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HEALTH RISK MONITORING AND EVALUATION RELATED TO SOOT FROM VEHICLES

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Abstract

Soot is emerging as a predominant pollutant in urban and rural areas. It is generated during the combustion of carbon-based fuels. Due to the increase in the population and the necessity to provide mobility options for all the citizens, vehicle numbers have increased in many Indian cities. Further, the driving profile of Indian road users involves complex acceleration, deceleration and braking patterns resulting in more emission of soot from the engines. Moreover, the limited options for proper maintenance of engines resulted in more emissions from the vehicles. It has also been observed that due to various socio-economic factors, usage of old vehicles within the city limits has increased resulting in increased generation of pollutants like Soot. Hence the emission of soot is of concern in order to safe guard the health of the citizens. Further, due to limited monitoring facilities available, emission of soot and its effect on the health of the citizens cannot be estimated and due to this reason, this study trying to give an estimated data for the health risk. There are no such parameters or protocol present in the present scenario of soot in India which make the society life in danger.

This study also enlightens the basics of the combustion chemistry in the combustion chamber of the vehicle. In order to check the trend of the soot increasing or decreasing, it is very important to understand the chemistry occurs in the combustion chamber. Air-Fuel Ratio gives the estimated soot which helps in predicting the soot number and the effect of soot on the human health as well as the environment. Mechanism and the equipment of vehicle also overviewed in this study in order to check and repair the vehicle to resist the harmful exhaust gas emission and soot.

This study focuses on measuring soot from the vehicles and estimate the pollutant generation from the soot by developing mathematical relations for the same. The study also focusses on developing health risk coefficients based on the predicted concentrations. The study has observed that the soot generated from the two wheelers has a significant correlation with the emissions of CO and CO2 emitted from the vehicles. The correlation helps to predict the concentrations of the pollutants with the help of the measurement of Soot.

Keywords: Air pollution, Soot particles, combustion of carbon, combustion chamber, Air-Fuel Ratio, emissions of CO and CO2

1. INTRODUCTION

The rapid growing industrialization is leading to a lot of environmental issues by its uncontrolled of emitted pollutants. On the other hand, reasons behind the pollutions in India are the emissions from vehicle, destruction of forests via natural reasons or manmade destruction by cutting forest for their comforts, land degradation due to uses of poisonous insecticide and pesticides for agriculture, rapid burning of wood, fuel, and many of the shortage of natural resources. Due to emission of pollutant in more concentration leads to lots of disease, health issues and long-term livelihood impact. The main cause of the exponential increase in the pollution levels is the fuel-thirsty vehicles which means automobile industries are the primary source of air pollution India's major cities. Developing countries like India with a population of almost 1300 million which is equivalent to 17.74% of the total world population as on May 27, 2019, based on the latest United Nation estimates. It is already getting difficult to breathe in most of the metropolitan cities and India is already facing some serious air pollution issues probably since last 10 years and it is increasing at an alarming rate. There are many kinds of sources which are responsible for the air pollution by contributing large amount of polluting compound into the atmosphere. Other than gaseous compounds, particulate matter is one of the most contributing air pollutants produced by human activities. Particulate matter present in ambient air can cause very serious problem not only for human health but it has also a severe impact on the environment. Some of the problems are change in the radiation balance of the Earth, change in cloud formation, contribution to global warming, and reduced visibility. Particulate matter is not only present in outdoor environment but it has also an impact and presence in indoor environment. Therefore,

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people can be exposed to particulate matter in both outdoor environment as well as outdoor environment.

Sizes of suspended particulate matter is generally taken as 0.1 micrometre to 100 micrometre but the main concern with respect to human health is suspended particulate matter with diameter less than 10 micrometre. Particulate matter with size diameter less than 10 micrometre is easily inhalable and because of this reason it become the more toxic for the human health and a hot topic for the study of effect of particulate matter. Particulate matter greater than 100 micrometre is not defined as suspended particulate matter. Now, it is relatively matter of concern is the source of emission of particulate matter which can be natural or anthropogenic but the mainly the particulate matter emits from the vehicle tailpipes or can say vehicle or automobile industry contribute a large amount of particulate matter into the atmosphere. Particulate matter from the vehicle is mainly known as soot which has the size diameter less than 2.5 micrometre, which means it is more dangerous than the PM2.5. Therefore, it is becoming a great matter of concern for the health of society we are living in. There are very less numbers of research and study done in this field so it needs more research and study to control the emission of soot into the environment. Soot is the result of incomplete combustion of fossil fuel, bio fuel, wood, coal, oil etc. due to not having the proper air or oxygen. It is a fine black or grey coloured particle, chiefly composed of carbon. It can consist of dust, metals, acids, soil and chemicals. It lies under the suspended particulate matter (SPM) having the size of 0.25 microns to 1000 microns. It is about the 1/30th the diameter of the human hair and comparatively smaller than the dust. The combination of having fine or tiny particle size and toxic composition is what it makes soot more dangerous and a serious concern for the society. However, it is very disappointing that soot or black carbon in many countries has not been effectively controlled, mainly in developing countries like India and China. Y. He, G.L. Zhang et al., (2009) studied that atmospheric aerosol are the major air pollutants which have the global as well as local environmental impacts. It can directly affect the climate through scattering as well as the absorption of incoming solar radiation. And it can result in serious health issues and environmental problem M.Y. Jiang et al., (2011) and E. Uherek et al., (2010) described that described that soot particles produced from the incomplete combustion of carbonaceous matter. The sources of soot emission are mainly from, burning of coal, burning of fuel in vehicles, consumption of fuel by industrial process, mass burning etc. K.R. Kumar et al., (2011) studied that soot is both local as well as the global pollutant and a serious matter of concern for all the. This study shows that in order to reduce the effect of soot and its emission, it is necessary to remove and reduce the effect of soot by using surfactant solution before it is exposed into atmosphere. Surfactants are the compound which lower the surface tension or interfacial tension between a liquid and a solid, between gas and liquid and between liquid and liquid. It can be act as a dispersant, wetting agents, detergents, foaming agents and emulsifiers. Surfactants contains both the hydrophilic groups as their head and hydrophobic group as their tail.

