Asian Journal of Water, Environment and Pollution, Vol. 8, No. 3 (2011), pp. 29-35.

Recovery and Utilization of Sulphur Dioxide from Exhaust Flue Gases to Control SO_2 Emission at Thermal Power Plant, Rajasthan

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Received October 28, 2009; revised and accepted June 2, 2011

Abstract: SO_2 is a major constituent in air pollution. Pet coke (having 6 % Sulphur) with lime stone are being used for power generation in thermal power plants. Sulphur dioxide is produced during combustion of fuels containing sulphur and affects the environment in number of ways like acid rain corrosion and severe damage to health. Flue gas desulphurization (FGD) is the technique used for removal of SO_2 from exhaust flue gases in power plants. In accordance with the invention, flue gases containing sulphur dioxide are passed through a solution which was rich with sodium ions to produce sulphate by using SO_2 monitoring kit of SO_2 measurement.

To find the optimum temperature of absorption of SO_2 in NaOH solution, the study was carried out at various temperatures. As is clear from Table 2 it is 20–25 ºC which is the most appropriate for the maximum absorption of SO_2 by NaOH solution. Similar sets of experiments were carried out by varying the time intervals for absorption of SO_2 by NaOH solution. As is shown in Table 4 the increased absorption of SO_2 is observed with increase in time intervals.

Key words: Flue gases, sulphur dioxide, sodium hydroxide, thermal power.

Introduction

There are three control technologies which have major application in the field of sulphur dioxide control (Sheth et al., 2006; Buecker, 2006; Gosavi, 2005; Fan and Brown, 2002; Sung and Brown 2002).

- Adsorption
- Catalytic Oxidation/reduction
- Absorption

Adsorption is a control technology for control of SO_2 from stack gases but suffers from several following drawbacks:

1. Higher energy requirements
2. Penetration of SO_2 in the granule is difficult
3. Highly active absorbent surfaces cause oxidation of SO_2 to SO_3 which react with moisture in flue gases to form acid
4. Regeneration techniques are costlier

Catalytical oxidation/reduction is a control technology for control of SO_2 from stack gases but suffers from several drawbacks, like the following:

1. Higher energy requirements
2. Large equipment size
3. Costly Catalysts
4. Regeneration and disposal of catalysts is also a problem
5. Contractor design is complex

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Absorption is a control technology for control of SO_2 from stack gases and is most widely practiced. However, this technology also suffers from following drawbacks:

1. Stack gas cooling and reheating is required
2. Mist elimination is required

However, these problems can be easily encountered with proper engineering design. Besides this, reducing operator's intensiveness, cost and ease of handling of liquid sorbent makes it an attractive option. It is one of the most widely used control technology employed for removal of SO_2 (Butler et al., 2002; Dene, 2002; Buecker, 1986; Kohl and Nielsen,1975; Slack and Hollindon, 1971).

Experimental

First SO_2 monitoring kit of SO_2 measurement was set up at chimney inlet for determination of concentration of SO_2 emitted from boiler of thermal power plant. 10% sodium hydroxide solution was prepared by dissolving 10 g NaOH in 100 ml of DM water. Then this solution was taken in first impinger and flue gases containing SO_2 was provided in first impinger using a flexible pipe connected to the SO_2 monitoring kit. The flow of SO_2 was controlled using an inlet line rotameter and one end of flexible pipe was connected to chimney inlet for suction of SO_2 and other end of flexible pipe was connected to SO_2 monitoring kit having impingers of 10 cm diameter and 100 cm length. The impinger was filled with 100 ml of scrubbing media, i.e., NaOH solution. Experiments were conducted at different temperatures of solutions at the rate of 3 litre/min. The pH of solution was 12.57 and time period for every experiment was half an hour. Similarly, experiments were conducted at different times of intervals, i.e., 20 minutes, 40 minutes, and 60 minutes. It was carried out by preparing 10% NaOH solution in about 100 ml. Temperature and pH of solution was kept constant at 25 ºC and 12.57, respectively. This reaction took place by passing of flue gases containing SO_2 directly in impingers for half an hour at the rate of 3 litre/min (IS 11255 (Part 2) 1985; IS 5182 (Part 2) 2001; IS No. 1514; IS No 1760 Part 3 1992; IS 248: 1987; IS 252: 1991). Experimental set-up is shown in Figure 9 and operating conditions for SO_2 absorption are given in Table 1.

