Catching the Fumes: Tailpipe Emissions from Adulterated Fuel Usage

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ABSTRACT
While the debate about air pollution in India continues to focus on visible pollution sources such as rapid growth in coal-based thermal power generation, mining operations etc., tremendous growth of vehicles inside the cities is largely out of considerations of urban Indians and is one of the key drivers of the crisis. This work exposes the key factors responsible for urban air pollution emission.

Identification of the problem clearly indicates that large numbers of vehicles are the dominant sources of urban air pollution growth, with those running on adulterated fuel as the main driver. The secondary particulates formed from aerosols like SO_2 and NOx are key cause of the recent increase in $PM_{2.5}$ levels, which is causing damage to human health and creating potentially a health emergency situation in India. This study emphasizes on the urgent need to comply with the most stringent vehicular emission standards in order to solve vehicular air pollution crisis.

KEYWORDS: Fuel Adulteration, Traffic related air pollution, Urban air pollution, Vehicular emission

I. INTRODUCTION

The quantum of petroleum product utilization in India is increasing due to increase in population, urbanization, development activities and changes in life style, which leads to widespread pollution in the environment. Thus tailpipe emissions from low level public transport such as auto rickshaw is a menace and become a serious problem due to their contribution in pollution and bypassing the subsidized kerosene to adulteration market. As fuel prices rise, the public transport driver cuts costs by blending the cheaper hydrocarbon into highly taxed fuels. In the present work developed techniques for fuel adulteration with kerosene and resulting tailpipe emissions causing environmental impacts has been studied.

This research work shows that deadly air pollution is not a problem restricted to Delhi-NCR (National Capital Region) or even to India's metros. It is a national problem that is killing 1.2 million Indians every year and costing the economy an estimated 3% of GDP. If the country's development is important, fighting air pollution has to be a priority.[1]

There is poison in the air. With every breath we take, we shorten our lives or ruin our health. And it is getting worse every year. There is death in the air and more and more people are dying prematurely every year. In 1991-92, studies revealed that around 40,000 people were dying in India due to air pollution. By year 1995 the toll reached to 50,000. The figure had shot up dramatically to 6,20,000 in the year 2010 according to WHO's Global Burden of Disease report-2010.[2] And then it comes year 2017, Greenpeace, India's report, titled 'Airpocalypse'. According to which India's air pollution has become a "public health and economic crisis" lends it further credence that 11,98,000 people die of air pollution-related diseases every year. Is our quest for economic growth self defeating? It seems so, for tiny particles of matter floating in the atmosphere known as suspended particulate matter or SPM are slowly but silently choking people to death. And this is not all. There is cocktail of deadly gases like benzene, ozone, CO, CO_2 and SO_2 to add to these degradations.

II. MATERIALS AND METHODS

To assess deviation in the tailpipe exhaust emission of autorickshaw from combustion of adulterated petrol (kerosene in petrol) consequent to the extent of adulteration, we prepared the samples of various combinations of base fuel (Petrol) and adulterant (Kerosene).

Materials: The raw material for the study of the characterization emissions from adulterated fuel was locally available petrol and kerosene. The depiction of exhaust emissions subsequent to adulterated fuel were carried out using Bajaj Auto Rickshaw (2 stroke).

a) Procurement of materials: The petrol as a base fuel was procured (15 liters) from local HPCL petrol pump (Filling station). The adulterant used was kerosene (15 liters), procured (collected) from local sources.

b) Preparation of custom samples or blends: Two sets of 11 (Eleven) samples each for the pseudo-binary Petrol + kerosene mixtures were prepared at room temperature for various volume fractions, in order to cover the entire composition range, and stored in different containers. Petrol and kerosene were mixed in: 100:00, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, and 20:80, 10:90 and 00:100 ratios.

11 sample of 2000 ml (2 Liters) each, were administered in autorickshaw for complete study and understanding of the problem, viz.-mechanical performance of the engine & measuring tailpipe exhaust emissions consequent to adulteration. Total volume of samples prepared was 22 liters.

Methods: In general there are many critical parameters, which are likely to be affected or altered by adulteration and increase the exhaust emissions and can be evaluated. Characterization of exhaust emissions from the tail pipe of auto rickshaws was carried out for various parameters, according to ASTM standards.