Soot formation

The formation of soot is a very complex process in which number of molecules participated many physical as well as chemical reactions in very short time interval or few milliseconds. Hydrocarbon thermodynamic stabilization is a key factor for the formation of soot studied by Paul Domenic Teini et al., (2011). Further in this studied included that soot formation is dependent upon Carbon concentration, fuel type, temperature, stoichiometry, time and pressure. There are many contradictions about the research on the formation of soot, there are many questions which are unanswered and controversial on the formation of soot but there have been few papers which described the formation of the soot. The formation of soot mechanism is defined of:

- Soot comes in existence with some building blocks or precursors (a compound that participate in the chemical reaction to form another compound).
- Nucleation takes to form to form particles from heavy molecules
- Surface growth of the particles (by adsorption of gas phases)
- Coagulation and agglomeration
- Oxidation

Glassman et al., (1989) identified that acetylene play an important role as a precursor in the formation of soot and hence it is necessary to give an attention to acetylene which is also confirmed later by Richer and Howard et al., (2000).

Soot composition and structure

In order to understand the soot mechanism and its formation, it is better to briefly understand the chemistry of the soot. Soot is a particulate matter roughly one part of hydrogen and eight **parts** of carbon. According to Choi MY, Hamins A et al., Its density is about 1.8701 g/cm3 which is reported by most of the author and their values lies nearly this value. In urban areas, soot is produced mainly due to incomplete combustion of fuel in the combustion chamber. Soot is a part of black carbon/smoke when it is present as large particle size. From above study we understand that soot precursor helps in soot existence or can say that precursor process in which gas phases turns into the particle with the help of building blocks and after that soot nucleates from the gas phase to a solid phase at the elevated temperature during fuel-rich regions. Hydrocarbons and other available molecules absorbed by soot particles depends on the surrounding conditions. Shndilya K.K., Kumar A. et al., (2013) described in their study that young soot particles have the highest hydrogen content and the other hand its C/H ratio is as low as 1. And as soon as the soot getting mature the C/H ratio is also increased simultaneously.

Health effect of soot

Soot from the combustion chamber causes many health problems in humans as well as animals. The ultrafine particulate matter which Is also known as soot having very tiny particulates matter and due to having this characteristic it penetrates deep into lungs and affect the internal parts of our body. After going through many of

the research paper it seems that there are four major diseases which occurs in humans.

- Cancer,
- Respiratory disease,
- Cardiovascular disease,
- Liver kidney, and other soot toxicity diseases

Fig 1, shows all four major health problem associated with soot and how they affect the human bodies. Most hazardous disease among all of them is Cancer, which is caused by DNA adducts formation, DNA strand break or mutation in genes. A very well-known mechanism of soot transportation in which soot is absorbed by the airway epithelium and transported to the blood. Majority of cancers in human body parts causes due to this mechanism only. A population-based study done by Bosetti C, Boffetta P et al., (2007), which exposed those occupational exposures to PAHs (Polycyclic aromatic hydrocarbons) which is an important component of soot is relatively participated in urinary tract cancer and respiratory problems.

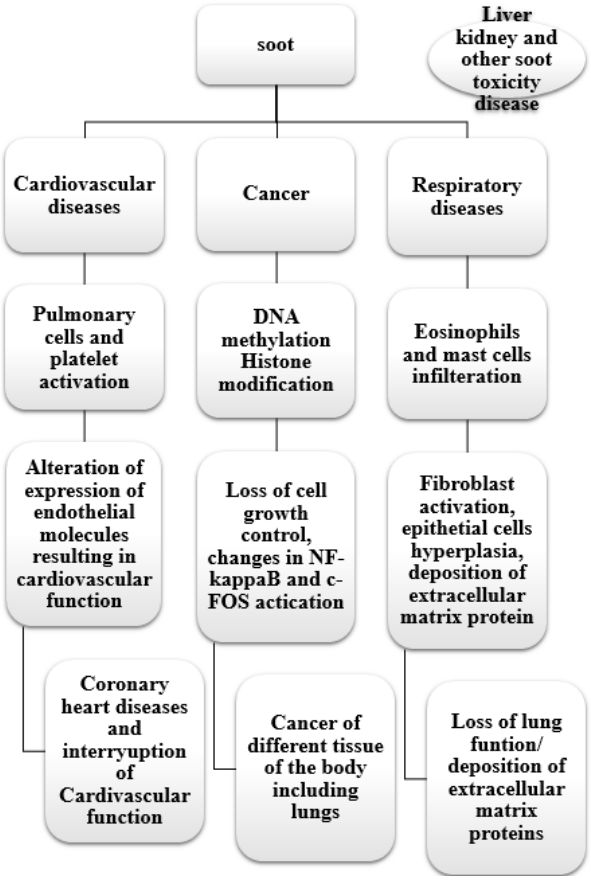

Figure 1 Major health problem associated with soot

Respiratory disease is the second most hazardous disease which is caused by the dysfunctional immune response by involving activation of eosinophil and mast cells infiltration. Soot from vehicle combustion chamber present in the environment firstly comes in contact with respiratory epithelium tissue which is a prat of lung in the human body. Respiratory process in human being is a most important function in humans or animals or plants, which is directly affected by soot particle or interrupted by soot particle by alteration in lung function. Hussain S, Thomassen LC et al., in 2010 studied and described that there is may be two kind of mechanisms helps in interrupting the reparation process. The first mechanism includes Reactive Oxygen species (ROS) generation, cell death, cell hyperplasia and other adjacent cells which is the direct contact –mediated dysfunctions of cells in lung due to soot particles. And the second mechanism deals with the involvement of systematic immune response which resulting in the development of fibrosis and tissue remodelling due to soot particle. And due to this mechanism, it causes problem in lung dysfunctions and breathing. Asthma and chronic obstructive pulmonary disease are the two main respiratory diseases which are reported in many studies due to soot in humans.

