METHOD TO CONTROL EMISSIONS OF SULFER OXIDES FROM MOTOR VEHICLES

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Abstract : The Environmental Protection Agency (EPA) states that emissions from vehicles are responsible for about two-third of air pollution in urban areas. The major pollutants emitted by motor vehicles that have damaging effects on both human health and ecology are SO_x (oxides of sulfur), NO_x (oxides of nitrogen) and CO_x (oxides of carbon). This study suggests the economical and effective methods to curb SO_x gas emanating from the motor vehicles. We propose a chemical filter, which can absorb SO_x appreciably and the released by-products. The by-products so obtained, have potential commercial applications. The average concentration of SO_x gas when measured without the filter is reported to be 1430 PPM and 167 PPM for petrol and CNG car respectively. Also when the exhaust gas from the car was passed through the proposed chemical filter, the concentration of SO_x gas was found to be reduced to 765 PPM and 41 PPM, respectively. Given the fact that de-sulfurisation of fuel is an expensive process and is not practiced widely, we proposed filter developed with the capability of reducing SO_x emissions drastically and thus mitigating its toxic effects to an appreciable extent.

Keywords: Air pollution, Filter, Oxides of sulfur, Vehicular emission

1. INTRODUCTION

The continuous rise in air pollution is indeed a serious health hazard in the twenty first century. A survey finds 35% of children in India to have weak lungs with Delhi being on top of the list, with 40% of its children reported to have weak lungs. Air pollution not only affects our health by giving rise to inhalation diseases and skin disorders but also causes acid rains and water contamination (1). In the present work, we have focused on the oxides of sulfur in the exhausts from motor vehicles that cause harm to the environment, plant life, wildlife and humans(2). This effect also passes into food chain. Oxides of sulfur not only cause health-related diseases, but also play an important role in acidification of aquatic ecosystems, leading to change in diversity and loss of aquatic animals and plants and result in deforestation too .

Traditionally, measures are taken to reduce localized ground-level concentrations of sulfur oxides (SO_x). However, sulfur compounds reaching upper atmosphere lead to in-calamitous effects in the environment, far from their original sources [4]. Several studies have shown short-term exposure to sulfur dioxide (SO_2) at concentrations above 1 milligram per cubic meter, measured on a 10-minute average is considered to be fatal for humans Hence, the main objective of the present work was to reduce the emission of SO_x. We propose an economical chemical filter which is able to absorb the SO_x from the vehicular emission even when present in low concentrations. The proposed chemical filter provides an economical way to curb the problem of pollution caused by vehicular emission[5].

Flue gas analyzer is used to examine the sulfur oxide emissions from the motor vehicles that are either petrol or CNG driven. The filter prototype that we have designed and developed, involves wet flue gas desulfurization and causes chemical reduction of sulfur oxide exhaust from the vehicles, which is better than the previously adopted dry methods [6]. The slurry, designed constitute combination of chemicals like Calcium Hydroxide [8] . The byproduct obtained, which is calcium sulfite has commercial applications like in gypsum production [8].

2. METHODOLOGY

Emissions from silencer of the motor vehicle were measured using the flue gas analyzer from Indus scientific Pvt. Ltd. The analyzer was first calibrated, and then was connected to a probe, which was injected into the silencer of the vehicle. Suction-enabled flue gas analyzer was then powered. Sets of readings were automatically fed into the computer through a USB connector.

After the initial sets of readings were taken, a fresh slurry of calcium carbonate in water base was prepared in an air-tight durable plastic container. The silencer of the vehicle was then connected via the pipe to the container filled with slurry. The engine was ignited and the flue gas was then bubbled through the slurry and the probe of flue gas analyzer was inserted into the gas outlet pipe of the container. Sets of readings were then recorded into the computer automatically.

FIGURE 1 : Photos of experiment performed

The choice of calcium carbonate was made on the fact that it was inert to flue gas. Similar process of filtering out sulfur oxides from flue gas was repeated using calcium hydroxide slurry too and the readings were noted.The steps were repeated for pure flue gas to ensure results. It was observed concentration of emitted sulfur oxides did not reduce.

