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INVESTIGATIONAL ASSESSMENT ON GASEOUS STACK EMISSIONS FROM LIQUID FORM OF FUELS UNDER VARIOUS LOADING CONDITIONS

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ABSTRACT

Air pollution is defined as the presence of unwanted substance in the air medium which alters its quality. The substance which is present in the air medium which alter its quality is called as the pollutant. The main source of manmade air pollution are Industrial Emission and the Vehicular emission. Both the Industries as well as the Vehicles majorly uses liquid form of fuels for their operations. Both the Industries as well as the vehicles were at very high rate in case of the urban cities. Manali, the Northern part of Chennai city was selected for the study and industries were located within it. Industries were identified based on the usage of liquid form of fuel. The industries considered for the studies are Food and Beverage industry and the Rubber tyre manufacturing industry. The fuels used in the respective industries are high speed diesel and the furnace oil. Emission results were achieved through the stack monitoring. Stack monitoring was performed as per IS: 11255 (Part 1, Part 2 and Part 7) – 1985 procedure. The stack parameters considered for the studies are stack diameter, stack height, stack temperature, stack discharge and the stack velocity. Stack emission parameters considered for the studies are SO_x and NO_x Stack monitoring was conducted under two scenarios namely fully loading and partially loading of fuel rate. The stack monitoring results shows that the temperature produced from the stacks with respect to the partly loaded fuels shows the higher rate of stack temperature when compared to the fully loaded fuel. This excess temperature increases the concentration of the stack emissions. Thus it is concluded that the gaseous emissions coming from the stacks operated with the partial fuel rate will be higher when compared to the stacks operated with the fully loaded fuel rate.

KEY WORDS : Stack monitoring, Stack emissions, Stack fuel, High speed diesel, Furnace oil, Stack temperature.

INTRODUCTION

Chennai, the coastline Metropolitan city located at the Tamilnadu and south portion of India. Chennai lies at the cove of Bay of Bengal and was considered as the thickest populated city among all the cities in Tamil Nadu. The population of Chennai as per 2019 census was found to be 1.3 million. Recently The report given by Times of India states that, Chennai holds the second place for the highest Vehicle Density in India. The vehicular population of Chennai was almost of 3.7 million, which is almost twice that of the Chennai population. These vehicular movements creates a huge devastation to the Chennai Ambience. Because of the continuous vehicular movements Chennai city is also considered as one of the major cities which is highly affected due to Vehicular emissions. In addition to the Vehicular emissions Chennai City is also highly exposed to Industrial Pollutions also. Chennai is also well known for its Industrial activities and the major Industrial belts of Chennai city lies in the areas like Manali, Kathivakkam, Thiruvottiyur, Maraimalai Nagar and Ambattur. Among these

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areas major Industries like fertilizer Industry, Rubber Tyre Manufacturing Industry, Polymer and plastics industry, Petro Chemical Processing, food processing, Beverages, distilleries and Thermal Power plants were located at the belt of Manali and Thiruvottiyur. Also once an article from Times of India mentioned that the "Ennore thermal plant", "Fertilizer Industry" and the "Petro Chemical Industry" creates an alarm at the ground level. All the major Industries located at the North Chennai bay, are provided with the huge stacks which is been operated by the various forms of the fuels. All the toxic contaminants are discharged only through the stacks in to the Manali Environment. Stack Emissions related to the Industries were categorized based on the nature of the operations happens with in the industry. In few cases stacks are attached with the DC gen sets, which serves as a principal energy source for that particular industry and also in Rubber Manufacturing Industry, Some stacks are used to discharge chemical fumes during chemical processes. Thus in North Chennai, Industrial stacks serves as an interconnection source between the industrial discharge and the Ambient Environment (Pavlos *et al.*, 2019).

Meteorological constraints also plays a crucial and dynamic role in case of the Pollutant distribution in to the Environment. The factors considered for the meteorological studies are Wind Speed, Wind path, Relative Humidity, Atmospheric temperature, Stability Class and the Ambient Temperature (Karthick, 2018). The emission scenarios considered for the studies are Stack Specifications like Stack diameter, stack height, stack temperature, stack discharge, stack exit velocity and the stack emissions characteristics (Papagiannakis *et al.*, 2017).The concentration of the emission parameters also depends upon on one of the factors called loading rate. The term loading rate refers to the amount of fuel used in the stack engine. Fully loaded refers that the stack engine or the Gen set is operated with the fully filled fuel, whereas the term partly loaded refers to the stack engine or either the Gen set is operated with the partially filled fuel.