Third one is the cardiovascular disease which is caused by activation of pulmonary cells and platelets by Alteration of expression of endothelial molecules resulting in cardiovascular function and also include the coronary heart disease. And apart from all of these diseases soot particles enters in the human body through respiration process can damage some other body organs by some other unknown mechanism. It is the major concern now a days that the cardiovascular disease due to soot particles which is distal appearance from the site of exposure and the involvement of the systematic responses. According to the previous study on soot and its effect on humans showed that soot from vehicle is responsible for many cardiovascular diseases like, myocardial infraction, depression in patient suffering from coronary disease etc.

According to the previous study available provide us and showed us that soot is the reason behind all the above-mentioned disease and to protect the human health from soot which is an ultrafine particle has to removed or reduced from the ambient air or the environment. it has not only the impact on only human being it can affect animals, weather changes, irrigation problem, property, historical monuments etc.

Health risk assessment associated with soot

Health risk assessment which also known as health risk appraisal is a process which collect all the information about health issues and to assess an individual's health status, habits and risks. This process can alone reduce little of health risk and give a strategy to reduce or to remove the health risks. However, many of the papers described about the health risk assessment associated with respirable suspended particulate matter but not for soot emissions from vehicles. Therefore, it is necessary to also set a health risk assessment for the soot coming from the emission of vehicle. After going through many of the paper about HRA (health risk assessment), I studied one of the papers in which it is well defined that how respirable suspended particulate matter affect the human health with the help of mortality and morbidity rate. However, recent studies define the effect of respirable suspended particulate matter and provided lots of evidence of an association with mortality and morbidity. Mortality, it is defined as the number of being dead or refers the condition of being death due to general or any specific death. The number of deaths over some particulate period of time with specific reason or general reason among a particular type or a group of people is known as the mortality rate. Morbidity, it is referring to the condition of being diseased or ill or

unhealthy which include acute illness as well as chronic illness. Acute illness includes sudden onset and worsen or improve in short period of time whereas chronic illness present and progress slowly for the long period of time. Both the term mortality and morbidity played an important role to calculate the health risk assessment. Dr. Chinthala Sumanth and Anju Goel., (2012), described and calculate the health risk assessment for the RSPM and also included a case study of Bengaluru. In this paper a methodology is introduced to calculate health risk and quantify the health benefits by applying different kind of strategies.

Environmental impact of soot

Soot is not only affecting the human's health but directly or indirectly, it is also affecting the environment. Soot causes several impacts on environment because it is present everywhere while having the characteristics of travelling (covering) more distance and being suspended in the air ambient for the long time.

- Climatic condition disturbed due to soot present in the air ambient
- Haze appears in the more pollutant place where soot is emitted more. It is formed when sunlight interacts with particulate matter in the atmosphere.
- Rise in temperature due to soot particles which absorb the sunlight and it heats direct the surrounding of the air. And the soot deposited on the ice absorb the sunlight sand increase the melting rate of ice which also a reason of global warming.
- Soot is also correlated with acid rain. Soot present in the ambient air reacts with sulphur dioxide and nitrogen oxides with the help of atmospheric moisture to acidify precipitation which resultant in acid rain.
- Acid rain can degrade the quality of water like lakes, river and other sources which dangerous for aquatic life. And not only have the aquatic life it will degrade the quality of agriculture land by depleting the nutrients presented in soil and also damage the sensitive crops.
- Soot is also the reason behind discolouring and damaging the historical monuments, iconic building and other property in the form of acidic rain.

2. MATERIALS AND METHODOLOGY

Monitoring of soot done by flue gas analyser and the other pollutant like, CO, CO2, HC are measured by pollution under control machine which is certified by the Indian government. The soot is collected by the flue gas analyser on the filter paper which is inserted into the flue gas analyser. Data of other pollutant taken simultaneous on the basis of requirement of the study. This method is combined study of soot and other pollutant from vehicle emission is taken by combining both the equipment.

Flue gas analyser is a portable electronic device which is used to measure the emissions or to monitor the emissions of the product of combustion from domestic as well as commercial fossil fuelled appliances. It also displays the concentration of flue gases and also can measure the ambient air quality in rooms or buildings. The flue gas analyser which is used in this study is sensonic 1400 which is a further development from the tried and tested sensonic 1200 with new features.

Working of flue gas analyser

In order to understand the use of flue of flue gas analyser we need to understand flue gases. Flue gas are the gas which emitted in the air by flue which can be a pipe or channel for conveying exhaust gases from fireplace, boiler, oven, furnace etc. to monitor these gases there is a need of this kind of flue gas analyser. Probe holder which is connected to the flue gas analyser sucks the emission with help of gas probe pipe. This gas probe pipe transfers the flue gases through probe holder to the flue gas analyser and then the flue gas analyser analyse these gases and give the result on the LCD which is inserted on the top of the flue gas analyser. A filter paper is inserted on the probe holder on the given slot which collect the soot on the filter paper for the further comparison. I used this machine to only collect the soot and no other gases because many times it shows a bad result or wrong result for the measurement that's why I used another equipment for measuring the gases which I will mention below. They are two methods to analyse the soot collected on the filter paper mention below,

