

An Effective Treatment Removal of NO_x from Process Gas Stack

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Abstract - Nitrogen oxides (NO_x) are a very interesting and important family (N₂O, NO, NO₂, N₂O₂, N₂O₃, N₂O₄, N₂O₅) of air polluting chemical compounds. Nitrogen oxides are major pollutants in the atmosphere, being accountable for acid rain, photochemical smog, and ozone accumulation. There are various industries such as cement industry, petroleum refineries, paper mills, and pharma intermediate plants which are the main source of emission after automobile exhaust. This paper will put light on the NO_x coming from process gas stack. The aim is to provide a reasonably clear and uncomplicated basis for evaluation of potential treatment methods to help determine method which can provide lowest environmental footprint, reduced scrubbing time, reduction in scrubber bleed off, useful byproduct, reduction in sludge, and certain APCM measures to reduce the pollution.

Key Words: Para Nitro benzoic acid, Nitrogen oxides,

1. INTRODUCTION

The ongoing emission of NO_x is a serious persistent environmental problem, because these gases play an important role in the atmospheric ozone destruction and global warming. Furthermore, urban NO_x is regarded as one of the most important precursors to photochemical smog.¹⁻³ Smog products irritate eyes and throat, evoke asthmatic attacks, reduces visibility and damages plants and materials as well⁴⁻⁵. Moreover, NO_x also contribute to acidification, because they dissolve in cloud and precipitation water to form the strong acids HNO₂ and HNO₃⁶.

Among several other technologies, such as catalytic reduction method, combustion, adsorption method; wet removal process is used as an ultimate tool for the removal of NO_x. It has high efficiency and cost effective as well. It can removal up to 90% NO_x.

In absorption method, various oxidants such as ozone, hydrogen peroxide, sodium chlorite, Potassium permanganate has been added to enhance the performance of scrubber⁷⁻⁸. Among all oxidants, hydrogen peroxide is most promising one because by the use of it, there will be no generation of byproduct. Ozone is also a strong oxidant present, but it will require ozonator to generate ozone, which is costly for commercial stage⁹.

Here we have taken the Para Nitro benzoic acid (PNBA) manufacturer for the case study. To find the cost effective as

well high NO_x removal method from the process stack. For oxidation from NO to NO₂, hydrogen peroxide is used. A lab batch of manufacturing of para nitro benzoic acid is conducted. Hydrogen peroxide is injected to convert NO to NO₂.¹⁰⁻¹¹ Yellow Phosphorus is used as an absorbent¹². At the end of process nitrogen phosphorous fertilizer is generated which can be used as a manure.

The main advantage of phosphorous as an absorbent is that no liquid waste will be generated. Also it will achieve the emission standards of Government of India. Effects of parameters which will affect the efficiency of removal of NO_x is discussed in detail along with the experimental procedure.

2. MATERIALS AND METHODS

2.1 MATERIALS

Para nitro toluene, nitric acid, and hydrogen peroxide has been procured from Sigma Aldrich of laboratory standards.

The glass apparatus has been made of 5-liter assembly with the air flow meter column condenser, separate apparatus for making hydrogen peroxide solution, thermometer, and powder funnel is required. REMI RQG-129/D stirrer has been used to dissolve the phosphorous into nitric acid solutions.

2.2 METHODOLOGY

Para Nitro Toluene of 1.7 kg and 3 kg nitric acid were added in the vessel. Reaction temperature was maintained between 80-85°C using magnetic stirrer at stirring speed of 450 rpm to achieve reflux. Continuous Stirring was maintained. Temperature was monitored at every fifteen minutes of time interval by the thermometer.

It was observed that as temperature exceeds 50°C the gas generation was started. The exothermic reaction took place and process is completed at the end of 5 hours.

The inlet gas was collected in the receiver where hydrogen peroxide is injected in different dosage varies from 0.65 to 1.5 mg/minute.

Soon, the gas got oxidized and weaker concentration of acid was generated at pH of 7.3. Then phosphorous slurry was added into the acid solution for the absorption of NO_x.

Stirring was increased up to 1400 rpm by using REMI RQG-129/D to dissolve the phosphorous solid content also various samples were analyzed at different temperatures.