Testing of Tail Pipe exhaust Emissions & Fuel Consumption:- The respective samples from the tailpipe emissions are tested for various types of pollutants and their combinations Also the qualitative and quantitative analysis of the pollutants is studied & estimated for data generation for emission assessment.

Samples (by vol. %)
Sample B-1, Petrol : Kerosene (100:00)
Sample B-2, Petrol : Kerosene (90:10)
Sample B-3, Petrol : Kerosene (80:20)
Sample B-4, Petrol : Kerosene (70:30)
Sample B-5, Petrol : Kerosene (60:40)
Sample B-6, Petrol : Kerosene (50:50)
Sample B-7, Petrol : Kerosene (40:60)
Sample B-8, Petrol : Kerosene (30:70)
Sample B-9, Petrol : Kerosene (20:80)
Sample B-10, Petrol : Kerosene (10:90)
Sample B-11, Petrol : Kerosene (00:100)

Parameters for Testing
Carbon monoxide Content
Unburned HCs Content
NOx content
Sox Content
Particulate matter Content
Benzene Content
Toluene Content
Ethyl benzene Content
xylene Content

Figure : Methodology Adopted for Analysis of Tailpipe Exhaust Emissions

I) Prerequisite vehicle maintenance work and emission test: Regular three seater auto-rickshaw (Make: M/s. Bajaj Auto Ltd, Model: RE 145 (145cc, 2-stroke, petrol)), year of manufacture: 2012, was selected for the tests. The air cleaner filter, oil filter, engine oil was replaced and various setting requirements were set according to the manufacturer specification. This was done prior to subjecting the autorickshaw to the emission test.

a) Gaseous Pollutants (Sampling & Analysis)

The HNL Multi Gas analyzer (GA200) was used which was suitable for sampling and analysis of all types of engine exhaust emissions. The requisite conditions to be followed for vehicles to be tested and the specified calibration steps of the emission tester were strictly adhered to as specified in the manual of the emission-testing equipment. Engine was kept idling for about 30 min. and then readings were taken for respective pollutants (as in case of obtaining PUC certificate). Analysis of BTEX composition in exhaust emissions was carried out by GC-MS.

b) Particulate Matter (Sampling & Analysis)

Stack sampler is used to measure the amount of particulate matter present in the exhaust emissions. SPM samples were collected on cellulose acetate membrane thimbles with constant flow rates at 24 l/min. Thimbles were weighted on a digital micro balance with accuracy of ± 0.1 mg before and after sampling. Duration of sampling for VOCs and SPM was 30 min. First we placed a clean, preweighted thimble/filter in the filter holder and tighten securely. Started the test after sampling rates have been calculated and train assembled & checked for leakages. When the equipment is ready in all respects, we inserted the probe into the exhaust pipe. The sampler uses a blower to suck in air. Particle size classifier separates particles greater than 10µm size from the air stream which is then passed through a filter paper (thimble) to collect particles lesser than 10µm size to get PM_{10}. Gravimetric analysis for SPM was carried out using digital balance. The SPM concentrations expressed in µg /Nm3 were calculated by dividing the blank corrected filter mass increase by total volume sampling. Simultaneously fuel consumption for each sample was measured for the idle running of 30 min.

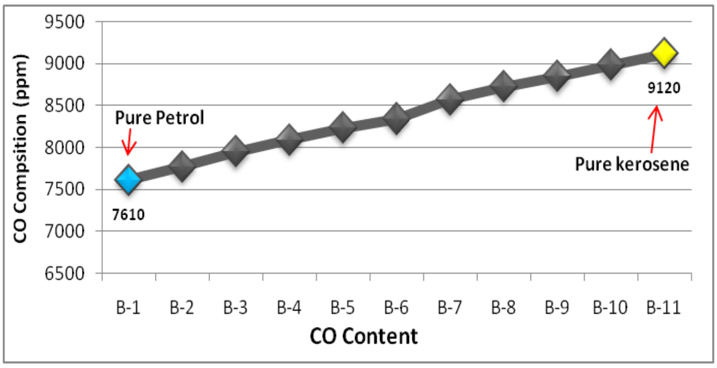
III. RESULTS AND DISCUSSION

Environmental pollution due to vehicles and its adverse effects on human health is one of the top issues which should be taken quite seriously. Vehicle exhaust emissions raise the levels of various pollutants in the air. Especially in urban environment, it was shown that air pollution from motor vehicle emissions accounts for about 70%. The adulteration of fuel with kerosene, further intensify the magnitude of the problem.

