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EFFECT OF ABSORPTION OF SULPHUR DIOXIDE IN SODIUM HYDROXIDE SOLUTION TO PROTECT ENVIRONMENT : A CASE STUDY AT SHREE POWER, BEAWAR, RAJASTHAN

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ABSTRACT

Laboratory studies were conducted to know about the effect of concentration of sodium hydroxide, pH of sodium hydroxide solution, flow of flue gases in impingers, temperature of NaOH solution and time period for reaction for absorption of SO_2 contained in flue gases. Thus, it is concluded that the 5% concentration of the NaOH was found to be optimum. pH of the solution should be alkaline for good absorption of SO_2. Maximum absorption of SO_2 was found by direct passing of SO_2 in impinger as compared to indirect passing of SO_2 in impingers. Maximum absorption of SO_2 was found in temperature range between 20- 25^oC. It is also concluded that maximum recovery of SO_2 was obtained, when the reaction took place for a longer time period.

Key words: Flue gas desulphurization, Flue gases, pH, Concentration, Sodium hydroxide, Temperature, Sulphur dioxide.

INTRODUCTION

Thermal power plants are major sources of air pollutants[1] Three major air pollutants emitted from thermal power plant are SPM, SO_x, and NO_x. The amount of pollutants emitted from any power plant depends upon the type of the fuel used, burning method and type of control equipments. These pollutants are finally found in ambient air[2]. The major sources of pollutants in ambient air from Shree Cement are stack, which release SPM, NO_x and SO_x. Various coals such as petcock, lignite, bituminous etc. are used in power plants, in which % S are 6.0 percent, 4.0 percent and 3.8 percent, respectively[3]. Sulphur in coal cannot be destroyed. It can only be converted from one form to another. During the combustion process, sulphur reacts with oxygen and formed SO_2 and SO_3[4,5] Sulphur dioxide affects the

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environment in number of ways like acid rain, corrosion and causes severe damages to the health. These emissions causes health problems reduce visibility and contributes to the acid rain problems. The three constituents of flue gases, which mainly affect acidity of the rains are CO_2, SO_2 and NO_x[6]. The SO_2 emitted to the environment combines with water to form sulphuric acid and similarly, NOx formed nitric acid. During the rainy season, the acid formed in the atmosphere falls on to ground. This rain increases the acidity of the lake, well water and rivers. When the acidity is increased above a particular level (pH < 5), then fish population dies totally[7]. Due to acid rains, the metals like Hg, Pb, in earth crust are gradually dissolved and are found in the body of the fishes and enter into body of human beings and cause many diseases[8,9]. The concentration of acid rain completely destroyed the agricultural potential of the land. The acid rain also damages national monuments and buildings; such effects has already been identified in case of Taj Mahal in Agra.

Flue gas desulphurization (FGD) is the technique used for removal of sulphur dioxide from the exhaust flue gases in power plants. Therefore, the aim of this project is to reduce the percentage of SO_2 in environment. Therefore, our environment becomes eco-friendly[9,10].

All most complete removal of SO_2 in flue gases has been observed using this process in the Shree Power, Beawar, Rajasthan.

EXPERIMENTAL

In present experiment, flue gases containing sulphur dioxide are passed through a solution, which was rich with sodium ions. SO_2 monitoring kit was used for SO_2 measurement. This SO_2 reacts with these ions to produce sodium sulphate. Dissolved sodium sulphate can be extracted from solution by heating till dryness. Three parameters have been analyzed in precipitates. i.e. % SO_3 (gravimetric), % SO_2 (Volumetric) and % alkalinity. The methods used work as per Indian standard methods from Bureau of Indian Standards. Prepared Na_2SO_4 can be used as a home laundry detergent, and in paper production. In the laboratory, it is used as an inert drying agent, for removing traces of water from organic solutions[11–15].