Stirring was varied to get optimum agitation speed to get maximum phosphorus mixture.

$$\eta = \frac{C_{\text{inlet}} - C_{\text{outlet}}}{C_{\text{inlet}}}$$



Where, C_{inlet} is the concentration of NO_x in inlet process gas, mg/m³; C_{outlet} is the concentration of NO_x in outlet process gas, mg/m³.

A sample of NO_x was taken from process gas stack. Initial NO_x concentration was 250 mg/Nm³.

3. RESULTS AND DISCUSSION

During the experiment, the major parameters affecting NO_x removal are described below:

3.1 EFFECT OF REACTION TEMPERATURE

NO_x removal has direct relation with the reaction temperature. In this experiment, readings were taken at several temperatures. In the temperature range between 45-65°C NO_x removal efficiency was observed in linear form. As it is shown in fig 3(A), at 70°C temperature the NO_x removal was 72% to its initial concentration value. Maximum NO_x removal efficiency (i.e. 88%) has been observed between temperature ranges from 85-90°C. With high temperature; solubility of NO_x decreases which results in decreases in removal rate depicting equilibrium stage of NO_x removal. Thus, experimental data suggests that for higher removal of NO_x, temperature should not exceed 90°C.

3.2 EFFECT OF pH SOLUTION

From fig 3(B), it clearly suggests that NO_x removal efficiency increases with the increase of the pH of solution. 87% removal rate was recorded at the pH of 8. It has been observed that acidic pH is not beneficial for absorption of NO_x. Alkaline pH of solution is beneficial to eliminate NO_x, due to the good absorbing ability of slurry solution with high pH for acidic NO_x. Therefore, it is recommended to maintain the state of slurry between pH 6.5-8.0 for high absorption of NO_x.

3.3 EFFECT OF PHOSPHORUS CONCENTRATION

Different dosage has been made with the help of distilled water such as 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 4.0 g/L and the results are represented in the fig 3(C). Yellow phosphorous powder has been added in the distilled water to make a solution. At initial stage removal efficiency has been found 68% at 1.0gm/L. After increasing the dosage, we have found that the efficiency has also been increased.

At 2.5gm/L, maximum 86.5% efficiency has been found. As the solid content of slurry increases the dispersion degree of yellow phosphorus also increases and promotes the reaction between yellow phosphorus and oxygen. After that the dosage has been increased up to 4 gm/L, but the absorption has an adverse effect on it. Considering this 2 gm/L has been considered in the process.

3.4 EFFECT OF STIRRING INTENSITY

Stirring is an integral part of the entire operation of NO_x removal. It is seen that efficiency increases as stirring intensity increases, and this is mainly due to the fact that increasing stirring intensity promotes the dispersion of aqueous emulsion.

Besides, increasing the stirring intensity also enhances the gas-liquid transfer rate and increases the dispersion and holdup of O₂. Several readings are taken at the several RPM, as shown in fig 3(D). The stirring is kept at 1400 rpm for the desired result.

3.5 EFFECT OF GAS FLOW RATE

NO_x removal efficiency decreases as the gas flow rate increases, which may be ascribed to the fact that increasing the gas flow rate can decrease the contact time between yellow phosphorus and oxygen, thus leading to the decrease of ozone amount during the reaction.

If gas flow rate is lower, it would decrease the NO_x removal efficiency. As it is shown in fig 3(E), at various flow rates, its effect on performance has been noted. Based on this, flow rate has been kept 350gm/L throughout the experiment.

