc., the vehicular pollution seems to be the main culprit in public perception and as well as in reality [15] with particulate matter at the heart. Further, the vehicular pollution continues through out the year while some other pollution components come and go..

The role of diesel engines comes to the centre stage as diesels are important source of particulate matter. The evolution of the Euro Standards show the main concern continues to be PM 2.5 and NOx in the exhaust of diesel engines. While the literature shows that practically all major auto companies are working towards compliance, only a few models are available which are Euro 6 complaint, specially among diesel engines. It is possibly due to complexity of the technology and hence the implementation cost. Maruti Suzuki, the largest manufacturer of passenger vehicles in India has decided [16] to discontinue the production of diesel cars for now.

Part of the reason could possibly be the increased taxation on new diesel vehicles registration in Delhi and reduced validity of registration to 10 years as compared to 16 years for petrol vehicles.

Literature suggests as Euro Norms (Standards for pollution) were being set, the efforts from Euro 1 to Euro 6 (Fig 3)were to get towards almost zero unwanted emissions. Starting from the year 2018 the Euro 6 or equivalents are the standards being followed in most countries [17] and the required engines and the fuel both have been evolved. It has become a practical technology.

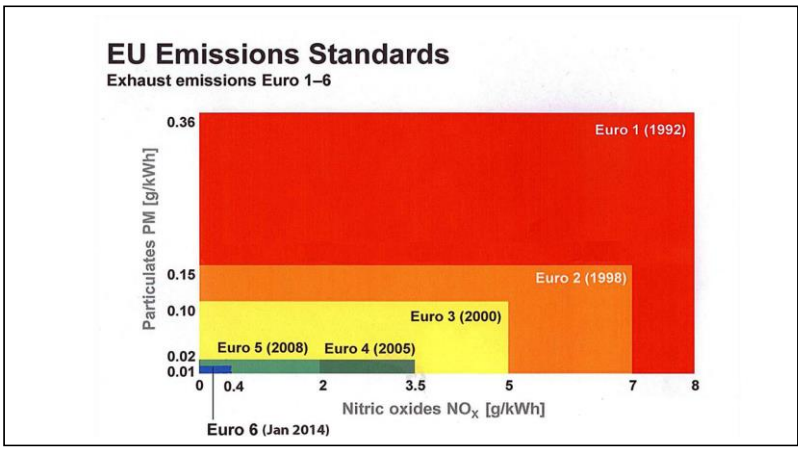

Fig 3 The Euro Emission Standards

For diesel engines to meet Euro 6 (or BS VI/ 6) standards it is necessary to reduce the Sulphur content in the fuel from nearly 50 ppm (Euro 4 and older standards) to 10 ppm for Euro 6. Indian efforts to produce this fuel at commercial scale have been successful though it involved an enormous cost.

III. EURO 6 FUELS AND THEIR IMPARATIVES

The literature review has shown that solutions to bring diesel engines to Euro 6 level emissions has been found. Huge investments have been made in R&D with success and the firms are keen in marketing the clean diesel engine [18]. The solutions are based on the after combustion treatment systems like Selective Catalytic Reduction or SCR, Exhaust Gas Recirculation, and diesel particulate filters etc.. A particular technology [19] requires addition of a separate substance (A reduction agent trade named AdBlue) during the operation of the engine.

However, other solutions have also been found. An alternative to this is to add a Lean NOx trap that traps the NOx pollutants from the engine in its porous core. Some major manufacturers are committed to this technology.

The AbBlue and Lean NOx trap technologies are quite complex in reality. Never the less world can continue with diesel and petrol vehicles complying with the stringent Euro 6 norms. This may continue with increasing adoption of electrical vehicles as the ultimate solution.

It appears that apart from the improvement of technologies there could be many strategies towards adoption, such as:

a. Exploring the benefits of using Euro 6 fuels In Euro 4 engines. No manufacturer in India is yet offering Euro 6 complaint diesel engines.
b. Finding the ways to add additional converters and filters to Euro 4 complaint engines to make use of Euro 6 fuels available in India.
c. To come up with engine design modifications (like compression ratio, injection methods, drive trains etc.) that reduces harmful emissions with the use of Euro 4 engines

IV PROSPECTS FOR LUCKNOW

Considering the possible benefits from the literature, it is proposed that adoption of Euro 6 should be brought forward to 2019 at Lucknow as well. The required fuel supply will need to be insured. This looks practical as it has already been achieved at Delhi.

As the results from Delhi on the success of the efforts of using Euro 6 fuels have yet to be established, the problem has to tackled speculatively.

While some data is available that show [20] the expected reduction in emissions, when Euro 6 fuel is burnt in a Euro 6 engines, with catalytic convertor or EGR technologies, little information is available on the burning of Euro 6 fuel in Euro 4 vehicles (without catalytic convertors or EGR etc.). This estimate is important as it will take quite some time to have all Euro 6 vehicles on the road.

