## TO STUDY THE REMOVAL CAPACITY OF COMMERCIAL SLAKED LIME AS AN ADSORBENT FOR "NO" GENERATED IN INDUSTRIAL EVOLUTIONS

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**ABSTRACT:**

In the present work, NO in flue gas is removed by the adsorption method. For this purpose, a pilot plant for flue gas treatment is constructed which contains a furnace, cyclone separator, baghouse filter, and water scrubber. The dust-free gas is passed through a fixed bed adsorber. The novel adsorbent shows 100% removal of NO.

**KEY WORDS:** Flue gas treatment, Removal of NO, Adsorption method
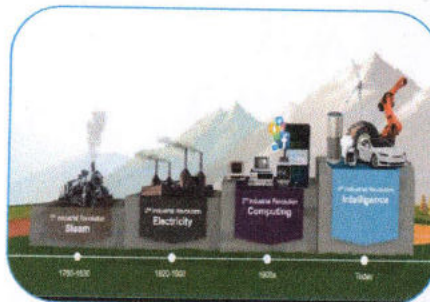
## INTRODUCTION :

$NO_x$ is a generic term for mono-nitrogen oxides NO and $NO_2$ (and not $N_2O$)[1]. $NO_x$ react to form smog[2] and acid rain[3]. During daylight, the concentration of these two is in equilibrium with each other. The ratio NO: $NO_2$ is determined by the intensity of sunshine and the concentration of ozone which reacts with NO to form $NO_2$[4]

The burning of fossil fuels by industries and vehicles adds to $NO_x$ in the atmosphere. They are formed in two stages during combustion[5]

1. The reaction of oxygen with nitrogen compounds in fuel termed as fuel $NO_x$
2. The reaction of nitrogen with oxygen termed as thermal $NO_x$

To reduce the emission of $NO_x$ produced by combustion of fossil fuels, there are two ways[6]

1. To prevent the production of $NO_x$ during combustion which is achieved by using low $NO_x$ combustion burners, stage combustion, or fluidized bed combustion.
2. To removal $NO_x$ after combustion which is done by several ways including Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction (SNCR), Activated Carbon process, etc.

The methods in practice are costly and they cannot be employed for the existing boiler plants. The level of emission of $NO_x$ may not decrease to the limit set by the US Clean air act 1990[7] and Air pollution act.

Post-combustion methods[8] baring reduction methods are in search of a sorbent for $NO_x$, typically NO which difficult to trap. Among MOF, Smit, and Peng[9] claim that Mg-MOF-74 was found to be the most promising adsorbent for simultaneous removal of $CO_2$ $SO_2$, $NO_x$ from dry flue gas mixture however the presence of moisture largely affects the performance of MOFs. Chang et al[10] showed that H-β zeolites show removal capacity of 0.1 to 221 µmol/gm when feed is 400ppm NO, 1-20% $O_2$ and Argon. Yasutake et al[11] predicted that ordinary active carbon may adsorb sufficient NO but fails to exhibit sufficient

oxidizing power. Bandoz and co-workers[12] employed copper oxide/SBA-15 silica composites. They found that the Si-OH group catalyzes the reaction of NO. Ritter et al[13] modified the SCR process by using a fixed bed in the form of honeycomb bodies and plates. Neal et al[14]mentioned the processes for removal of $NO_x$ . These include many inorganic salts. M. Anpo, T. Nomura A et al[15]showed that the copper ions supported with silica can decompose NO molecules photochemically. MahanazPourkhalil etal[16] worked for various catalysts for low temperature selective catalytic reduction. Chu[17] proved that the addition of NaOH to fly ash- $Ca(OH)_2$slurry increased the reactivity of $NO_x$ from 1 to 4 mols of $NO_x$. Nellie and Rochelle[18] studied the reaction of $NO_x$with surface water on alkaline solids such as hydrated lime and calcium silicate. Hiroaki, Tsuchiai, Ishizuke[19]prepared a slump with $CaO$, $CaSO_4$, and fly ash which showed higher activity for $NO_x$ removal. Chiung- Fang Liu[20]explained the reactions that take place in the water layer of calcium hydroxide adsorbent.

