



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 NO₂ (and not N₂O)¹. NO_x react to form smog² and acid rain³. During daylight, the concentration of these two is in equilibrium with each other. The ratio NO: NO₂ is determined by the intensity of sunshine and the concentration of ozone which reacts with NO to form NO₂⁴

The burning of fossil fuels by industries and vehicles adds to NO_x in the atmosphere. They are formed in two stages during combustion⁵

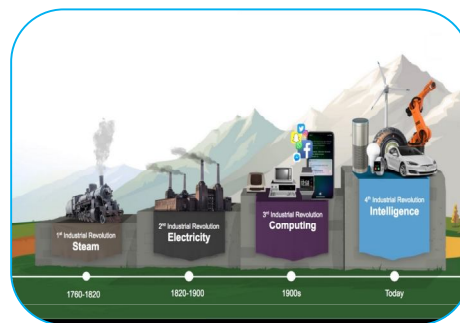
1. The reaction of oxygen with nitrogen compounds in fuel termed as fuel NO_x
2. The reaction of nitrogen with oxygen termed as thermal NO_x

To reduce the emission of NO_x produced by combustion of fossil fuels, there are two ways⁶

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 1990⁷ and Air pollution act.

Post-combustion methods⁸ bearing reduction methods are in search of a sorbent for NO_x, typically NO which difficult to trap. Among MOF, Smit, and Peng⁹ claim that Mg-MOF-74 was found to be the most promising adsorbent for simultaneous removal of CO₂SO₂, NO_x from dry flue gas mixture however the presence of moisture largely affects the performance of MOFs. Chang et al¹⁰ showed that H-β zeolites show removal capacity of 0.1 to 221 μmol/gm when feed is 400ppm NO, 1-20% O₂, and Argon. Yasutake et al¹¹ predicted that ordinary active carbon may adsorb sufficient NO but fails to exhibit sufficient oxidizing power. Bandoz and co-workers¹² employed copper oxide/SBA-15 silica composites. They



found that the Si-OH group catalyzes the reaction of NO. Ritter et al¹³ modified the SCR process by using a fixed bed in the form of honeycomb bodies and plates. Neal et al¹⁴ mentioned the processes for removal of NO_x. These include many inorganic salts. M. Anpo, T. Nomura A et al¹⁵ showed that the copper ions supported with silica can decompose NO molecules photochemically. MahanazPourkhalil et al¹⁶ worked for various catalysts for low temperature selective catalytic reduction. Chu¹⁷ 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 Rochelle¹⁸ studied the reaction of NO_x with surface water on alkaline solids such as hydrated lime and calcium silicate. Hiroaki, Tsuchiai, Ishizuke¹⁹ prepared a slump with CaO, CaSO₄, and fly ash which showed higher activity for NO_x removal. Chiung- Fang Liu²⁰ 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 ppm with accuracy $\pm 2\%$, Sampling done by Auto suction Response time is 30 seconds at 95% variation, the Operating temperature is 5 to 55°C.

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 NO by Different Quantities of Slaked Lime is shown in Table No. 1 and 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 NO as Observed in Combinations of Slaked Lime, Common Salt and Commercial Bleaching Powder shown in Table No. 2 and plotted as Graph No 2

Nitrogen oxide being a non - acidic gas has poor affinity towards alkaline sorbents. 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 pass through the sorbent.

The addition of 100 gm bleaching powder shifts the removal to 80%. The mixture becomes moist and the available chlorine reacts with NO on the surface of the sorbent and the product gets adsorbed strongly.

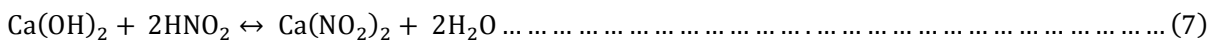
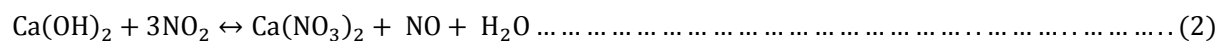
The efficiency of the total mixture is slightly lower than that of slaked lime plus bleaching powder.

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, NO₂ 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.