We had employed the prepared samples of adulterated petrol in the autorickshaw and the consequent exhaust emissions were tested for various pollutants and parameter.

1) Carbon monoxide

Exhaust emissions from motor vehicles threaten the environment and human health. Carbon monoxide poisoning, especially the use of exhaust gas CO in suicidal attempts is well known in the literature. Carbon monoxide is a tasteless, odorless and colorless gas and a by-product of partial combustion of fuel in the engine.



Graph : Results for Carbon Monoxide Content

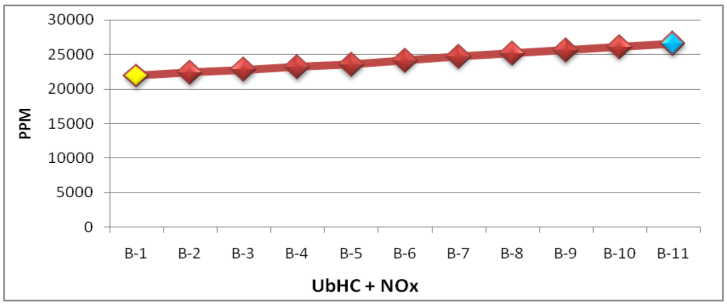
Given above are the findings of exhaust emissions from tailpipe of autorickshaw for carbon monoxide. Findings are quite expected, as we increase the adulterant to petrol, consequently emissions of carbon monoxide increases in the same manner. The trend of CO emissions was continued throughout the samples. While pure petrol combustion in engines shows the CO emissions readings of 7610 ppm, pure kerosene burning shows value of 9120 ppm.

This may happened due to incomplete combustion of fuel because of mixing of heavier hydrocarbon fuel with comparatively lighter fuel. Incomplete combustion of fuel is a result of increased flash point and viscosity of fuel which increases the emissions. Increase CO content in air primarily causes adverse effects on humans by combining with hemoglobin to form HbCO preventing the blood from carrying oxygen. It is easily absorbed through the lungs. Inhaling the gas can lead to hypoxic injury, nervous system damage, and even death. On average, exposures at 100 ppm or greater is dangerous to human health. Thus increased kerosene in petrol further amplifies the extent of carbon monoxide and thus increases the adverse effects on human health.

2) Unburned Hydrocarbons & Oxides of Nitrogen.

Increased viscosity, specific gravity and flash point of the fuel exaggerate the amount of unburned hydrocarbons in the vehicle exhaust. When we add kerosene to petrol, all these fuel properties shows further increase in value as seen previously. All these consequences leads to increase in unburned hydrocarbons release from vehicle tailpipe. On the other hand

Due to decreasing calorific value of samples with increasing fraction of kerosene in petrol, more fuel is required to generate the required power and consequently more air is required to maintain the designated air-fuel ratio. More air means more nitrogen to combustion chamber leads to more generation of NOx due to oxidation. Also the incomplete combustion of fuel occur which further adds up the increased amount of unburned hydrocarbons to the atmosphere.



Graph: Composition of Unburned Hydrocarbons & NOx in tailpipe exhaust

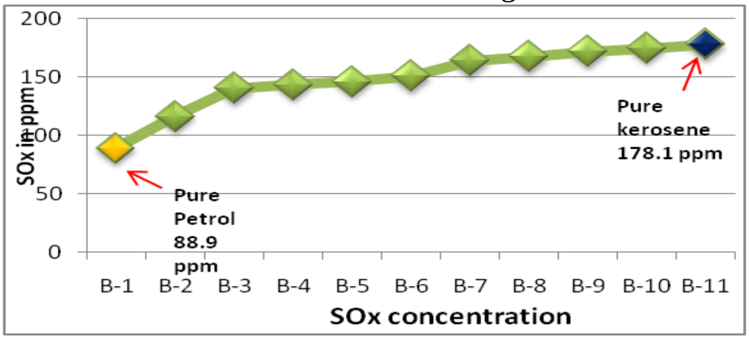
Figure above illustrates the same fact, samples with high kerosene content shows higher emissions of NOx than that of lean mixtures of petrol and kerosene. There is a gradual increase in NOX concentration with subsequent degree of adulteration.