## Materials and Methods:

A prototype of a flue gas treatment plant is erected consisting of the following components

a. **Furnace-** The furnace is made up of 6 mm thick steel plates. The dimensions are made to the scale. The flue gas is released at the top of the furnace.

b. **Cyclone Separator-** In cyclone separator, due to the centrifugal force, the heavy particles of the coal and ash settle down at the bottom, and the flue gas leaves from another end at the top.

c. **Bag House Filter-** Smaller particles are trapped in the baghouse containing 12 bags.

d. **Water Scrubber -** A 'counter-current' flow type of scrubber is constructed. The ash-laden gas entering the scrubber becomes clear while coming out from the top.

e. **Outlet Fan-** The slow-moving gas is accelerated further in the adsorber.

f. **Adsorber-** It contains four beds supported on a steel frame. The powdered adsorbent is spread on the mesh. The gas enters the device from the bottom, diffuses through the layer, and leaves from the chimney at the top.

g. **Sampling points-**Inlet and outlet pipes of adsorber are provided with a tiny outlet fitted with nipple to connect to the gas analyzer.

h. **ATS 206 A Gas Analyzer -** It measures NO in ppmwithaccuracy ± 2 %. Sampling done by Auto suction Response time is 30 seconds at 95% variation, the Operating temperature is 5 to 55ºC.

The flue gas from the furnace was allowed to pass through all the devices removing particulate matter and the dust-free gas into the designed adsorber. The sampling points are fitted at the entrance and also at the exit of the adsorber. Each was connected to the detectors. Using a control valve alternately detector can be made to read the flue gas entering the device or leaving the device. The concentration of NO was recorded using ATS 206 A as 'IN' and 'OUT' NO of the adsorber.

## Results and Discussion:

1. Comparative Study of % Removal of NOby Different Quantities of Slaked Limeis shown in Table No. 1and plotted in Graph No. 1

20% removal capacity shown by the 1kg layer indicates that commercial slaked lime can act as a good sorbent for nitrogen oxide. With an increasing amount of sorbent per layer, the extent of removal increases. A distinct removal is obtained by 4 kg per layer bed. The removal efficiency observed is between 55-40% for one hour which is greater than that of reagent grade hydrated lime.

2. Comparative Study of % Removal of NOas Observed in Combinations of Slaked Lime, CommonSalt and Commercial Bleaching Powder shown in Table No. 2 and plotted asGraph No 2

Nitrogen oxide being a non - acidic gas has poor affinity towards alkaline sorbets. The addition of common salt did not increase removal capacity instead, the extent of removal decreases slightly. The openings in the vicinity of salt crystals allowed the unadsorbed gas to passthrough the sorbent.

The addition of 100 gm bleaching powder shifts the removal to 80%. The mixture becomes moist andthe available chlorine reacts with NO on the surface of the sorbent and the product gets adsorbed strongly.
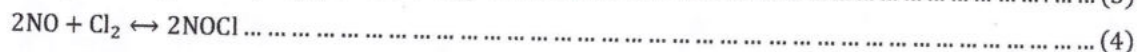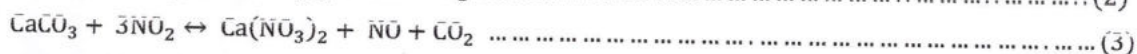
The efficiency of the total mixture is slightly lower than that of slaked lime plus bleaching powder.
3.  Comparative Study of % Removal of NO as Observed in Combinations of Slaked Lime, Common Salt, Commercial Bleaching Powder, and Precipitated $Ca(OH)_2$ is shown in table No.3 and plotted as graph No 3

An increase in the concentration of $Ca(OH)_2$ increases the removal of the acidic gases substantially. The remaining active sites are available for adsorption of non-acidic gases. Addition of 100gm and then 150gm of precipitated $Ca(OH)_2$ corresponds to 1.965% and 2.91% increase in the concentration of $Ca(OH)_2$ in the mixture of slaked lime + common salt + bleaching powder which results in 100% removal of NO which is rarely achieved before.