- By weight and
- By comparison of colour

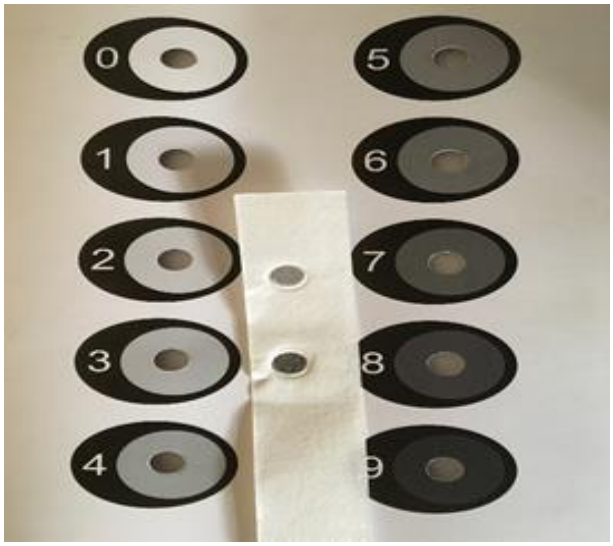

Figure 2 Soot comparison scale by Bacharach method

For first method, soot collected on the filter is weighted on the weighting machine and compare it to the filter paper before collecting the soot. And on the other hand, soot collected on the filter paper is compared to the soot measurement scale. From these two methods I preferred the second one because this method clearly shows that how much soot is comes in existence by the emission sources. Soot measurement scale is produced duly in the past nineteenth century which quantify the particulate emission of domestic as well as the industrial burners. Soot comparison scale developed on ringelmann method in which compares the visual aspects of the soot with a grey a scale. ringelmann used 0-5 spot for the comparison

of soot but this cannot clarify all the aspects of soot and smoke density that's by the new method is developed named as Bacharach method in which there is 0 to 9 spot available which gives clear and all the aspects of soot. Soot comparison scale also known as opacity index because this is the result of visualise of soot on the comparison scale.

Exhaust gas analyser

It is used to measure the exhaust gases from the combustion engine which can help in evaluating the engine performance and diagnose problem. This exhaust gas analyser capable of measuring Oxygen (O), Carbon Monoxide (CO), Carbon dioxide (CO2), Hydrocarbons (HC), Nitrogen Oxide (NO), Nitrogen dioxide (NO2). It is also used in giving the pollution under control vehicle certification and because of this we can fully trust on this exhaust gas analyser. It is reliable, cost effective, and very easy to handle. The exhaust gas analyser can be used for monitoring the emissions from gasoline as well as the diesel engine which includes the small engine as well as big engine like motorcycle, cars, tractor, and truck etc. the exhaust gas analyser equipped with a gas probe pipe and probe holder which collect the emission to the main setup where it is calculated that the engine is giving how much emission.

The above figure explained that both the equipment the flue gas analyser and exhaust gas analyser is connected with the monitoring computer. The work of the computer is only to display the results and to keep all the measuring data. Flue gas analyser and exhaust gas analyser both have their own display to show data. Both the equipment works parallel like when we are taking measurement of a motorcycle for the exhaust gases and after removing the probe of the exhaust gases, we insert the flue gas analyser. From flue gas analyser we are measuring or collecting only the soot sample on the filter. Same vehicle is used for the measurement of gases and soot at same time.

First of all, take the measurement from the exhaust gas analyser with the help of probe, from the tail pipe of the two-wheeler vehicle (motorcycle). The concentration will be displayed on the screen or monitor of the system after one to two minutes. Then note down the reading and save the data in the computer storage.

After finishing the first process of taking measurement just go through the second process which is the flue gas analyser. Before taking the sample of soot from the vehicle, a filter paper has to insert in the probe holder of the machine. Slots will be present for inserting the filter and collecting the sample on the filter paper. Take the sample of the soot and keep it in a plastic packet so it can be prevented from the other ambient gases.