CONCLUSION:

In existing removal methods for NO_x, nitrous oxide NO is oxidized to nitric oxide NO₂ or reduced to N₂ 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	48.72
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

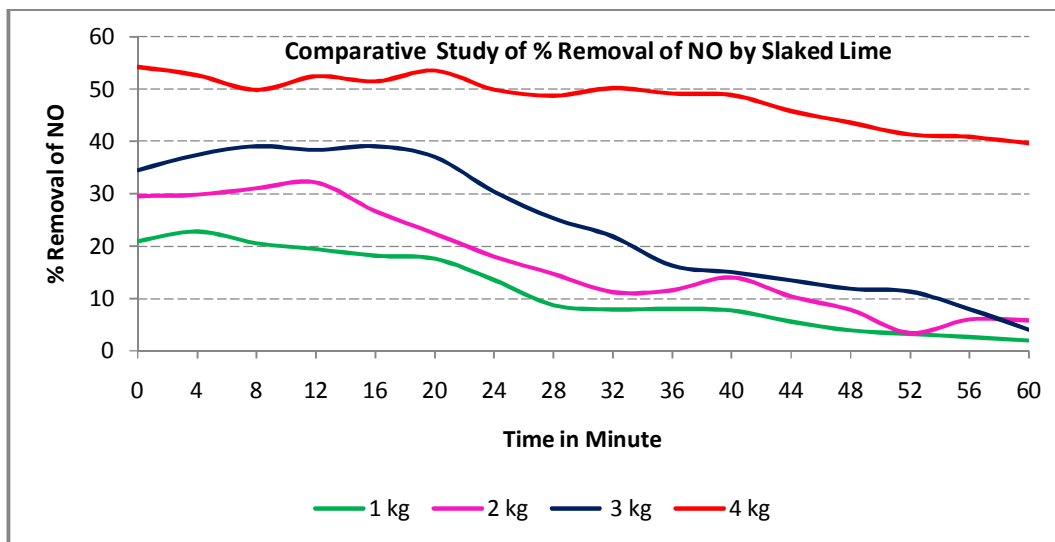
B 4 kg S. Lime + 1 kg Common Salt + 0.1 kg Bleaching Powder + 0.1 kg Ca(OH)₂

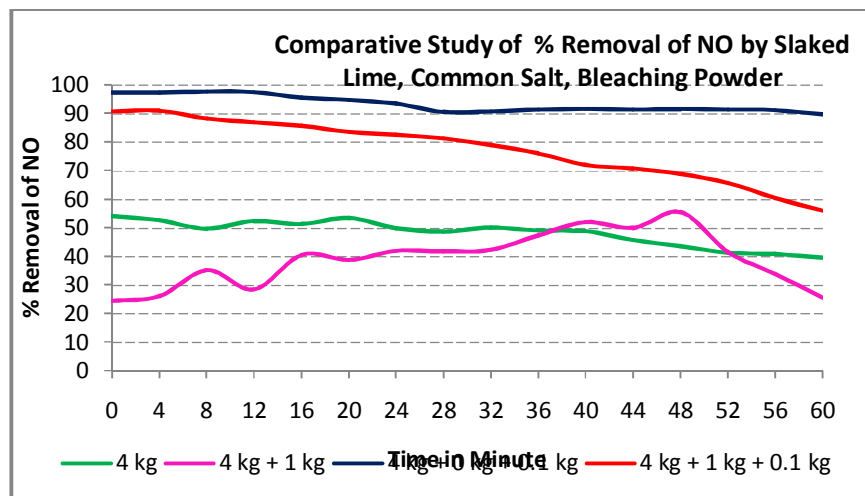
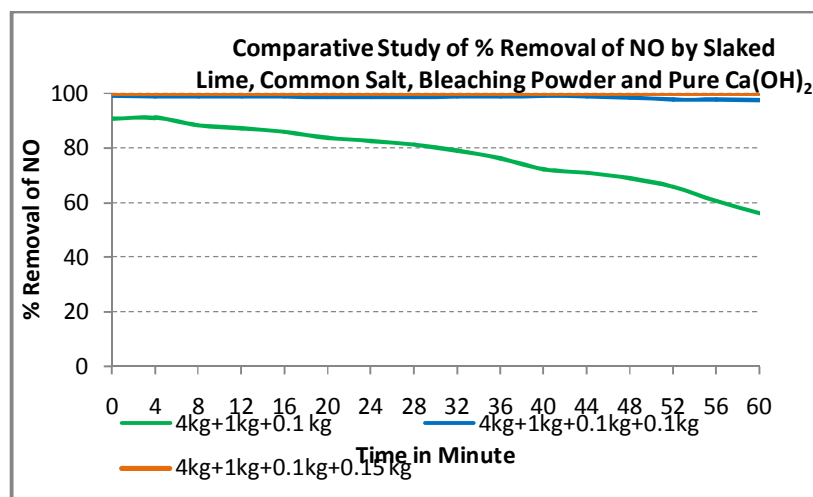
C 4 kg S. Lime + 1 kg Common Salt + 0.1 kg Bleaching Powder + 0.15 kg Ca(OH)₂