To examine the trapped sulfur oxides in slurry, an alternative method was used. The procedure involved qualitative analysis for sulfites and sulfates were studied on the residual in the form of precipitate**.** The procedure of the quantitative analysis can be seen in**Table I** and **Table II**.

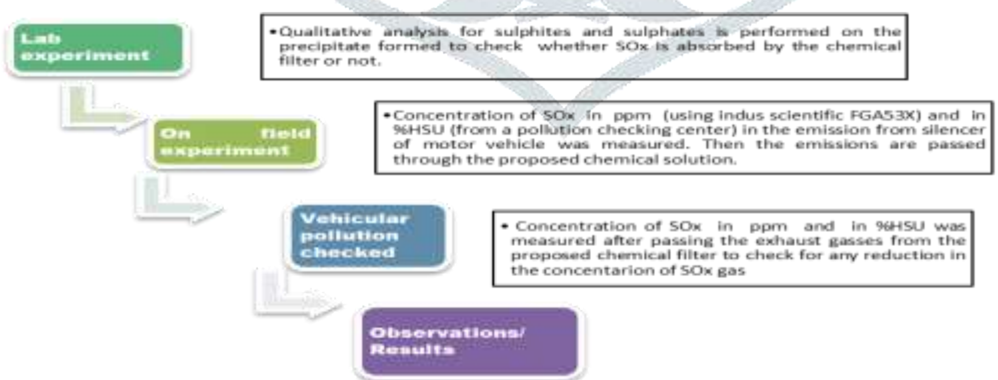

FIGURE 2: Overview of the methodology

3. RESULTS AND DISCUSSION

The test car used in the present work was SANTRO 2004 model, having both petrol and the CNG mode. The 2004 model was chosen since old cars would emit higher concentrations of SO_x in to the atmosphere. The same car was used to check the reduction in the levels of $SO_{x,}$ when operated in petrol

mode or in the CNG mode to rule out any discrepancies in the observed readings due to difference in the design of engines of two different cars.
The results showed remarkable reduction in the undesirable pollutants such as SO_x , when exhausted gas (from car) was brought in contact with an aqueous solution or slurry containing a lime-based sorbent. The most common sorbents are lime ($Ca[OH]_2$) and limestone ($CaCO_3$) [6].

3.2 Laboratory experiments

The exhaust gases were allowed to pass through the setup containing the slurry of lime or limestone. A slurry of calcium hydroxide and calcium carbonate was prepared with varying concentration. The lime or limestone reacts with the SO_x in the flue gas to create insoluble calcium sulfite ($CaSO_3$) (8) as shown in the equation below:

Limestone: $CaCO_3$ (s) + SO_2 (g) → $CaSO_3$ (s) + CO_2 (g)
Lime: $Ca(OH)_2$(s)+ SO_2 (g) → $CaSO_3$ (s) + H_2O(l)

The slurry in the proposed chemical filter absorbed SO_x gas, leading to formation of sulfites. The presence of sulfite ions, corroborated the absorption of SO_x gas.

Table-I Tests performed for the presence of sulphite ions

Reactant	Procedure	Observation	Inference
$CaCO_3$	**1.**Add dilute hydrochloric acid to suspected sulphite **2.** Test any gas evolved with fresh potassium dichromate(VI) paper. **3.** Add barium chloride or barium nitrate solution.	**1.** Gas evolved. **2.**Gas evolved does not turn dichromate paper from orange to green. **3.**No white precipitate formed.	Sulphite ion absent.
$Ca(OH)_2$	1. Add dilute hydrochloric acid to the suspected sulphite. 2. Test any gas evolved with fresh potassium dichromate (VI) paper. 3. Add barium chloride or barium nitrate solution.	1. Acrid choking sulfur dioxide gas formed. 2. The dichromate paper turns from **orange** to **green**. 3. A white precipitate of barium sulfite which dissolves in excess hydrochloric acid to give a clear colourless solution.	**Sulphite ion present**

Figure 3: Experiment performed in the laboratory

As per the literature, the resultant calcium sulfite may be further reacted with oxygen to produce Gypsum ($CaSO_{-4}$.2 [H_2O]) by the following reaction:

$CaSO_3$ (s)+ ½O_2 (g) + 2H_2O(l) → $CaSO_4 \cdot 2(H_2O)$(s)

The present study showed no presence of sulphate ions.