Materials and methods

All experiments were conducted on Stack monitoring kit (Model No. VSS1, 141 DTH -2005, Vayubodhan). First of all SO_2 monitoring kit of SO_2 measurement was set up at chimney inlet of Boiler No. 4 of Shree power. Flue gas containing SO_2 was supplied from chimney via probe connected with flexible pipe of stack monitoring kit. The flow of flue gas

was controlled using an inlet line rota meter and was maintained at a value of 2-3 liter per minute. The other end of flexible pipe carrying air and SO_2 was connected to an impinger of 10 cm diameter and 100 cm length. The impinger was filled with 100 mL of scrubbing media in this experiment. i.e. sodium hydroxide. Then five sets of readings were taken by taking different concentrations of NaOH. 100 mL of solution was taken into first two different impingers for better absorption of SO_2 and 30 mL H_2O_2 was taken in third impinger for determination of remaining SO_2. For determination of the effect of pH of solution, 50 mL of 10 percent sodium hydroxide solution was taken in first two impingers and SO_2 gas was flown. 10 mL of this solution was pipetted out in every 15 min. and pH was analyzed. It was also titrated with 1 M oxalic acid for determination of fall in concentration of NaOH. To determine the effect of flow of flue gases in impingers, direct and indirect methods have been developed. In direct method, flue gases were passed directly. But in indirect method, flue gases were passed after passing them in water for separation of any dust particle. Similar experiments were conducted at different temperatures of NaOH solution and different time period for reactions keeping other parameters constant. Operating conditions of SO_2 absorption are given in Table 1. Experimental set up is shown in Fig. 1.

Table 1: Operating conditions for SO_2 absorption in sodium hydroxide solution

Operating condition	Value
Initial concentration of sodium hydroxide solution	Varying
pH of solution	12.57
Total liquid hold up	100 mL
Temperature of solution	25-30^oC
Time period for reaction	0.5 hr
Flow of flue gas in impinger	Varying
SO_2 load in flue gas	3000 – 3200 ppm
Flue gas temperature	135^oC
Flue gas flow in duct of ESP O/L	150522 m^3/hr
Pet coke feeding rate	13 ton/hr
Lime stone feeding rate	1.0 ton/hr

Fig. 1: Experimental set up using SO_2 monitoring kit for absorption of SO_2

RESULTS AND DISCUSSION

Fig. 2 and Table 2 gives the effect of concentration of NaOH solution on absorption of SO_2 with recovery and analysis results of ppt. It was confirmed that when the concentration of NaOH was increased, there was a significant decrease in recovery of SO_2, which is also confirmed by analysis results of ppt. The ppt., which was prepared by lower

Table 2: Effect of concentration of reagent with recovery of SO_2 absorption

Conc. of NaOH (%)	Recovery of sulphur dioxide (%)	Analysis results of ppt. (% SO_3)	Analysis results of ppt. (% SO_2)
5	97.96	20.76	35.49
10	95.08	5.67	17.01
15	90.18	1.49	9.81
20	88.02	0.52	5.77
25	85.19	0.24	3.99