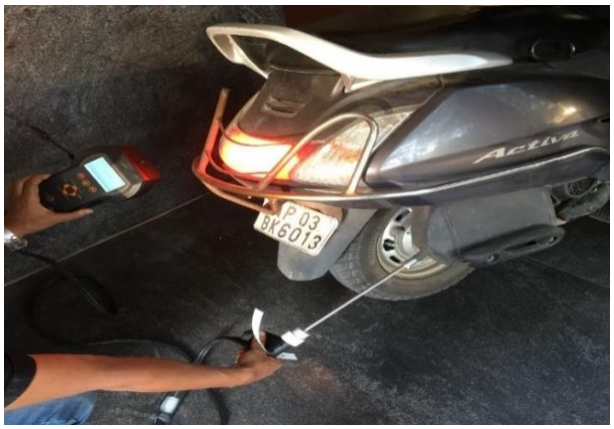

Figure 3 Collection of soot sample from vehicle

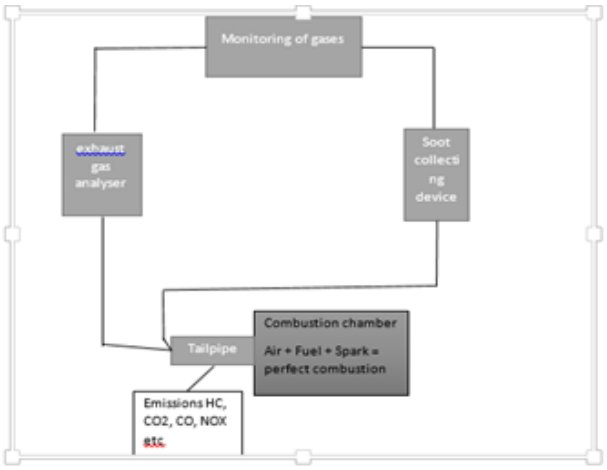

Figure 4 Schematic diagram of experimental setup

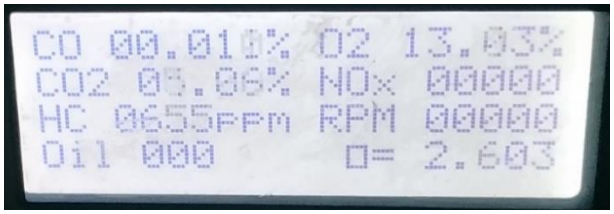

Figure 5 Display-exhaust gases emission concentration

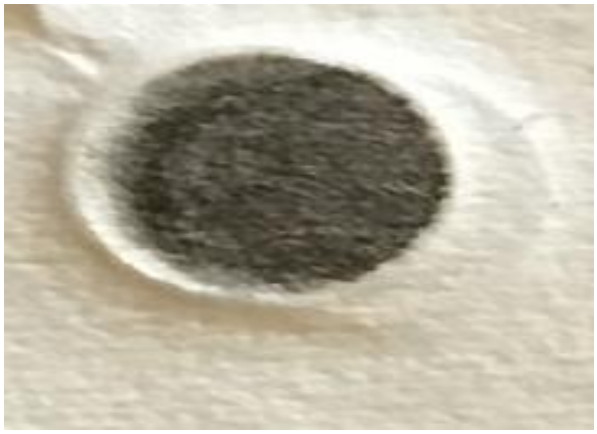

Figure 6 Soot sample collected on filter strip

After then the comparison process is started with the help of soot comparison scale. During this analysis we have to be very careful about selecting the numbers of the soot. The filter paper along with the soot comparison should be placed at eye level line at such distance that the section appears to be different degrees of uniform grey or black shades. For this type of study, it is necessary to take a greater number of sample and after taking all the samples

and the readings of the exhaust gas analyser, compare it to the other exhaust gas emission and set parameter meter that this much of co result this much amount of soot. Make a correlation between soot and the other pollutant emitted from the vehicle tailpipe.

Precaution Measure

In order to minimize the error in result and getting a scientific good result it is necessary to have some precaution which are mentioned below-

- Before taking the soot sample on the filter strip, this is to be ensure that the equipment is fully charged and connected to the electric power supply, if power supply is not given to the instrument or battery is fully charged, it will show error on the screen.
- Before taking the sample, it is to be ensure that the instrument is on for 5 to 10 minutes to heat the probe, if heat is not properly heated it will not collect the soot sample on the filter strip.
- Filter strip should be pure white and not used twice after taking sample because this filter strip plays an important role for comparing the soot with soot comparison scale. if any dust or not fully white strip is used it will give error to the result.
- Probe cone is properly inserted in the tailpipe of the vehicle, if any leakage is there in the emission, it will give error to the result.
- It is also to be ensure that ambient air and other dust particle did not comes in contact with the collecting sample.
- Sample should be kept in plastic bag suitable for the strip.
- During this analysis we have to be very careful about selecting the numbers of the soot. The filter paper along with the soot comparison should be placed at eye level line at such distance that the section appears to be different degrees of uniform grey or black shades.

Preventive Maintenance

Proper maintenance and systematic maintenance should be done while using the flue gas analyser which can give the instrument long life and proper reading. There are few steps which can safe and give the instrument a long life mentioned below:

- Don’t expose the flue gas analyser after substantial thermal shock before using it, and if by mistake it happens just wait for the instrument to normalise the temperature to working values.
- Don’t use the instrument without attaching a filter trap.
- While finishing the collection of soot sample don’t disconnect the instrument and allow it to draw some fresh air or wait for returning it to the normal value.
- Every after one year just calls the service man to complete overhaul and cleaning of the instrument.
- After collecting the soot sample from the vehicle kindly clean the gas probe before keeping it to the instrument case.
- Filter which is provided in the instrument should be clean or appears to be white if not replace the filter otherwise it will affect the machine and the result as well.
- Don’t use the same filter for collecting the soot

Study Area and Sample Location

There are two places in Warangal selected for the monitoring of air pollutant and sampling of soot from vehicle, named as GWMC public garden and the other one is Fatima junction. Warangal is located at 18.0◦N 79.58◦E and it has an average elevation of 302 meters. It is the second largest city after Hyderabad in Telangana state before the formation of smaller districts, spreading across 406.87 km2 with a population density of 811,844 as per 2011 census. In the recent past Warangal town has registered increase in its spatial growth. Due to the growth in population in Warangal.

Warangal served as the capital of the Kakatiya dynasty which was established in 1163. It is settled in the eastern part of Deccan Plateau made up of granite rocks

and hill formations which left the region barren making the cultivation depend on seasonal rainfalls. There are no river flows nearby warangal, which makes it to

Rely on Kakatiya Canal which originates from Sriram Sagar Project to meet the drinking water requirements. Located in the semi-arid region of Telangana, Warangal has a predominantly hot and dry climate. Summer starts in March, and peak in May with average high temperatures in the 42 °C range. The monsoon arrives in June and lasts until September with about 550 mm (22 in) of precipitation. A dry, mild winter starts in October and lasts until early February, when there is little humidity and average temperatures in the 22–23 °C range. Bhadrakali lake, Dharmasagar lake and Waddepally lake are the three famous lakes which adds scenic beauty and also are the major sources of drinking water.

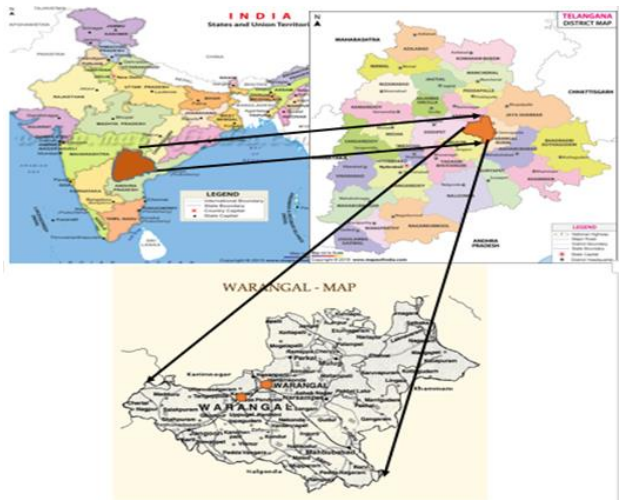

Figure 7 Index map of Warangal

Sampling location

There are two locations are selected for the monitoring of soot and sample collection of soot. The area selected for the study depend on the traffic, availability of the exhaust gas analyser and the location nearby NIT, Warangal.