Agro based industries mostly used two forms of fuels for their combustion activities namely the agro based bio fuels and the other one was the wood oil. In this current study both the bio fuel and the wood oils are used at the various loading rates. The results shows that the partly loaded fuels shows more amount of emission concentration when compared to the fully loaded fuel rate (IS 11255. 1985). The production of electricity was performed in a fuel cell of varying loading rates. The emission studies were also carried out at the different loading rates. The emission parameters considered for the studies are Temperature, relative Humidity, sulphur di oxide and the oxides of Nitrogen. The results shows that the dynamic loading rate of the fuel cells produce more amount of emissions when compared to the static loading rate of the fuel cells (Dmitri Neshumayev. 2018). The partially loaded fuel produce more amount of heat and temperature when compared to the fully loaded fuel, especially in case of High speed Diesel as the fuel. In some studies this heat problem is resolved by replacing the High speed diesel (HSD) with the Water-Diesel Emulsion fuel (WDE). Experimental studies shows that the WDE produce less heat when compared to the other Some experimental studies were also done by injecting the diesel fuel at the various feeding rates. The parameters considered for the studies are combustion efficiency, thermal efficiency, exhaust gas concentrations, hydrogen combustion etc. The tests was conducted at the various loading rate of the fuel. The experimental results shows that the low level of fuel loading ends up with the more amount of toxic emissions when compared to the fully loaded fuel. In addition to that the engine efficiency are found to be very low in case of low level loading (Qifei Jian, 2015).

In a thermal power plant the efficiency of the stack is analysed by varying the fuel consumption rate of the stacks. The parameters such as the mass balance flow, thermal characteristics, flow rate of the emissions, combustion power were considered. The experimental results shows that the highest level of emissions occurs through the low level fuel feed rate and also the thermal efficiency of the stacks are also drastically increased under the low fuel feed rates. Experimental evaluation of stacks which is operated by gaseous forms of fuels were also considered in few studies. Gases like ammonia and gasoline were used as the source of fuel in the relative studies. The results shows that the temperature efficiency of the stacks were highly altered by the variations in the loading rate of the gaseous fuels. Experimental investigation on the diesel engines operated with various forms of diesel was also carried out. The various forms of diesel considered for the study are Diesel, Bio-Diesel, High Speed Diesel and Bio-Ethanol Emulsion. The performance of the fuel was analysed by

combustion activity and the emissions generated. The results shows that the heating value and the density of the fuels increase with the sulphur content and decrease with the bioethanol content. The emission concentrations for the parameters like $CO_{2,}$ CO, $SO_{2,}$ and NO_x were found to be relatively higher in case of Normal Diesel and lower in case of Bio-Diesel and Bio-Ethanol (Yie Hua Tan *et al*., 2017). The stack monitoring of a cement industry at Korea was carried out on the basis of the various loading rates. Results of the stack monitoring shows that the drastic increase in temperature and the Sulphur dioxide during the low rate of loading (Kashid Rashid, 2017). The combustion, emission results of an single cylinder diesel engine also shows that the more amount of emissions and temperature were generated during the partly loading when compared to the fully loading (Jung-Han Yoo *et al*, 2006).

The study area recognised for the investigation are Manali Industrial Area, Which is located at the Northern part of Chennai. The geographical location of the Area is 13˚10'19'' N 80˚15˚06''E.

The pollutants released from the stacks are categorized into particulate matters (PM) and other gaseous emissions like oxides of sulphur (SOx), oxides of nitrates (NOx), carbon monoxide (CO), ammonia (NH_3), hydrogen sulphide (H_2S) and volatile organic compounds (VOC_s).

Based on the literature review done, the objective of the study are as follows:

- Selection of relevant Industries from Manali Industrial Area (Liquid based fuel)
- Identifying the Geographical location of the respective Industries
- Study on fuel characteristics
- Collection of the Emission parameters based on the Loading rates (Fully loaded, Half loaded)
- Inference of the various stack emission results based on the loading rate of the fuels.