Probable Reactions for Removal of Nitrogen oxides:
Nitrogen oxide and nitrogen dioxide get converted into each other during the flow as well as during adsorption. The presence of moisture, oxygen, and temperature play a vital role in the interconversion. On an inert surface, $NO_2$ gets converted into NO which becomes hard to trap. An alkaline surface retards the conversion utilizing moisture however the surface itself gets acidified and loses its removal capacity.

$$NO + \frac{1}{2}O_2 \leftrightarrow NO_2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$Ca(OH)_2 + 3NO_2 \leftrightarrow Ca(NO_3)_2 + NO + H_2O \dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

$$CaCO_3 + 3NO_2 \leftrightarrow Ca(NO_3)_2 + NO + CO_2 \dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

$$2NO + Cl_2 \leftrightarrow 2NOCl \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

$$NO + NO_2 + H_2O \leftrightarrow 2NO_2^- + 2H^+ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (5)$$

$$Na^+ + NO_2^- \leftrightarrow NaNO_2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (6)$$

$$Ca(OH)_2 + 2HNO_2 \leftrightarrow Ca(NO_2)_2 + 2H_2O \dots\dots\dots\dots\dots\dots\dots\dots\dots (7)$$

$$Ca(OH)_2 + 2HNO_3 \leftrightarrow Ca(NO_3)_2 + 2H_2O \dots\dots\dots\dots\dots\dots\dots\dots\dots (8)$$

$$CaCO_3 + 2HNO_2 \leftrightarrow Ca(NO_2)_2 + H_2O + CO_2 \dots\dots\dots\dots\dots\dots\dots\dots (9)$$

## Conclusion:

In existing removal methods for $NO_x$, nitrous oxide NO is oxidized to nitric oxide $NO_2$ or reduced to $N_2$ and the removal follows. Those methods are costly and their efficiency does not exceed 60%. This research has discovered an affordable, green, sorbent for Nitrous oxide. This novel sorbent can be utilized to remove NO from the flue gases. The efficiency of this method is 100%. The products after adsorption are water-soluble, they can be leached by water and the solution can be utilized as fertilizer.

**Tables**

**Table No. 1 -** Comparative study of % Removal of NO by Slaked Lime

| Time in Minute | Amount of Slaked Lime in Each Layer of the Adsorber | | | |
|---|---|---|---|---|
| | 1 kg | 2 kg | 3 kg | 4 kg |
| 0 | 20.95 | 29.51 | 34.46 | 54.27 |
| 4 | 22.82 | 29.80 | 37.41 | 52.67 |
| 8 | 20.55 | 31.00 | 39.04 | 49.84 |
| 12 | 19.44 | 32.11 | 38.33 | 52.45 |
| 16 | 18.19 | 26.65 | 39.04 | 51.46 |
| 20 | 17.60 | 22.38 | 36.99 | 53.55 |
| 24 | 13.54 | 18.00 | 30.36 | 49.91 |
| 28 | 8.75 | 14.71 | 25.28 | 48.721 |
| 32 | 7.95 | 11.25 | 21.81 | 50.18 |
| 36 | 8.03 | 11.62 | 16.25 | 49.13 |
| 40 | 7.71 | 14.05 | 15.01 | 48.84 |
| 44 | 5.60 | 10.41 | 13.46 | 45.77 |
| 48 | 3.95 | 7.86 | 11.85 | 43.54 |
| 52 | 3.29 | 3.47 | 11.32 | 41.27 |
| 56 | 2.68 | 6.03 | 8.00 | 40.82 |
| 60 | 1.99 | 5.84 | 4.04 | 39.60 |

**Table No. 2:** Comparative Study of % Removal of NO by Combinations of by Slaked Lime, Common Salt, and Bleaching Powder

| Time in Minute | Adsorbent | | | |
|---|---|---|---|---|
| | 4 kg S. Lime | 4 kg S. Lime + 1 kg Common Salt | 4 kg S. Lime + 0.1 kg Bleaching Powder | 4 kg S. Lime + 1 kg Common Salt + 0.1 kg Bleaching Powder |
| 0 | 54.27 | 24.46 | 97.33 | 90.74 |
| 4 | 52.67 | 26.05 | 97.46 | 91.05 |
| 8 | 49.84 | 35.19 | 97.70 | 88.36 |
| 12 | 52.45 | 28.43 | 97.58 | 87.11 |
| 16 | 51.46 | 40.56 | 95.77 | 85.75 |
| 20 | 53.55 | 38.85 | 94.83 | 83.71 |
| 24 | 49.91 | 42.03 | 93.51 | 82.66 |
| 28 | 48.72 | 41.88 | 90.67 | 81.27 |
| 32 | 50.18 | 42.31 | 90.77 | 79.01 |
| 36 | 49.13 | 47.42 | 91.54 | 76.13 |
| 40 | 48.84 | 52.13 | 91.73 | 72.09 |
| 44 | 45.77 | 50.00 | 91.54 | 70.84 |
| 48 | 43.54 | 55.56 | 91.60 | 68.91 |
| 52 | 41.27 | 41.56 | 91.47 | 65.82 |
| 56 | 40.82 | 33.87 | 91.29 | 60.59 |
| 60 | 39.60 | 25.49 | 89.79 | 56.13 |