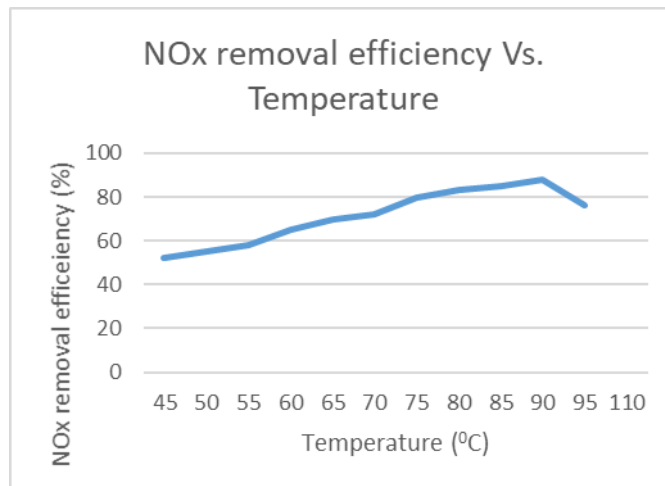


Fig 3(A): Effect of Temperature

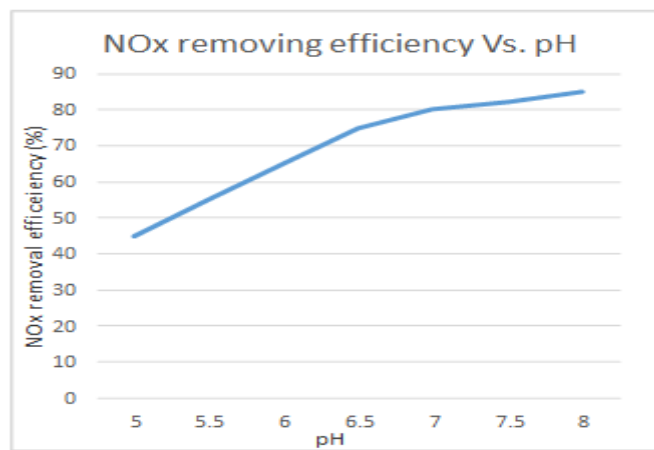


Fig 3: (B) Effect of pH solution

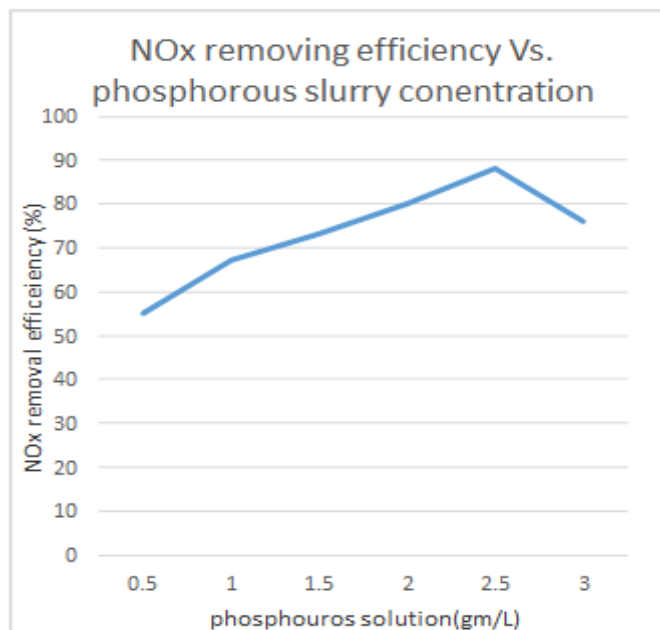


Fig 3: (C) Effect of phosphorus concentration

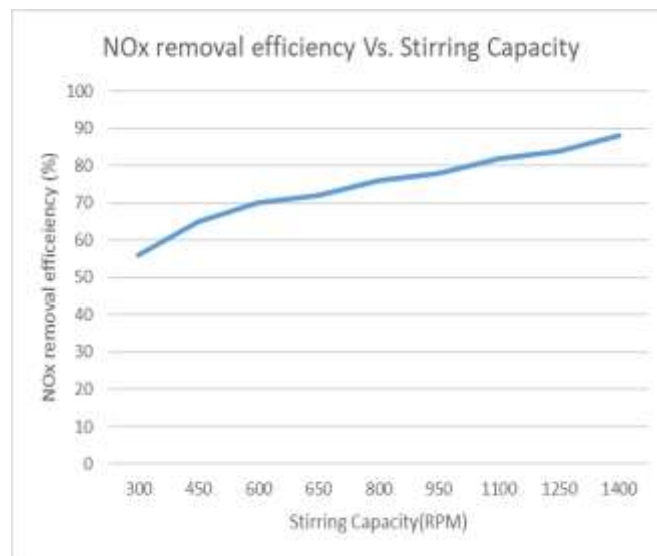


Fig 3: (D) Effect of stirring capacity

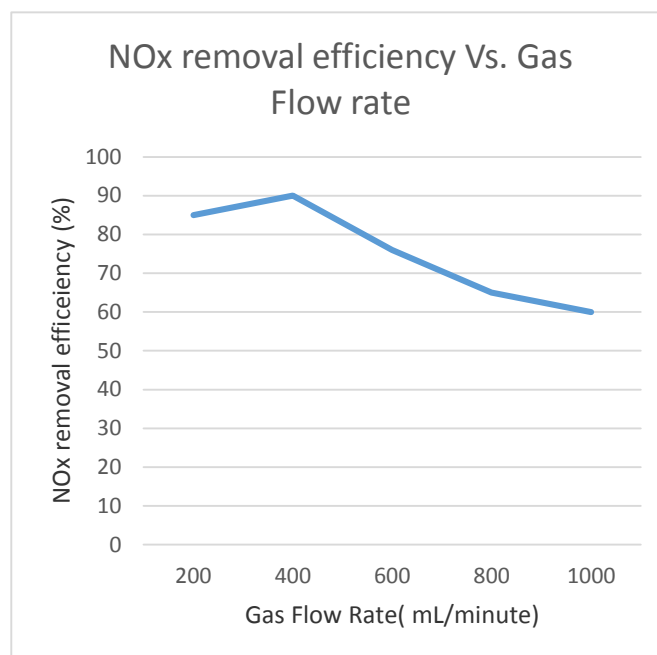


Fig 3: (E) Effect of Gas Flow Rate

4. CONCLUSION

In this study, removal of NOx was carried out by using hydrogen peroxide as an oxidant and was absorbed into yellow phosphorous. It has been observed that NOx has less solubility in water. That is why it needs the oxidant to oxidize NO into NO₂. The batch scale production was experimented in the laboratory, NOx measured initially was i.e. 250 mg/Nm³. Different affecting variables i.e. temperature, pH of solution, Phosphorus concentration and stirring intensity were considered for the maximum NOx removal from process gas. Optimum conditions for highest

removal were depicted which showed that temperature of solution should not exceed 90°C, pH of solution should be kept at 8.0, optimum phosphorus concentration should be 2 mg/L and stirring intensity to be kept at 1400 rpm. At the end of process, NOx measured was 40mg/Nm³, average 83% NOx removal efficiency was obtained. At the end of process, nitrogen phosphorus sludge was generated. It is not hazardous in nature therefore it can be used as fertilizer/manure for greenbelt development.