1. GWMC Public Garden, Hanamkonda: it is located in Sai Nagar, Hanamkonda, Telangaga. Purpose of selecting this location for sampling because of heavy traffic near this location due to crossroad traffic (three roads intersect).
2. Fathima Junction, kazipet: it is also located on the tri road junction and on the national highway which means this road connected to the main city like Hyderabad. Due to connectivity of this road to main cities the vehicle movement is more which helps in this study.

3. RESULT AND DISCUSSION

Sample data for gasoline from 1st location (two-wheeler vehicle) is given in table-1

Table 1 Sample data for bike, Fuel type: Gasoline from 1st location

CO (%)	CO2 (%)	O2 (%)	HC (ppm)	Lambda	A/F Ratio	Soot No.
0.269	5.05	12.79	68	2.64	38.8	5
0.276	5.8	11.59	899	2.13	31.3	5
0.017	5.64	12.21	27	2.51	32.6	4
3.654	1.17	13.73	412	2.22	32.6	7
4.195	2.28	13.07	397	2	29.4	8
5.216	3.34	10.82	604	1.51	22.2	9
6.384	7.45	3.83	390	0.95	14	9
5.288	10.12	1.15	449	0.87	12.8	9
3.771	3.49	11.96	754	1.79	26.3	7
6.491	10.19	0.16	344	0.81	12	9
5.315	10.12	1.1	452	0.87	12.8	9
0.1	4.89	13.43	669	2.7	39.7	5
1.487	3.83	13.43	316	2.55	37.5	7
1.522	3.65	13.53	349	2.59	38	7
0.031	1.78	17.67	1145	2.69	39.6	4
0.076	3.7	14.82	38	3.72	54.8	4
0.02	3.5	15.19	35	4	58.8	4
0.268	12.96	1.84	250	1.07	15.7	5
0.232	13	2.06	180	1.09	16	5

Table 2 Sample data for bike, Fuel type: Gasoline from 2nd location

CO	HC	CO2	O2	Soot no.
0.38	315	2.75	15.72	5
1.64	419	0.99	17.25	7
0.09	147	0.18	20.38	4
0.03	146	0.18	20.52	4
0.46	410	2.78	15.73	6
0.36	839	0.09	18.99	5
1.83	647	2.09	15.06	7
0.48	424	0.79	17.74	6
1.27	139	1.9	16.59	7
0.08	73	3.51	15.36	4
0.36	269	4.13	14.06	5
0.21	186	0.74	19	5
0.13	61	1.46	18.3	5
0.58	207	0.95	17.15	6
0.35	311	2.83	16.52	5
0.43	614	1.28	18.82	6
0.05	101	0.2	19.35	4

Table 3 Sample data for cars Fuel type: Gasoline from 2nd location

CO	HC	CO2	O2	Soot no.
0.09	147	0.18	20.38	4
0.03	146	0.18	20.52	4
0.55	139	1.13	20.83	6
0.42	395	0.41	19.47	6
0.42	201	1.05	20.69	6
1.45	395	1.55	20.65	7
0.41	255	0.52	19.47	6
0.47	473	0.68	19.61	6
0.2	341	0.09	20.16	5

Effect of A/F Ratio on Exhaust HC

Fig.8 shows that exhaust Hydrocarbon production is lowest when the A/F ratio is slightly leaner than the ideal which means however hydrocarbons increase when it turns into the too leaner or too richer condition. Reasons behind this result are maybe the deposition of hydrocarbons in the combustion chamber because these carbons are porous, Hydrocarbons may be forced into pores as the A/F mixture is compressed and when combustion takes place in the combustion chamber fuel does not burn completely because of piston begins its exhaust stroke and hydrocarbons emit through the tailpipe. Or the other reason behind this result is misfire which occurs due to ignition, fuel delivery. Last but not least excess hydrocarbons emit through the tailpipe due to temperature if the temperature of air intake is low then it may cause poor mixing of air and fuel which results in a partial misfire.

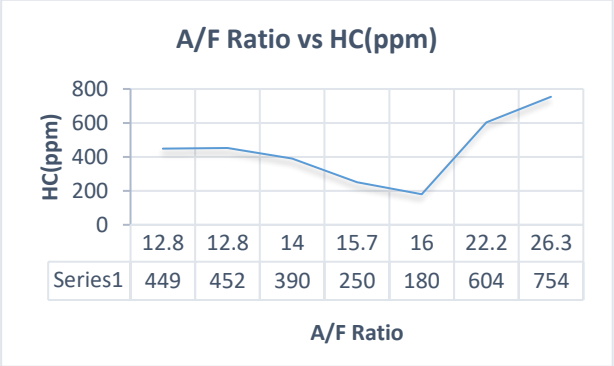

Figure 8 Effect of A/F on exhaust HC (ppm)

Effect of A/F Ratio on Exhaust CO

Fig.9 shows that when the A/F ratio is slightly leaner the level of CO concentration is the lowest however, CO concentration is increasing when the A/f ratio becoming richer and also increases when too leaner condition. CO is the result of incomplete combustion which means there is no complete fuel burn in the combustion chamber due to insufficient Oxygen. This may be because of several engine operating condition which includes defective O2 sensor, leaky fuel injector, and clogged air filter etc. if there is reach condition. But if there is a too lean condition, ignition coil, spark plug wire, spark plug and timing retire, etc. defective can be the reason of high CO.

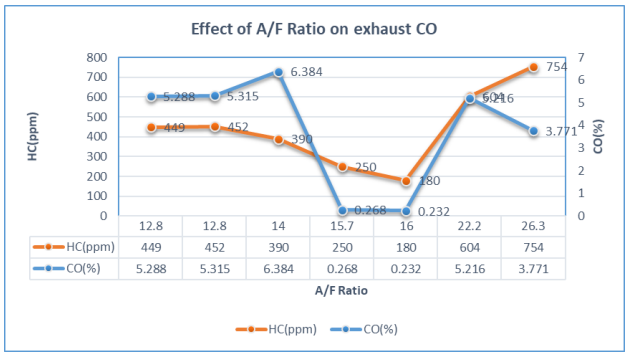

Figure 9 Effect of A/F ratio on exhaust HC (ppm), CO (%)

Correlation between O2 and CO

Fig.10. expresses the correlation between O2 (%) and CO (%), CO (%) is less where the O2 (%) is more or can say Carbon Monoxide emission is decreasing with the increase in Oxygen percentage. This represents that there is complete combustion in the combustion chamber of the vehicle when there is a sufficient amount of Oxygen. There can be errors occur if whole data will be graphed at once because of the air-fuel ratio. This graph is only to show the standard correlation between Oxygen and Carbon Monoxide. The mechanism responsible for the CO emission is the same as the previous one (defective Oxygen sensor, clogged air filter, leaky fuel injector, etc.).