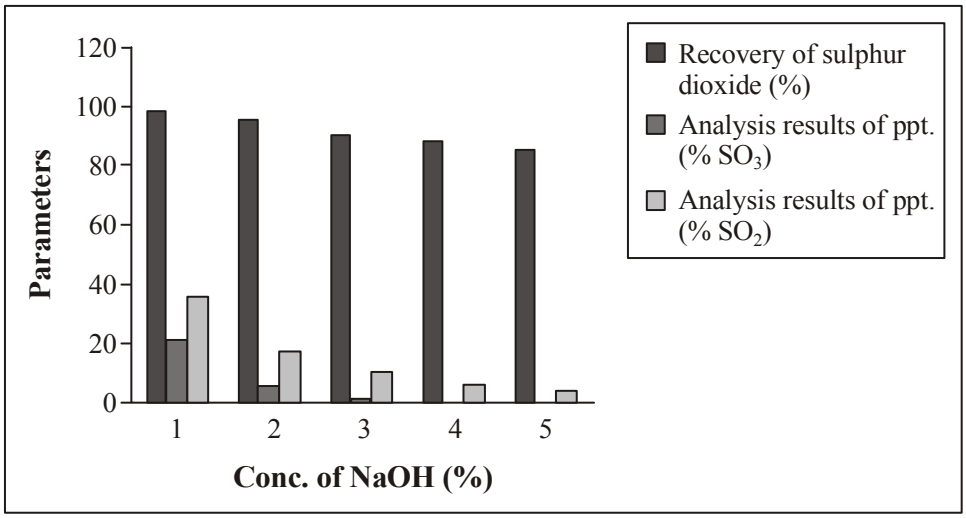

Fig. 2: Relation between concentration of NaOH solution and recovery of SO_2

concentration of NaOH was having maximum % SO_3 and maximum % SO_2. Fig. 3 and Table 3 indicate that when time period for absorption of SO_2 in NaOH solution was increased, then there was a significant decrease in pH. Fig. 4 suggests that with the increase of time period for absorption of SO_2 in NaOH solution, there was a significant decrease in concentration of NaOH Solution.

Table 3: Effect of pH of NaOH solution for absorption of SO_2

Time (min)	pH of solution	Volume of 1 M oxalic acid consumed in titration using phenolphthalein indicator (mL)	Conc. of NaOH (%)
0	12.57	20.05	80.06
15	10.62	15.56	62.2
30	8.82	3.5	14.2
45	7.95	1.23	4.8
60	5.62	0.56	2.2
75	4.75	0.32	1.2