MATERIALS AND METHODS

The present study was carried out with respect to the Industrial Selection, Fuel characteristics studies and the emission scenarios. The industries selected for the studies are food and beverage Industry and the Rubber tyre manufacturing Industry. The geographical location of the industries was detailed in Table 1.

FUEL CHARACTERISTICS

Both the Industries were operated with the liquid forms of fuel. The commonly used fuels are High Speed Diesel (HSD) and the Furnace oil (FO). High speed Diesel is a type of diesel which possess lower viscosity and the higher volatility when compared to the normal fuel. HSD are normally used for the heavy duty engines as well the higher capacity DC gen sets. The characteristics of the HSD was mentioned in the Table 2. Furnace oil is a dark viscous sediment fuel obtained from a fractional distillation of crude oil. The characteristics of the furnace oil is detailed in the Table 3. The stack capacities and the mode of the fuel of the respective Industries were explained in detail in Table 4. The total number of stacks located within the Industry and their capacities are described in Table 5.

Stack Monitoring Procedure

Table 2. High Speed Diesel Characteristics

S.No	Parameters	Specifications
1	Density (kg/m^3)	840
2	Water Content, %v	0.03
3	Flash Point, ˚c	23
4	Kinematic viscosity	3.0
5	Sulphur Content %w	0.10
6	Ash, % w	0.01

Table 3. Furnace oil Characteristics

S.No	Parameters	Specifications
1	Density (kg/m^3)	760
2	Water Content, %v	0.02
3	Flash Point, ˚c	75
4	Kinematic viscosity	1.6
5	Sulphur Content %w	1.7
6	Ash, % w	0.04

The Industries considered for the studies are Rubber tyre manufacturing Industry and the Food and the beverage Industry. Liquid form of fuel is only

Table 1. Industries and their Geographical Location

S.No	Type of the industry	Geographical location
1	Rubber Tyre Manufacturing	Latitude 13°10´40´´N Longitude 80°18´35 ´´ E
2	Food and Beverage Industry	Latitude 13°10´45´´N Longitude 80°18´29 ´´ E

Table 4. Industries and their Mode of Fuel

S.No	Type of the Industry	Name of the Stack	Type of Fuel Used
1	Rubber Tyre Manufacturing	Boiler 1	Furnace Oil
		Boiler 2	Furnace Oil
2	Food and Beverage Industry	Dg set 1	High Speed Diesel
		Dg set 2	High Speed Diesel
		Dg set 3	High Speed Diesel

Table 5. Industries and the stack Specifications

S.No	Type of the Industry	Name of the Stack	Capacity of the Stack
1	Rubber Tyre Manufacturing	Boiler 1	20 T
		Boiler 2	20 T
2	Food and Beverage Industry	Dg set 1	750 KVA
		Dg set 2	750 KVA
		Dg set 3	1000 KVA

considered for the studies and it is elaborated in the above sections. The parameters considered for the Stack monitoring are Oxides of Sulphur (SO_x)and Oxides of Nitrates (NO_x). The stack monitoring was done with the stack monitoring kit. The sampling procedure was carried out as per IS 11255 (Part 1, Part 2 and Part 7) 1985.

The sampling train has a jet which is used to collect the stack samples of gaseous emissions and the particulates (PM), The internal diameter of the jet is 7mm. Sampling probe is used to connect the stack with the sampling train.

As per the IS11255, part 2 measurement of $SO_x$was given by the formula:

$$C = 0.032 \times \frac{(V - V_b)}{V_N} \times N \times \frac{V_{s0}}{V_a}$$

where V = volume of barium perchlorate titrant used for the sample, mL; V_b= volume of barium perchlorate titrant used for blank, mL; N= normality of barium perchlorate titrate, g-eq/L; V_{s0} = total solution volume of sulphur dioxide, ml; V_a = volume of sample aliquot titrated, mL and V_N = volume of gas sampled through the dry gas meter (normal conditions), m^3.

As per IS 11255, part 7, measurement of $NO_x$was given by:

$$C = \frac{(A_s - A_b)}{V_{sc}} \times K_c \times 1000 \times 2 \times F$$

where A_s = absorbance of the sample; A_b = absorbance of the blank; C = concentration of NO_X as NO_2 corrected to standard conditions, mg/Nm^3; *F* = dilution factor (that is, 25/5, 25/10 etc); K_C = spectrophotometer calibration factor and 2 = 50/25 the aliquot factor.