3.2.1 Test for presence of sulphate ion.

Reactant	Procedure	Observation	Inference
$CaCO_3$	Take the precipitate formed if any in calcium carbonate solution add distilled water to make its solution. Add dil. HCl solution to make the acidic medium and add barium chloride ($BaCl_2$).	Clear solution with no visible white precipitate.	No sulphate ion present.
$Ca(OH)_2$	Take the precipitate formed if any of calcium hydroxide solution add distilled water to make its solution. Add diluteHCl solution to make the acidic medium and add barium chloride ($BaCl_2$).	Clear solution Withno visiblewhite precipitate	No sulphate ion present.

Table-2: Test for presence of sulphate ion.

The experiment performed confirmed the efficiency of Calcium hydroxide slurry in reducing the SO_x gas, emitted from the car exhaust. Further different concentrations of Calcium hydroxide were studied to design an effective chemical filter.

3.3 Real-time experiment in the college premises

In the present study, we have taken same car SANTRO 2004 Model which can be operated with two different modes (Petrol mode and CNG). The experiment was performed for ten minutes. The exhaust gases were bubbled through the chemical filter. The concentration of SO_x (in PPM) emitted by the car silencer was measured using gas analyser (INDUS FGA53X instrument). Afterwards, the flue gas was bubbled through our chemical filter and the concentration of SO_x gas was again measured. This experiment was performed for both petrol and CNG mode. Following observations were made:

3.3.1 On a petrol car (SANTRO 2004 Model)

1. It was observed that the average amount of SO_x emitted (for ten minutes) by the car withoutusing any chemical slurry was **1430 PPM** approximately (as detected using INDUS FGA53X instrument).

2. The exhaust gases are made to flow through the proposed chemical filter (consisting of a chemical slurry of $Ca(OH)_2$). It was observed that the amount of SOx is reduced to **765 PPM, which is nearly 46.50% of reduction.**

3.3.2 On a CNG car (SANTRO 2004 Model)

1. Initially, we found that without using any chemical slurry the amount of SO_x emitted (for ten minutes) by the CNG car was **167 PPM** approximately (as detected using INDUS FGA53X instrument).

2. After passing the exhaust gasses through the chemical filter the amount of SO_x isreduced to **41 PPM, that is nearly 75.44% of reduction.**

4.The striking features of the Results

- Initially, in the first five minutes, the concentration of SO_x gas was observed to be very high, both for Petrol car and for CNG car. The concentration of SO_x in case of petrol car is more than in CNG car clearly indicating CNG to be a cleaner fuel in comparison to petrol.

- In the initial five minutes, the average concentration of SO_x emitted by the **petrol car**, as measured directly was observed to be 1947 PPM and the average concentration of SO_x after passing through the flue gas from the chemical filter is observed to be 959 PPM. (**Figure 4**)

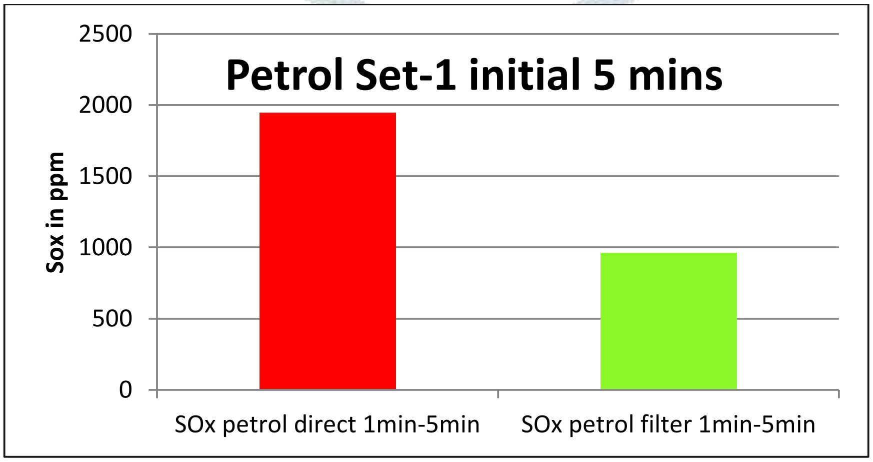

Figure-4

- In the initial five minutes, the average concentration of sulfur oxides emitted by the **CNGcar**, as measured directly was observed to be 194 PPM and the average concentration of SO_x after passing through the flue gas from the chemical filter is observed to be 54 PPM. (**Figure-5**)