Correlation between O2 and HC

Fig.10 showing the correlation between Oxygen and Hydrocarbon, Hydrocarbon is lowest when Oxygen is more which means there is complete combustion in the combustion chamber of the vehicle but if not, that means somewhere the mechanism of the vehicle is not running well or the vehicle is too old. That means if the A/F ratio is good and however it is giving or emitting more Hydrocarbons, good servicing and maintenance or the driving condition is responsible for it. Sometimes it happens that engine oil is getting into the combustion chamber and burns with the A/F ratio and maybe this is the reason behind it.

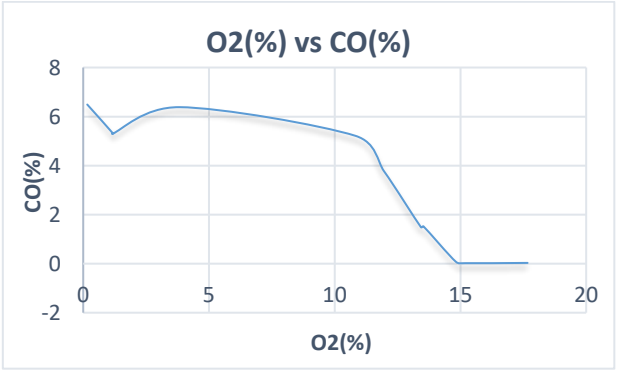

Figure 10 Correlation between O2 (%) & CO (%)

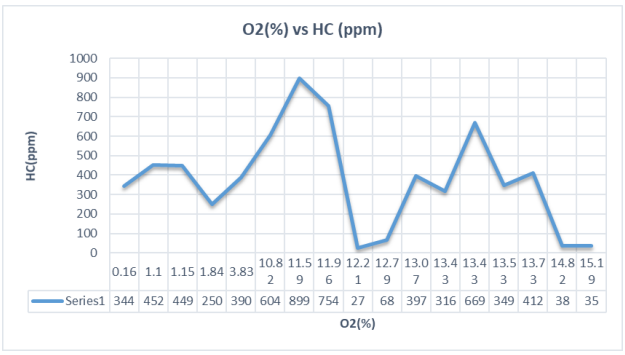

Figure 11 Correlation between O2 (%) and HC (ppm)

Air-Fuel Ratio and Soot Number

Fig.12 represents that soot number is lowest when the A/F ratio is slightly leaner and when it is too leaner than the result of soot number is increasing. But if too leaner or too richer conditions occur then the soot number is increasing drastically which means soot is also dependent on the Air-Fuel ratio. This happens because of a super dirty or clogged air filter and defective O2 sensor.

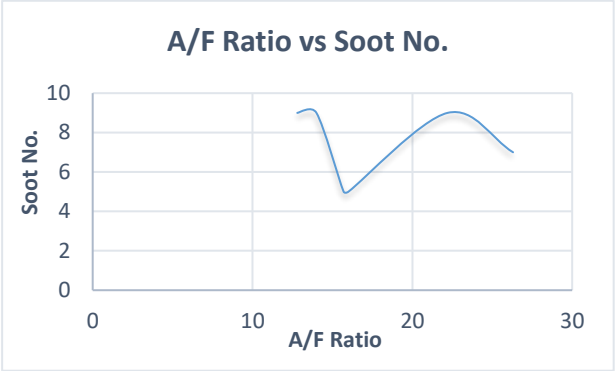

Figure 12 Effect of A/F Ratio vs Soot number

Correlation between CO and Soot number

Fig.13 showing that Soot number is low where the concentration of CO is low and if not, there is another mechanism that may happen due to the responsible machine of A/F ratio. Both are the result of incomplete combustion of fuel in the combustion chamber therefore both should be increasing or decreasing respectively. This graph is also giving the approximate proof for both Soot number and CO concentration are directly proportional to each other.

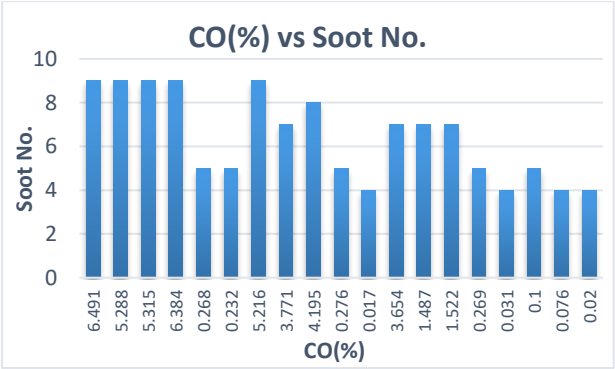

Figure 13 Effect of CO on Soot number

Effect of O2 on Soot number

Fig.14 is showing that the Soot number is dependent on Oxygen and also represents that the Soot number is lowest

when Oxygen concentration is more which means the combustion chamber is running smoothly and the A/F ratio is ideal or slightly leaner to the ideal condition of the A/f ratio. There is a complete burning of fuel when Oxygen is present in a sufficient amount in the combustion chamber to burn the fuel.