A general observation in the magazine Autocar [21] has been made that the pollution constituents may get reduced by half in the above mentioned efforts.

Literature reports a variety of possibilities when switch is made to Euro 6 fuel, particularly in diesel vehicles designed for Euro 4 fuels. Some of the harsh critics predict very little or no gain [22]in terms of emissions, but show the problems that will come with loss of lubricity of fuel due to reduction of sulphur . In reality it may be possible to overcome this problem through additives. They also predict some loss of output power as sulphur content is reduced.

Many Chinese estimates argue that with the huge reduction in sulphur content in the Euro 6 fuel, many harmful constituents related to sulphur will not produced by the Euro 6 fuel , which are very important from health point of view. The Chinese study[23] shows a significant reduction in pollution related causalities in a major city. They also estimate that PM 2.5 pollution may also reduce by half.

E Inferring the results for Lucknow

A rough estimate in reduction of harmful constituents in the city pollution may be arrived at by making the following assumptions:

a. The Euro 4 petrol vehicles when burning Euro 6 fuel will not increase PM content of exhausts

b. Ratio of petrol to diesel vehicles remains the same over time

c. The composition of PM 2.5 varies significantly across the year and also it is quite different in different cities. Thus no universal conclusions can be obtained but some estimates can be made.

For estimating the reduction in harmful contents the detailed studies carried out by Hodan [24] about the primary and secondary sources of PM 2.5 is proposed to be used. In these studies in several U.S. cities the constituents of PM 2.5 were identified and typical values were measured with all their variations across time and space. A few values are shown in the box:

Phoenix City:

Diesel Car	Gasoline cars	Road dust	Biomass	Others	Level
14.5%	38.9%	1.8%	15%	36%	8.2 micro gm/m3

Down Town L A.

35.7%	6.5%	11.1 %	5.8%	39.9%	32.5 microgm/m3

Also, extensive measurements have been carried in several Chinese cities, some are shown below in a box

Tianjin

Dust, tyre wear	Sulphate Nitrate	Coal Dust	Vehicle exhaust
30.0%	28%	19.8 %	15.95

Shenzehen

--	30% + 9.3%	Bio mass 9.8%	26.9%

It can be seen that the road dust and tyre and brake wear constituents are always present in significant amount. Vehicular exhaust seems to have roughly 25% value. Power Station emissions remain important in all cities.

A detailed break up of PM 2.5 constituents in Lucknow city is not available. But it is known that it varies with wind velocity, wind direction, day temperature, rains and crop residue burning etc.

However, from Hodan's work it can be seen that primary and secondary constituents of PM 2.5 from the fuel may be up to 50% of the total (with considerable variability). Half of it may be from the secondary sources(created outside the tail pipe). It may thus be estimated that as the secondary constituent is mostly due to Sulphur in fuel and its contribution may become negligible in Euro 6 fuels, with practically no Sulphur. Thus it may stand to reason that if half of PM 2.5 is secondary type (related to sulphur) in the city, and thus the pollution index may fall by half of the 50%. Thus it may be around maximum of 25% fall. In reality it may be much less. However actual use only may bring a reliable figure.

V CONCLUSIONS FROM THE STUDY

Many countries in the world have switched to Euro 6 compliant fuels without waiting for the Euro 6 vehicles. Delhi is already doing it. It will possibly be worth while for Lucknow also to make immediate switch, as the fuel can be made available by certain organisations. By studying the phenomenon of formation of PM 2.5, the main pollution constituent at Lucknow as well as in Delhi, the following conclusions are drawn:

1. Studies show that although the composition of PM 2.5 varies significantly in cities and with seasons, considerable reductions in vehicular emissions may be possible with Euro 6 fuels, if used in Euro 6 engines, provided there are no cheat devices fitted in the vehicle. Also better estimates can be obtained if the evaluation of vehicles is made under real driving conditions rather than in the laboratories.
2. It is established that Euro 6 fuel when used in Euro 4 vehicles also results in considerable reduction of pollutants. Estimates made for PM 2.5 in this chapter show that it can be a maximum reduction of 25% but the average values will be much less.
3. Based on literature it can be concluded that more benefits from Euro 6 fuels can be obtained if Euro4 vehicles are retrofitted with the required exhaust convertors. This may also help in quickly filling the Lucknow roads with less polluting vehicles.
4. At present cost of the fuel has not been changed much for Euro VI fuels in Delhi. It may be assumed that public may be willing to pay a little extra if the results become visible.
5. International studies show that much of the benefit will be in terms of improved health with reduction in pollution related health problems.
6. Higher cost of Euro 6 complaint vehicles may pose some real problems. The small diesel vehicles will be particularly facing this issue in a very harsh way.

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