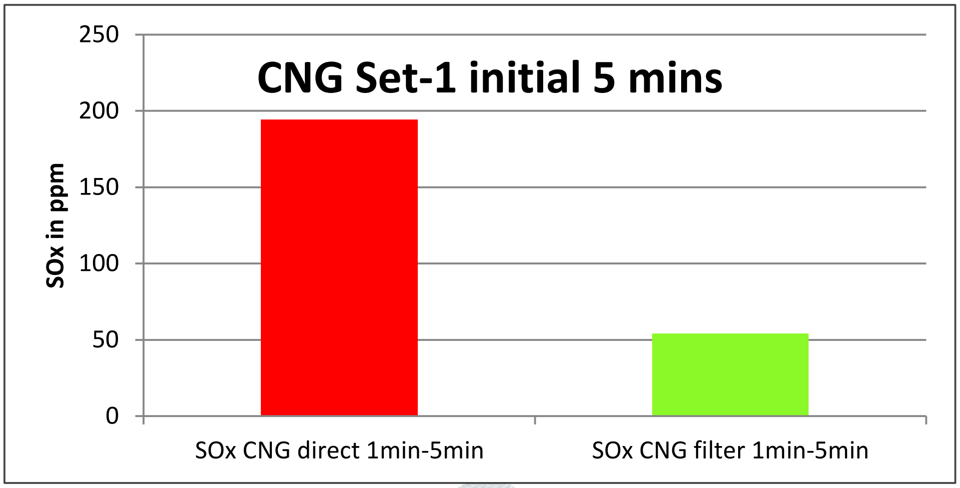

Figure-5

- After five minutes (6 Min-10 Min) the concentration of SO_x gas is reduced automatically as the engine is now heated enough, still, the proposed chemical filter is successfully able to reduce the SO_x gas from the car exhaust.

- For the last five minutes (6 Min-10 Min) the average concentration of SO_x emittedby the **petrol car**, as measured directly was observed to be 944 PPM and the average concentration of SO_x after passing through the flue gas from the chemical filter is observed to be 570 PPM. (**Figure-6**)

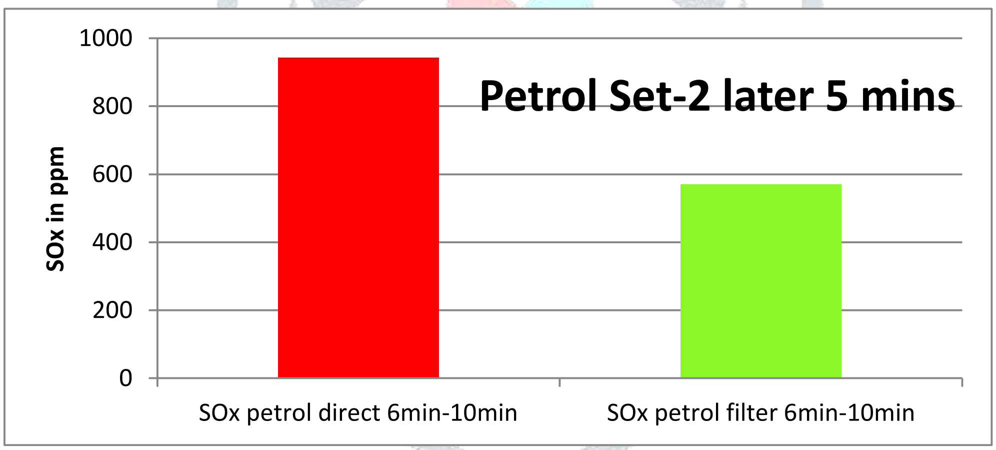

Figure-6

- For the last five minutes (6 Min-10 Min) the average concentration of Sox emitted by the **CNG car**, as measured directly was observed to be 139 PPM and the average concentration of SO_x after passing through the flue gas from the chemical filter is observed to be 27 PPM. (**Figure-7**)