Nitrogen dioxide is an irritant gas, which at high concentrations causes inflammation of the airways. NOx gases react to form smog and acid rain as well as being central to the formation of fine particles (PM) and ground level ozone, both of which are associated with adverse health effects.

3) Oxides of Sulphur

The main environmental concerns related to sulphur emissions are acid rain and the formation of particulate matter. When sulphur dioxide is emitted and combines with water it forms sulphuric acid, or acid rain. Acid rain has many negative environmental impacts including the acidification of aquatic systems, increasing soil acidity and damage to vegetation. Sulphur is also emitted from vehicles in the form of sulphate particles. Along with nitrogen oxides, these particles contribute to SPM formation.

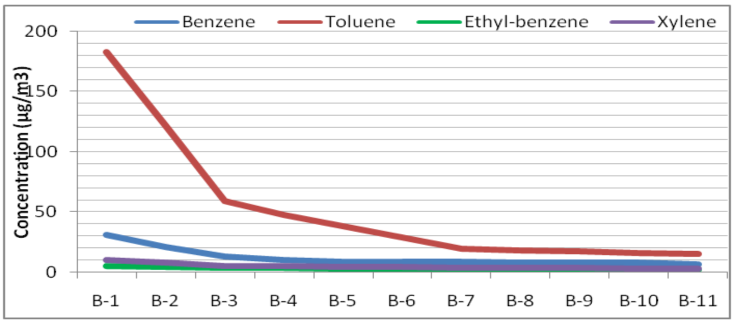
Sulphur compounds in exhausts contribute to poisoning of catalyst in catalytic converter in vehicles equipped with, thus increases the exhaust emissions. Sulphur is present throughout the range of petroleum fuels, although they are more abundant in the heavier fractions, and this fact were proved by our testing of blend samples for sulphur content. As it shows increased sulphur content in samples with increased kerosene fraction, the very same trend was observed in the exhaust emissions also, While pure petrol shows SOx content of 88.9 ppm in the emissions, blend (sample B-10) containing 10% petrol and 90% kerosene records 174.9 ppm and pure kerosene (sample B-11) shows 178.1 ppm of Sox emissions from the burning of respective fuel in autorickshaw with increasing trend.



Graph : Sox content in Exhaust of Autorickshaw

4) BTEX Complex

BTEX is an acronym for benzene, toluene, ethyl-benzene, and xylene. BTEX have in recent years attracted much attention, this is mainly due to the potential effects of benzene. Benzene from this new deadly air toxin is classified as a group A, human carcinogen by WHO and which is highly mobile in the Air, water as well as in the soil. Even when, additional BTEX compounds, classified as group D, not classifiable as human carcinogen, including toluene, ethyl-benzene and Xylenes, they are of concern for both acute & chronic health effects. Below are the findings for BTEX complex in exhaust emissions according to degree of adulteration.



Graph: BTEX Composition in Exhaust

Figure above shows the range of benzene, toluene ethyl-benzene and xylene at exhaust level for different percentage of petrol with kerosene to be used as a fuel in autorickshaw. Figure below illustrating the graphical representation of these BTEX at exhaust emissions showed that the concentration of these common

VOCs decreased significantly along with the increase in kerosene fractions in petrol fuel.

The initial trend showed that at elevated adulteration, BTEX emissions from tailpipe decreased. The statistical analysis shows that the level of benzene increased notably in sample B-1 which is pure petrol, as compared to remaining samples. The similar trend was observed with toluene Sample B-1 shows maximum content of toluene than any other group in the test. Correspondingly concentration of Ethyl-benzene & xylene declined significantly in the last five samples from B-7 -11.