RESULTS AND DISCUSSION

The present study was focused under two scenarios namely, the industries which uses the liquid form of fuels and the emissions generated from the industries at various loading conditions. Another environmental parameters which highly influence the emission discharge from the stacks are Stability conditions, Rural Mixing height and the urban mixing height. Stability conditions totally depends upon on the Environmental Lapse rate (ELR) of the Local terrain. The average wind speed at the local terrain was found to be 0 to 3.6 m/s.

The stack emission studies were carried out at the Industries located at the Northern bay of Chennai, Manali. The main criteria considered for the industrial selection was the usage of liquid form of fuel for their Industrial activity. The analysis of emission studies was done through stack monitoring. The stack monitoring was done on hourly basis, during the peak discharge of the plume through the respective stacks. The stack parameters considered for the studies are stack diameter, stack height, stack thermal efficiency (temperature), stack velocity of plume gas, stack plume gas flow rate and the concentration of the gases. The gaseous parameters considered for the studies are oxides of sulphur (SO_x) and oxides of nitrates (NO_x). The current study estimate the variations in the gaseous emissions under fully loaded and the partly loaded conditions. The stack specifications for the industries under fully loaded and partially loaded is mentioned in the Table 6 and

7.

Stack Emission Results Analysis: Stack monitoring related to various stack emissions was carried out at two industries (food and beverage Industry and Rubber tyre manufacturing Industry). Both the industries use liquid form of fuels namely High Speed Diesel and Furnace Oil. The gaseous parameters considered for the study are SO_x and NO_x. The emission results of the SO_x and NO_x is given in Table 8 and 9. The comparison of results between the fully loaded stacks and the partially loaded stacks are explained in Fig. 1 and 2. Emission studies pertaining to the solid form of fuels like Coal, Wood, Rice husk and the Bio mass is not possible because of the in feed provisions provided in those stacks. All the solid based fuel stacks has to be operated in fully loaded conditions only. Whereas the possibility of the varying loading

Table 6. Stack Specifications and Emission Parameters under Fully loaded conditions

S. No.	Type of the Industry	Name of the Stack	Stack Height (m)	Stack Diameter (m)	Stack Temperature (Kelvin)	Stack Velocity (m/s)	Stack Discharge Rate (Nm^3/Hr)
1	Rubber Tyre Manufacturing Industry	Boiler 1	47	1.2	435	7.16	20546
		Boiler 2	47	1.2	446	7.86	20649
2	Food and Beverage Industry	Dg set 1	47	1.2	423	7.16	20546
		Dg set 2	47	1.2	428	7.86	20649
		Dg set 3	30.50	0.80	595	10.89	10077

Table 7. Stack Specifications and Emission Parameters under Partly loaded conditions

S. No.	Type of the Industry .	Name of the Stack	Stack Height (m)	Stack Diameter (m)	Stack Temperature (Kelvin)	Stack Velocity (m/s)	Stack Discharge Rate (Nm^3/Hr)
1	Rubber Tyre Manufacturing Industry	Boiler 1	47	1.2	528	7.25	20632
		Boiler 2	47	1.2	546	7.92	20763
2	Food and Beverage Industry	Dg set 1	47	1.2	519	7.28	20632
		Dg set 2	47	1.2	493	7.98	20686
		Dg set 3	30.50	0.80	686	10.93	10093

Table 8. Stack Emission Concentrations – Fully loaded conditions

S. No.	Type of the Industry	Name of the Stack	Stack Fuel	Conc of SO_x (mg/Nm^3)	Conc of NO_x (mg/Nm^3)
1	Rubber Tyre Manufacturing	Boiler 1	Furnace Oil	278.6	5.49
		Boiler 2	Furnace Oil	213.09	6.39
2	Food and Beverage Industry	Dg set 1	High Speed Diesel	25.33	11.35
		Dg set 2	High Speed Diesel	14.28	10.65
		Dg set 3	High Speed Diesel	28.94	13.02

Table 9. Stack Emission Concentrations – Partly loaded conditions

S. No.	Type of the Industry	Name of the Stack	Stack Fuel	Conc of SO_x (mg/Nm^3)	Conc of NO_x (mg/Nm^3)
1	Rubber Tyre Manufacturing	Boiler 1	Furnace Oil	296.3	8.63
		Boiler 2	Furnace Oil	246.4	9.45
2	Food and Beverage Industry	Dg set 1	High Speed Diesel	29.33	15.56
		Dg set 2	High Speed Diesel	26.28	15.42
		Dg set 3	High Speed Diesel	41.69	16.78

operations is possible only in case of liquid forms of fuels.