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

1. Muzio LJ, Quartucy GC. Implementing NO_x control: Research to application. *Progress in Energy and Combustion Science*; **23**(3), 233, (1997).
2. Chemistry of the Natural Atmosphere, Volume 71 - 2nd Edition.
3. Asthana DK. Environment: Problems and Solutions. Reprint Ed. (2006) edition. S Chand Publications
4. Seinfeld JH, Pandis SN. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change. 3 edition. Hoboken, New Jersey Wiley (2016).
5. Fu M, Li C, Lu P, et al. A review on selective catalytic reduction of NO_x by supported catalysts at 100–300°C—catalysts, mechanism, kinetics. *Catal Sci Technol* **4**(1), 14, (2013).
6. Azimi M, Ommi F. Most effective combustion technologies for reducing No_x emissions in aero gas turbines. *The International Journal of Multiphysics* **6**, 417, (2012).
7. Beier CM, Driscoll CT, Sullivan TJ, et al. Air pollution success stories in the United States: The value of long-term observations. *Environmental Science & Policy* **84**, 69 (2018)

8. Jones CW, Lively RP, Monjezi SRezaei F, Rownaghi AA, SO_x/NO_x Removal from Flue Gas Streams by Solid Adsorbents: A Review of Current Challenges and Future Directions. *Energy Fuels* **29**(9), 5467, (2015).
9. Lin L-C, Peng X, Sun W, Smit B. Computational screening of porous metal-organic frameworks and zeolites for the removal of SO₂ and NO_x from flue gases. *AIChE Journal* **60** (6), 2314, (2014).
10. Chang X, Guo Y, Guo Y, Lu G. A high effective adsorbent of NO_x: Preparation, characterization and performance of Ca-beta zeolites. *Microporous and Mesoporous Materials* **165** (5) 113, (2013).
11. Mochida I, Korai Y, Shirahama M, *et al.* Removal of SO_x and NO_x over activated carbon fibers. *Carbon* **38**(2), 227 (2000).
12. Bandosz TJ, Ebrahim AM, Lefevre B, Mesoporous silica SBA-15 modified with copper as an efficient NO₂ adsorbent at ambient conditions. *Journal of Colloid and Interface Science* **377** (1), 347, (2012).
13. Asmuth P, Raible L, Ritter G. Method of removing SO_x and NO_x from effluent gas. US4839148A, (1989).
14. Haslbeck JL, Neal LG, Tseng H. Sorbent and processes for removing nitrogen oxides, sulfur oxides and hydrogen sulfide from gas streams. US4940569A, (1990).
15. Anpo M, Kitao T, Nomura T, *et al.* Approach to De-NO_x-ing photocatalysis. II excited state of copper ions supported on silica and photocatalytic activity for NO decomposition. *Res Chem Intermed* **15**(3), 225, (1991).
16. Bozorgzadeh H, Jafari Jozani K, Moghaddam A, Pourkhalil M, Towfighi J, Zarringhalam Rashidi A, Synthesis of MnO_x/Oxidized-MWNTs for Abatement of Nitrogen Oxides. *Catal Lett* **143**(2), 184, (2013).
17. Chu P, Rochelle GT. Removal of SO₂ and NO_x from Stack Gas by Reaction with Calcium Hydroxide Solids. *JAPCA* **39**(2), 175, (1989).
18. Nelli CH, Rochelle GT. Simultaneous Sulfur Dioxide and Nitrogen Dioxide Removal by Calcium Hydroxide and Calcium Silicate Solids. *Journal of the Air & Waste Management Association* **48**(9), 819 (1998).
19. Hattori H, Ishizuka T, Nakamura H, Tsuchiai H, Ueno T, Study of Flue Gas Desulfurization Absorbent Prepared from Coal Fly Ash: Effects of the Composition of the Absorbent on the Activity. *Ind Eng Chem Res* **35**(7), 2322, (1996).
20. Liu C-F, Shih S-M. Effects of Flue Gas Components on the Reaction of Ca(OH)₂ with SO₂. *Ind Eng Chem Res* **45**(26), 8765, (2006).