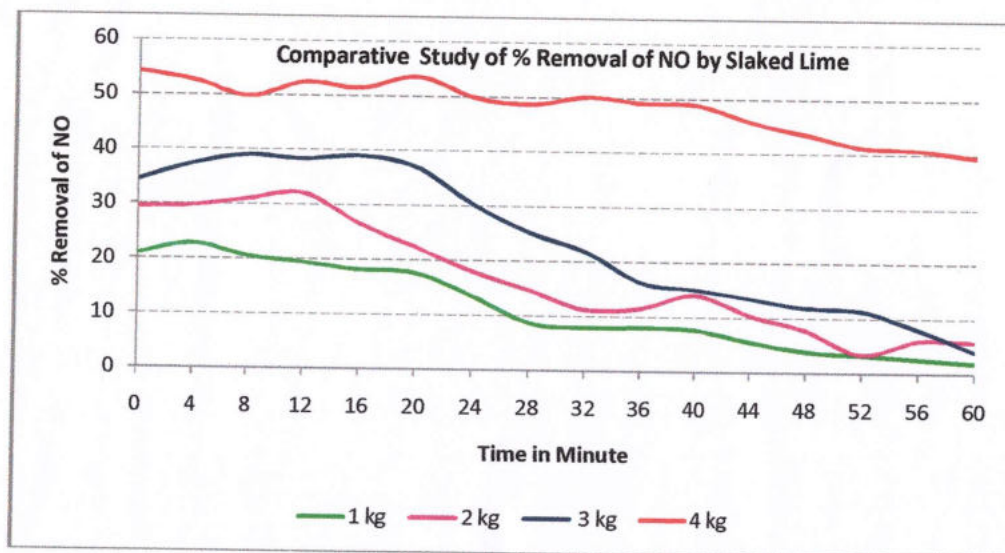### Table No 3 - Comparative Study of % Removal of NO by Combinations of by Slaked Lime, Common Salt, and Bleaching Powder and Precipitated Ca(OH)₂

A 4 kg S. Lime + 1 kg Common Salt + 0.1 kg Bleaching Powder
B 4 kg S. Lime + 1 kg Common Salt + 0.1 kg Bleaching Powder + 0.1 kg Ca(OH)₂
C 4 kg S. Lime + 1 kg Common Salt + 0.1 kg Bleaching Powder + 0.15 kg Ca(OH)₂

| Time in Minute | Adsorbent | | |
|---|---|---|---|
| | A | B | C |
| 0 | 90.74 | 99.13 | 100.00 |
| 4 | 91.05 | 98.94 | 100.00 |
| 8 | 88.36 | 98.90 | 100.00 |
| 12 | 87.11 | 98.88 | 100.00 |
| 16 | 85.75 | 98.88 | 100.00 |
| 20 | 83.71 | 98.64 | 100.00 |
| 24 | 82.66 | 98.60 | 100.00 |
| 28 | 81.27 | 98.63 | 100.00 |
| 32 | 79.01 | 98.76 | 100.00 |
| 36 | 76.13 | 98.83 | 100.00 |
| 40 | 72.09 | 98.99 | 100.00 |
| 44 | 70.84 | 98.84 | 100.00 |
| 48 | 68.91 | 98.38 | 100.00 |
| 52 | 65.82 | 97.73 | 100.00 |
| 56 | 60.59 | 97.71 | 100.00 |
| 60 | 56.13 | 97.51 | 100.00 |