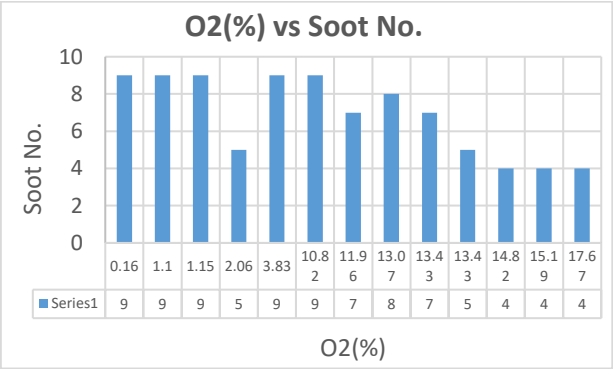

Figure 14 Effect of O2 on Soot number

The results show that there is a strong correlation between the CO, CO2, and the Soot Number measured. From this relation, the following mathematical equations can be best fitted. Equation-1 and 2 are given for Carbon Monoxide and Carbon dioxide respectively.

$$[(soot\ number) \times 5] \times CO(\%) < 4 \quad 1$$

$$[(soot\ number) \times 1.2] \times CO(\%) \geq 4$$

$$[(soot\ number \times 1.2)] \times CO2(\%) \quad (for\ all\ soot\ number) \quad 2$$

From the data, it can be observed that for a given soot number, the corresponding CO and CO2 concentrations can be predicted. And from the predicted CO and CO2 concentrations, the health risks can be obtained using the general risk equation. The risk equation states that the risk associated with a pollutant is equal to the average daily dose and the potency factor of the pollutant. The proposed protocol is shown in Fig.15.

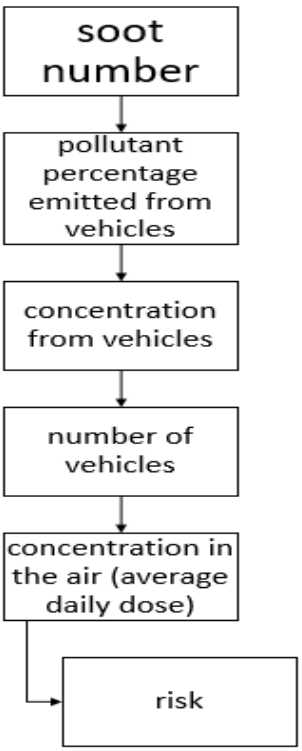

Figure 15 Protocol for measuring the health risk

Protocol for measuring health risk associated with soot

In order to measure the health risk associated with soot from vehicles we can use these general formulae in which we have to first find out the soot number after soot sampling and pollutant percentage emitted from vehicles. Then convert the pollutant percentage into ppm to find out the concentration of the pollutant at any place of the study. After getting these values we have to count the number of vehicles present in the study are from which this pollutant emitted. Concentration of pollutant which are present in the air ambient of the study area is calculated as the average daily dose. And after calculation of these scenario, health risk is defined.

4. CONCLUSION

The main objective of the study is to monitor the air pollutant and soot from the vehicles. To achieve the objective of the study, it is necessary to know about air pollution, types of air pollution, sources of air pollution and type of source which are deeply discussed in the previous sections. This study also shows the process of formation of soot, its characteristics, and how it comes in existence. With the help of all these information study goes to next level which is the monitoring of soot with help of flue gas analyser on the filter strip. And the other pollutant like Carbon monoxide, Carbon dioxide, Oxygen and Hydrocarbons are monitored with the help of exhaust gas analyser on two sites. After getting all the measurement and monitoring, the study correlated all the above pollutant mentioned above along with soot. This in return gives a broad idea to reduce or remove this pollutant from the ambient air or from the sources itself. Soot is so fine and tiny; it can stay in air ambient for weeks as suspended and only disperse or reduces while transportation. They can travel a long distance and that's why they are so harmful so this study gives an idea to

reduce at the source itself. And how it happens, the answer is to changes in equipment or fuel or type of driving, proper servicing of vehicle etc.

Further study gives a brief knowledge of health impact from air pollutant along with the SPM. Soot is also a kind of SPM (Suspended particulate matter) but due to having much more tiny size than PM2.5 And PM10, it has much more health impact on human as well as the environment, but this study mainly focusses on human health rather than environment. The equipment or the instrument like flue gas analyser and exhaust gas analyser is fully described in this study. This study also consists of the construction and specification of the instrument, which helps in handling the instrument smoothly and no any difficulties faced in between the monitoring process. Based on the study, the following conclusion were made:

1. The Soot value can be correlated with an index which can give an estimation about the health effects created by the release of the soot into the atmosphere.
2. It is observed that Carbon dioxide concentration increases with increase in Oxygen, thus it is also known as the indicator of complete combustion.
3. It is also observed that emission of Carbon monoxide concentration is more when there is less or no oxygen.
4. Soot production or emission is more when concentration of Carbon monoxide is more and less Oxygen or no Oxygen present there.
5. It is also observed during the study that, old vehicle which are 10-year-old, or more they are giving more soot and Carbon monoxide concentration to the ambient air.
6. If the combustion in vehicle is good enough it will give CO2 and water (H2O) and heat energy. That means water coming out of tailpipe of the vehicle can be an indicator of good combustion and less Carbon Monoxide and soot concentration.

5. LIMITATION OF THE WORK

The requirement of the sample of soot for the analysis of each parameter is different, and as a result, there is a variation in the sample collected. The collection of soot samples on site is difficult due to the presence of a greater number of vehicles on the road. Further, this study focused on only two-wheeler vehicle which have the 150 cc (gasoline using) engine. Further, many other possible cases where soot concentrations are significant could not be covered.

6. SCOPE FOR FURTHER STUDIES

The scope of the project can be extended to perform the following studies-

- When engine is started or in ignition without acceleration
- When engine is started with low or slight acceleration
- When engine is started and with medium acceleration
- When engine is started and with high acceleration

This study performs on a gasoline engine, so it can be performed on diesel engine because diesel engine emits more soot in comparison with gasoline using engine. The filter paper can be analysed for the presence of organic and inorganic fractions that are emitted from the vehicle.

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