The stack monitoring was carried out at the

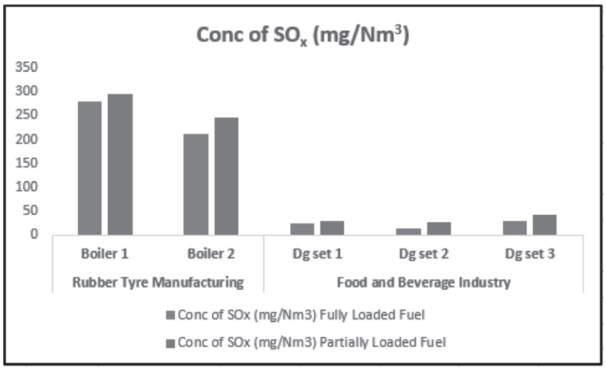

Fig. 1. Comparision of Stack Emissions (SO_x)

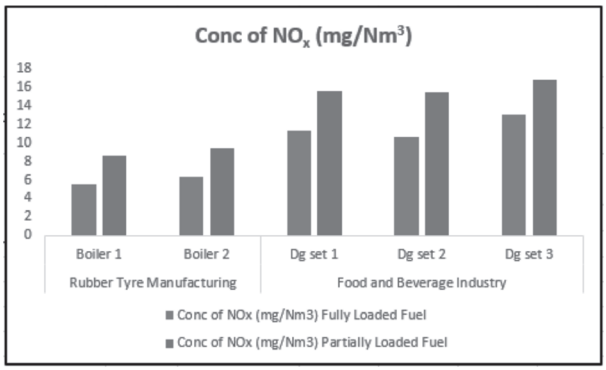

Fig. 2. Comparision of Stack Emissions (NO_x)

respective industries based of IS 11255 (Part 1, Part 2 and Part 7) 1985 procedure. While reviewing the stack Monitoring outcomes, it is been observed that the some variations are there in the flow rate (discharge) and the velocity of the plume gas in both the industries in all of the respective 5 stacks. But the variations are very less and hence it can be negligible. On the other hand definitely there is an increase in the stack temperature on varying the fuel loading rates. This occurs in both the industries and the both forms of fuels. Similarly variations also been identified in the gaseous parameters ($SO_x$and $NO_{x)}$ also.

The gaseous emissions shows the higher rate of concentrations with respect to the partial loading when compared to the fully loading of the liquid fuels. This is due to the excess generation of the Stack temperature in case of partial loading of fuel. The excess temperature produced results in the increase of the concentration of Gaseous matters. Thus the partly loading of fuels shows the higher rate of gaseous emissions in both the Industries, In addition to that the industry which uses the Furnace oil as the fuel produces more amount of gaseous emissions under partly loading scenario, This is due to furnace oil is the residue oil which is obtained at the final stage of product in the petroleum distillation process. Under partial loading furnace oil produce more amount of stack temperature when compared to the fully loading. The highest stack temperature on partial loading on furnace oil was found to be 546 K, where as in case of HSD was found to be 686 K respectively. From the overall stack monitoring results, it is concluded that the liquid forms of fuels under partial loading produce the higher rate of temperature and gaseous emissions, when compared to the fully loading.

CONCLUSION

Stack emission monitoring studies were carried out for the industries operated with liquid form of fuels of various loading rates. The industries considered were Food and beverage industry and the Rubber tyre manufacturing Industry. The total Number of stacks considered for the study are 5. The stack monitoring was done as per IS: 11255 (Part 1, Part 2 and Part 7) – 1985 procedure[10]. The stack emission parameters considered for the studies are $SO_x$and NO_x.

From the stack monitoring results, it has been observed that the partial loading rate of fuels produce more amount of Temperature and the gaseous emissions when compared to the fully loaded rate.

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