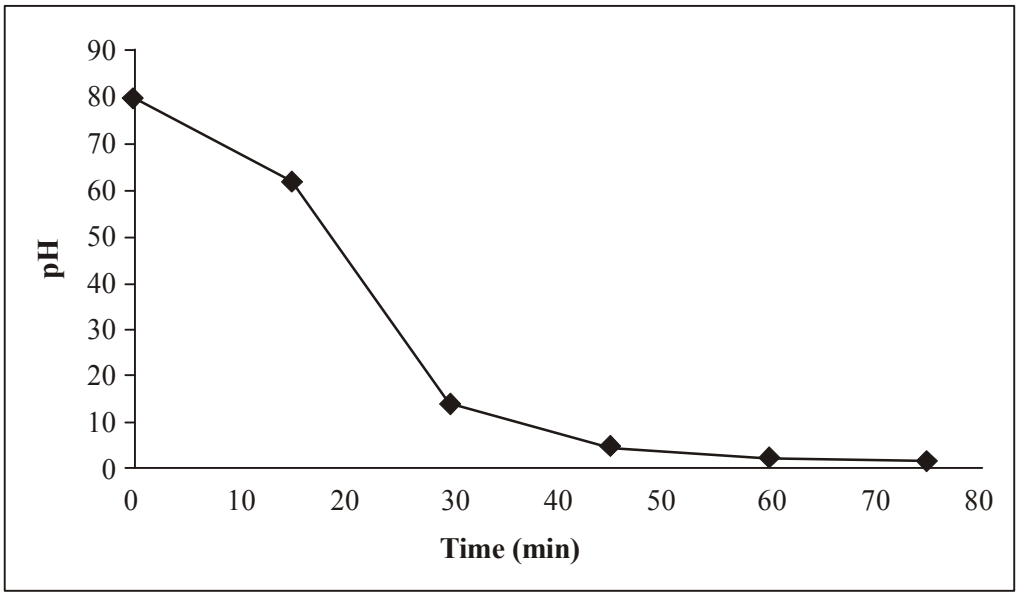

Fig. 3: Relation between pH of NaOH solution and absorption of SO_2

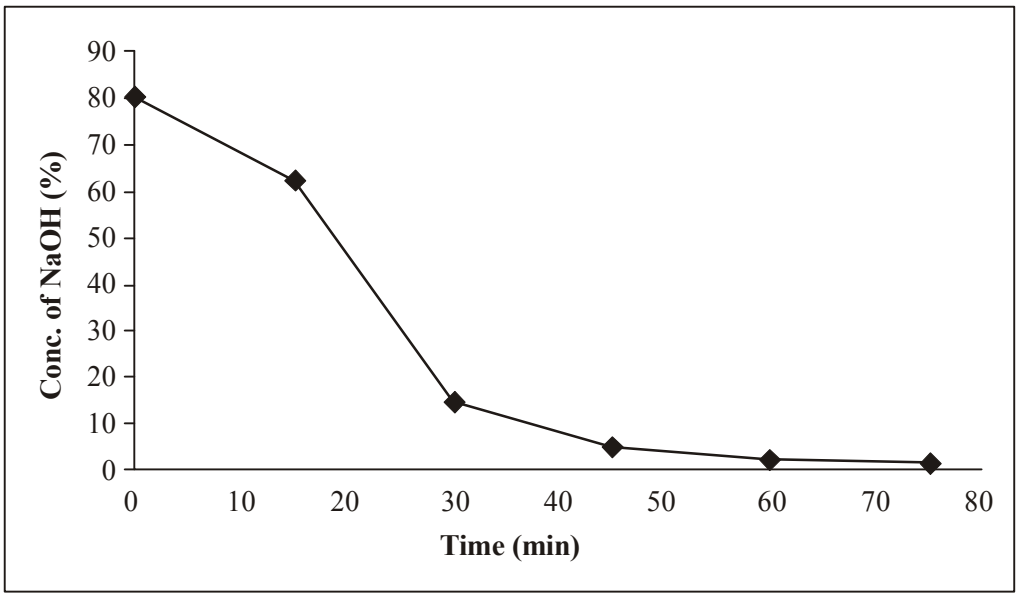

Fig 4: Relation between time period and falls in conc. of NaOH

Fig. 5 and Table 4 indicate that maximum recovery of SO_2 was obtained, when flue gases were passed in the NaOH solution directly instead of indirect passing. Table 5 and Fig. 6 report that by increasing temperature of NaOH solution, there was a decrease in significant value of recovery of SO_2, which is also confirmed by analysis results of ppt., i.e. the ppt., which was prepared at lower temperature of NaOH having maximum % SO_3 and maximum % SO_2. Table 6 and Fig. 7 suggest that by increasing time period for reaction between NaOH and SO_2, there was a decrease in significant value of recovery of SO_2.

Table 4: Effect of direct and indirect flow of flue gases in NaOH solution and removal efficiency of SO_2

Flow of SO_2 gas	Recovery of SO_2 (%)	Analysis results of ppt (% SO_3)	Sodium sulphate (%)
Direct	95.25	1.790	3.170
Indirect	59.62	0.233	0.413