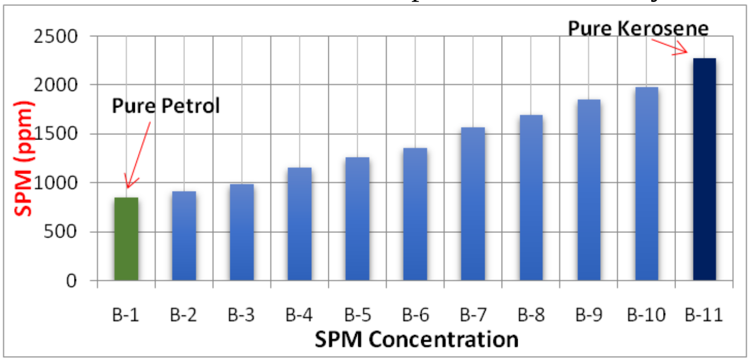
In other words BTEX level goes on increasing with decreasing kerosene composition. These findings were not in accordance with what was generally expected for total hydrocarbons. The behavior and physiochemical properties of common VOCs were different when considering the effect of fuel composition on total hydrocarbons and specific hydrocarbon. Moreover the emission factor of BTEX was entirely different than that of total hydrocarbon. That's why the concentration of BTEX in exhaust decreases in accordance with increased kerosene than that of total hydrocarbons.

The reason for decreasing VOCs in emissions with increasing kerosene % is due to the above proved fact that kerosene has lower aromatic content. As per our findings, petrol has aromatic content of about 65.25 and that of kerosene is 26.22 by vol. %. While benzene in kerosene was found to be 2-3 %, most aromatics in petrol are benzenes as petrol is considered to be lighter hydrocarbon fuel than kerosene.

Particulate matter

We assessed the emissions response of a petrol powered autorickshaw using nine different blends of petrol and kerosene along with pure petrol and pure kerosene, to assess the extent of particulate matter arising from tailpipe exhaust. It is clearly evident from the figure below, that there is significant increase in the emissions of suspended particulate matter with increased kerosene composition in the blend. Where sample containing 100% petrol shows the SPM reading of 850.95 mg/Nm^3, sample having 100% kerosene showed more than two and half times the value of pure petrol; 2270.24 mg/Nm^3. Gradual increase was observed in the SPM concentration with corresponding decrease in petrol content in blend.. The increasing particulate matter is a direct effect of burning kerosene in autorickshaw engine since there was incomplete combustion of fuel due to variations in various properties of base fuel due to adulteration such as viscosity, calorific value, density and hydrocarbon composition etc.

Increased SPM emissions due to result in reduced visibility and also have impacts on human health, resulting in an increased number of restricted activity days. Human health impacts are generally related to respiratory illnesses, including increased frequency in bronchitis and asthma. These illnesses have led to an increase in premature mortality.



Graph : Findings of Particulate Matter Concentration in Tailpipe emissions

IV. CONCLUSION

Adulterating gasoline with kerosene causes increase in emissions, as kerosene is more difficult to burn than gasoline and this result in higher levels of HC, CO and PM. High sulphur contents of the kerosene can deactivate the catalyst and lower conversion of engine out pollutants. Kerosene addition may also cause fall in octane quality, which can lead to engine knocking. Kerosene added to gasoline will increase engine deposit formation. The threat of fuel adulteration will not solve until the practical steps are not initiated at the grass root level. It is possible to improve the design parameters of engine used for transportation purpose. The lab test shows that adulteration of gasoline with kerosene would reduce the life of the vehicle engines and also increase environmental problems.

The more trucks we ply, the more three-wheelers we use, the more vehicles we manufacture, the worse the situation becomes. A sharp rise in cases of chest and throat disease in India is being blamed by doctors on worsening air pollution in the country, which is now home to 13 of the 20 most polluted cities in the world. According to India's National Health Profile 2015, there were almost 3.5 million reported cases of acute respiratory infection (ARI) last year, a 140,000 increase on the previous year and a 30% increase since 2010.[3] Unplanned economic growth has resulted in filthy, grimy and sub-human living conditions in our cities.

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