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REFERENCES

- [1] Wang, S.; Luo, K.; Wang, X.; Sun, Y. *Environ. Pollut.* 2016, 209, 107–113.
- [2] Zhang, X.; Zhang, B.; Lu, X.; Gao, N.; Xiang, X.; Xu, H. *Energy* 2017, 126, 677–688.
- [3] Kuroпка J., Purification of waste gases from nitrogen oxides, *Prace Nauk. Inst. Inż. Ochr. Środ.* No. 62, Ser. Monografie No. 30, Wrocław, 1988 (in Polish).
- [4] Pan, D.; Yu, R.; Bao, J.; Wu, H.; Huang, R.; Yang, L. *Energy Fuels* 2016, 30, 666–673.
- [5] Fang, Z.; Yu, X.; Tang, W.; Yu, X.; Zhao, S.; Tu, S. T. *Appl. Energy* 2017, 206, 858–868.
- [6] Miller J.S., Wilk M., Chacuk A., Ledakowicz S., Ozonation of nitrous acid in aqueous nitric acid solutions, IOA 17th World Ozone Congress – Strasbourg, France, 2005.
- [7] CHU H., CHIEN T., LI S., *Sci. Total Environ.*, 2001, 275, 127.
- [8] Joshi, J. B.; Mahajani, V. V.; Juvekar, V. A. Absorption of NO_x gases. *Chem. Eng. Commun.* 1985, 33, 1.
- [9] Jiang S D. Experimental and mechanism study on multi-pollutants control by ozone and active molecule. Hangzhou: Zhejiang University. (2010)
- [10] Thomas, D.; Vanderschuren, J. *Sep. Purif. Technol.* 1999, 18, 37.
- [11] De Paiva, J.; Kachan, G. *Chem. Eng. Process.* 2004, 43, 941.
- [12] Shuai Li, Jiaqiang Yang, Chi Wang, Delong Xie, Yongming Luo, Kai Li, Dedong He, Yi Mei. " Removal of NO from Flue Gas Using Yellow Phosphorus and Phosphate Slurry as Adsorbent ", *Energy & Fuels*, 2018