**Figures:**

**Graph No. 1:** Comparative Study of % Removal of NO by Different Quantities of Slaked Lime

**Graph No. 2:**Comparative Study of % Removal of NO by Slaked Lime, Common Salt, Bleaching Powder
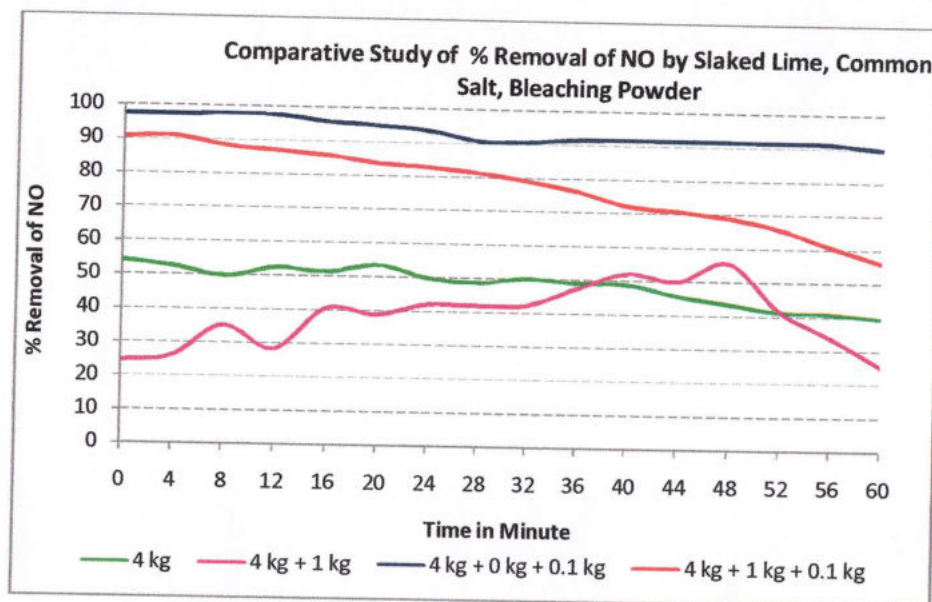


Comparative Study of % Removal of NO by Slaked Lime, Common Salt, Bleaching Powder

**Graph No. 3:** Comparative Study of % Removal of NO by Slaked Lime, Common Salt, Bleaching Powder and precipitated $Ca(OH)_2$



Comparative Study of % Removal of NO by Slaked Lime, Common Salt, Bleaching Powder and Pure $Ca(OH)_2$
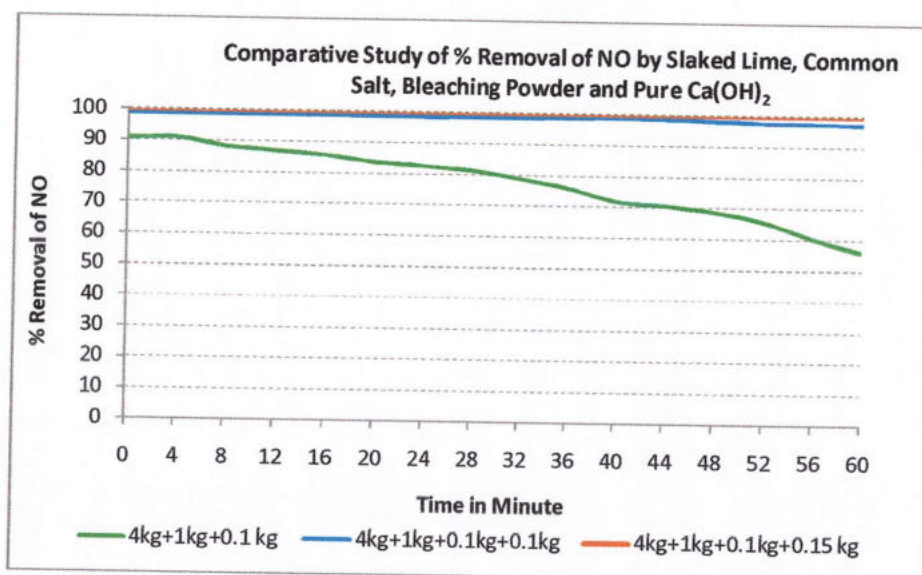
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