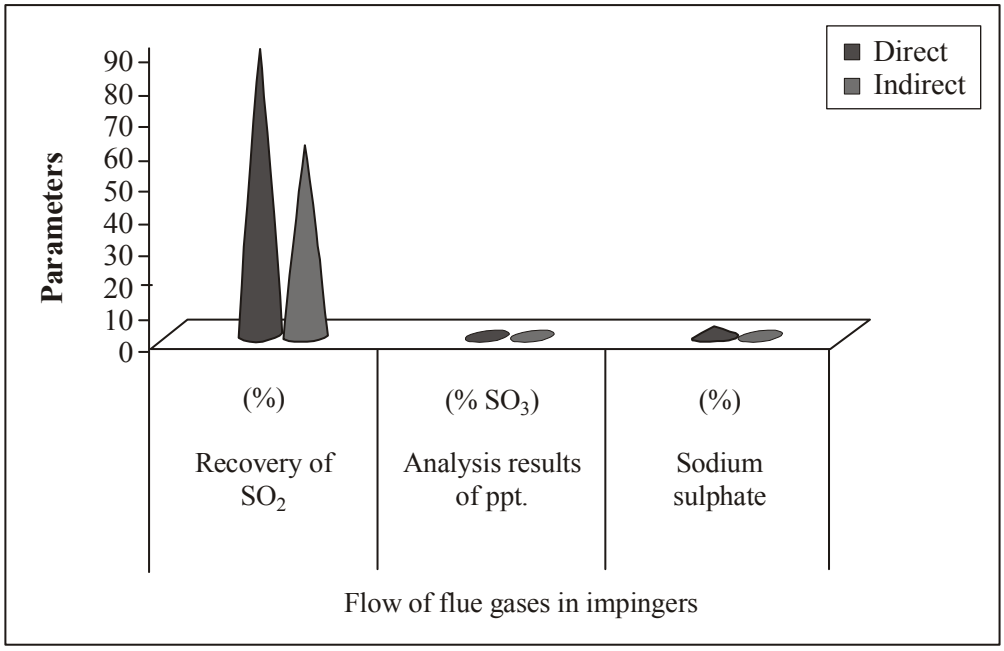

Fig. 5: Effect of direct and indirect flow of flue gases in NaOH solution on % recovery of SO_2

Table 5: Effect of temperature of NaOH solution and removal efficiency of SO_2

Temperature of NaOH solution (^oC)	Recovery of SO_2 (%)	Analysis results of ppt. (% SO_3)	Sodium sulphate (%)
20-25	90.18	0.62	1.1
25-30	81.62	0.42	0.745
30-35	78.08	0.22	0.39

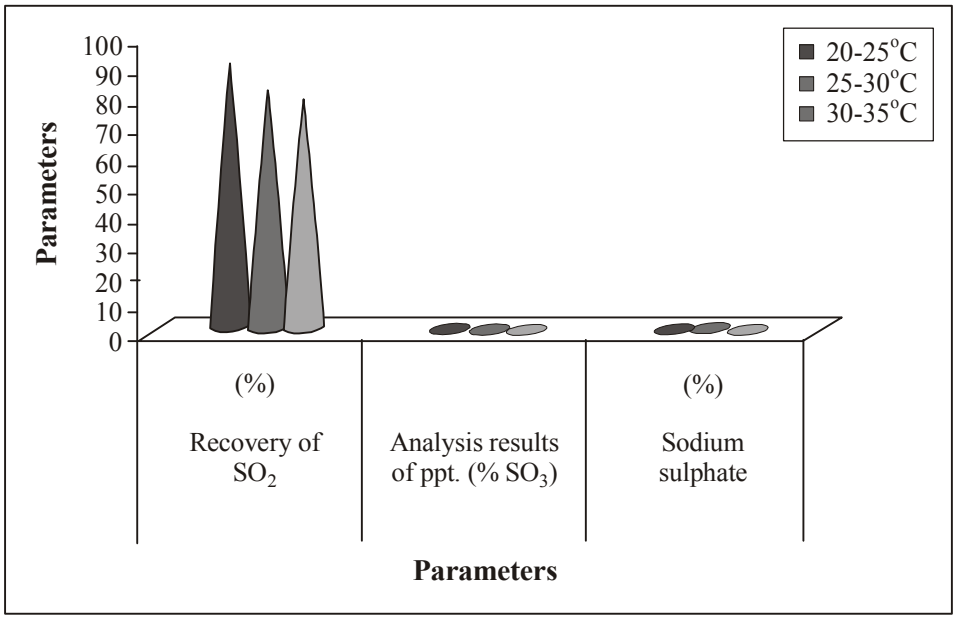

Fig. 6: Effect of temperature of NaOH solution and recovery of SO_2

Table 6: Effect of time period for reaction and removal efficiency of SO_2

Time period for reaction (min)	Recovery of SO_2 (%)	Analysis results of ppt (% SO_3)	Sodium sulphate (%)
20	75.25	1.63	2.89
40	80.18	2.35	4.17
60	88.27	3.06	5.03