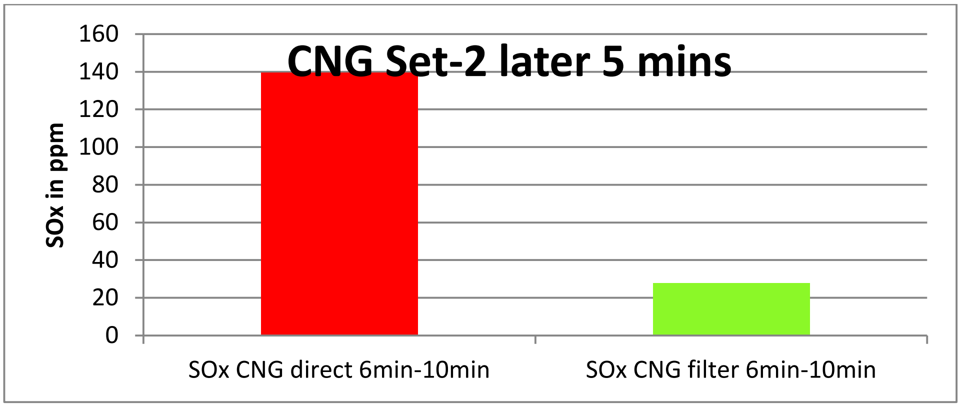

Figure-7

- Figure 8 gives a comparison between a Petrol car emission and CNG car emission with and without the use of the chemical filter.

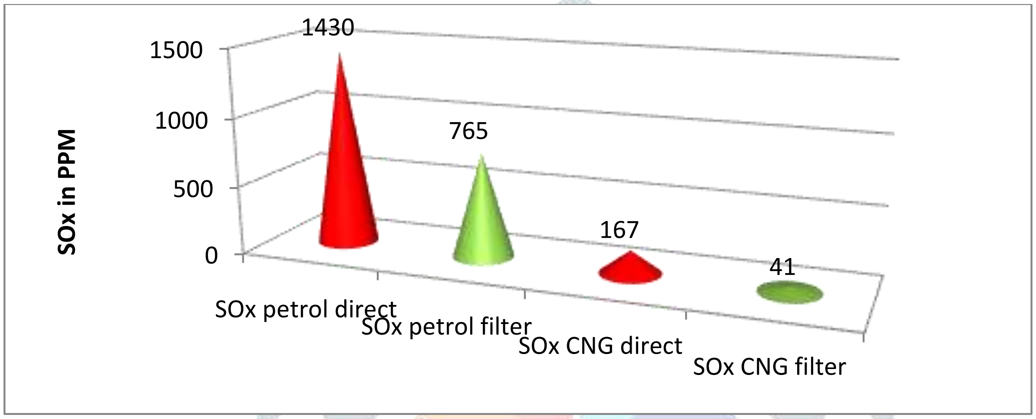

Figure -8

PETROL DIRECT: Measurement of concentration of SO_x directly from the exhaust of HYUNDAI SANTRO Petrol car.

PETROL FILTER: Measurement of concentration of SO_x via the filter fitted at the exhaust of HYUNDAI SANTRO petrol car.

CNG DIRECT: Measurement of concentration of SO_x directly from the exhaust of HYUNDAI SANTRO CNG car

CNG FILTER: Measurement of concentration of SO_x via the filter fitted at the exhaust of HYUNDAI SANTRO CNG car.

4. CONCLUSION

The present work proposes a chemical filter which can effectively reduce the SO_x gas emissions from the vehicles. This will not only help in reducing the sulphur content in the air and can contribute in containing air pollution to some extent, the byproducts formed in the experiment can be of commercial use. On further optimization, our proposed method has the potential to substantially bring down the concentration of toxic sulfur gases in the air (released by vehicular emission), it will also be economically viable.

5. ACKNOWLEDGMENT

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