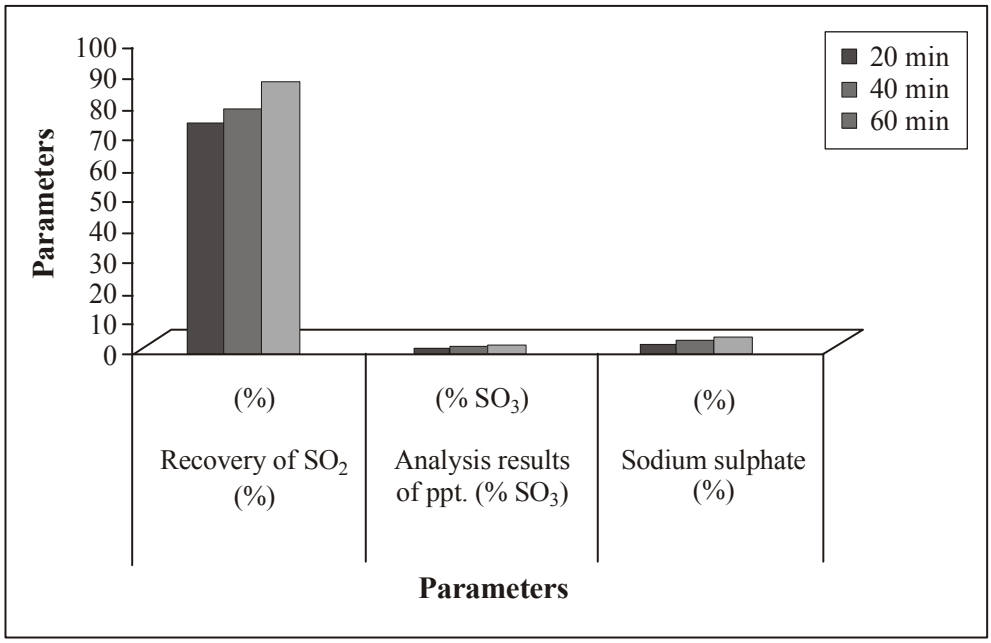

Fig. 7: Effect of time period for reaction with recovery of SO_2

CONCLUSIONS

Maximum absorption of SO_2 was obtained in 5% sodium hydroxide solution while less in other (higher) concentrations. Therefore, 5 % concentration of sodium hydroxide was used as an optimal concentration.

(i) The recovery of SO_2 in higher concentration of sodium hydroxide was found to be low due to following reason:

The nature of SO_2 is acidic and hence, it reduces the pH of solution in half an hour. So SO_2 absorption is not possible.

(ii) It may be concluded that addition of more NaOH in solution results into less absorption and therefore, it is not fruitful. This is because of load of SO_2 in flue gases is very low (at ppm level), Hence, reagent remains as it is in solution after complete absorption of SO_2.

(iii) If 5 % NaOH solution was sprayed in the path of flue gases, then maximum recovery of SO_2 is possible and the environment is protected from toxic effects of SO_2 yielding sodium sulphate also.

(iv) SO_2 absorption has taken place in the solution.

(v) The change in colour of the solution can be seen easily during the experiment i.e. initial colour was white, and after passing SO_2, colour of the solution was yellow.

(vi) The pH should be more alkaline for better absorption of SO_2

(vii) Maximum recovery of SO_2 was observed on passing SO_2 gas in direct medium; may be due to following reasons :

When flue gases passes through water (for separation of dust particles), they react with it and form sulfurous acid and thus, concentration of SO_2 falls. This is the reason that high % of SO_3 and % SO_2 were found in direct passing of flue gases through sodium hydroxide solution as compared to indirect passing. This effect can be seen by checking pH of the solution in the beginning and at the end of the experiment. i.e. (in start of experiment, the pH was 12.57 and after passing of SO_2, pH changed to 4.75)

$H_2O + SO_2 \rightarrow H_2SO_3$ (Sulphurous acid)

$H_2O + SO_3 \rightarrow H_2SO_4$ (Sulphuric acid)

(viii) Absorption and precipitation of sulphate is a temperature sensitive reaction. At higher temperatures, the sodium sulphate was formed but it remained soluble as solubility increases with the increasing temperature.

(ix) The maximum recovery of SO_2 was found at the temperature in the range of 20-25^oC. and this seems to be optimum temperature. At higher temperatures, the reversible reaction may takes place and partially formed sodium sulphate may change back into NaOH.

(x) The absorption of SO_2 in sodium hydroxide solution depends upon time period of the reaction. The maximum recovery of SO_2 was obtained, when the reaction was carried out for longer time period.

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