Table 1: Operating condition of SO_2 absorption in sodium hydroxide solution

S. No.	*Operating Condition*	*Value*
1	Initial Concentration of Sodium hydroxide solution	10%
2	pH of solution	12.57
3	Total liquid hold up	100 ml
4	Temperature of solution	Varying
5	Time period for reaction	0.5 hour (30 minutes)
6	Flow of flue gas in impinger	3 LPM
7	SO_2 load in flue gas	3000–3200 ppm
8	Flue gas Temperature	135ºC
9	Flue gas flow in duct of ESP O/L	150522 m^3/hour
10	Pet Coke Feeding Rate	13 tonne/ hour
11	Lime Stone Feeding Rate	1.0 tonne/hour

Table 2: Effect of temperature of NaOH solution and recovery of SO_2

S. No.	*Temperature of NaOH solution*	*Initial Conc. of SO_2 (ppm)*	*Conc. of SO_2 after formation of sulphate (ppm)*	*Recovery (%)*
1	20–25 ºC	3080	302	90.18
2	25–30 ºC	3080	566	81.62
3	30–35 ºC	3080	675	78.08

Table 3: Analysis results of precipitate which was prepared by different temperature of NaOH solution and SO_2

S.No	*Temperature of NaOH solution*	*Yield (g)*	*% SO_3*	*% SO_2*	*% Na_2SO_4*	*% Alkalinity*
1	20–25ºC	9.77	0.62	38.72	1.100	1.68
2	25–30ºC	9.25	0.42	31.92	0.745	1.80
3	30–35ºC	9.06	0.22	17.87	0.390	1.95

Table 4: Effect of time intervals of reaction and recovery of SO_2

S.No	*Time for reaction (min)*	*Initial conc. of SO_2 (ppm)*	*Conc. of SO_2 after formation of SO_4 (ppm)*	*Recovery (%)*
1	20	3075	761	75.25
2	40	3075	609	80.18
3	60	3075	360	88.27

Table 5: Analysis results of precipitate which was prepared by different times of intervals of reaction between NaOH solution and SO_2

S.No	*Time of reaction (min)*	*Yield (g)*	*% SO_3*	*% SO_2*	*% Na_2SO_4*	*% Alkalinity*
1	20	8.62	1.63	26.68	2.89	1.16
2	40	8.95	2.35	29.34	4.17	0.96
3	60	9.02	3.06	36.51	5.03	0.75

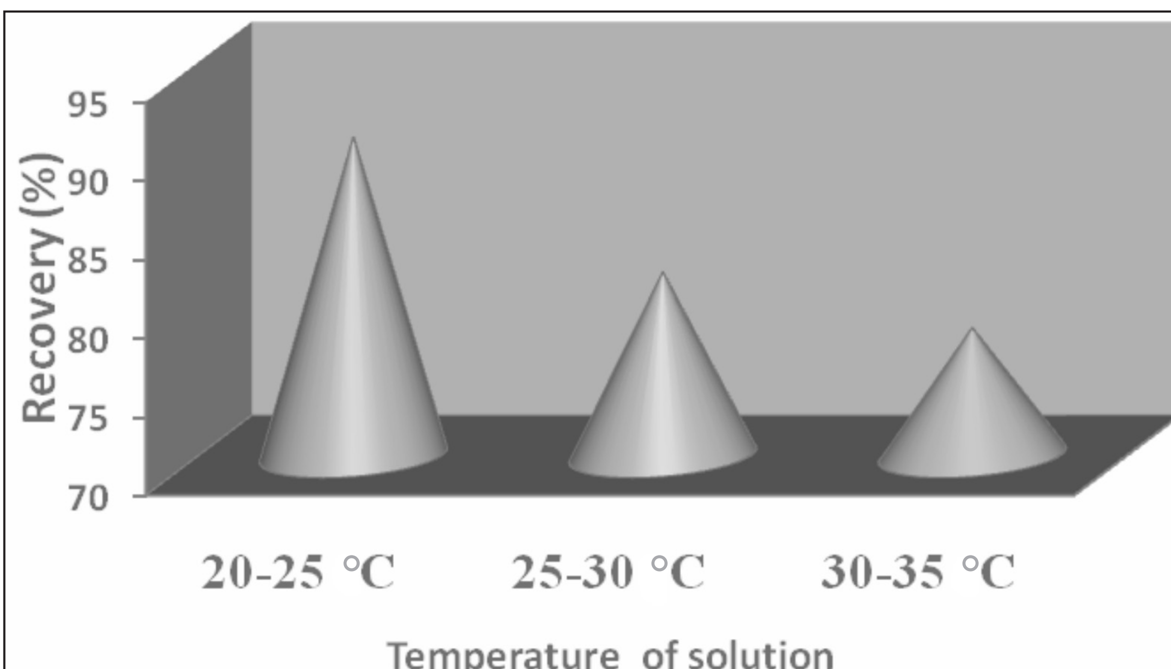

Figure 1: Effect of temperature of NaOH solution and recovery of SO_2.

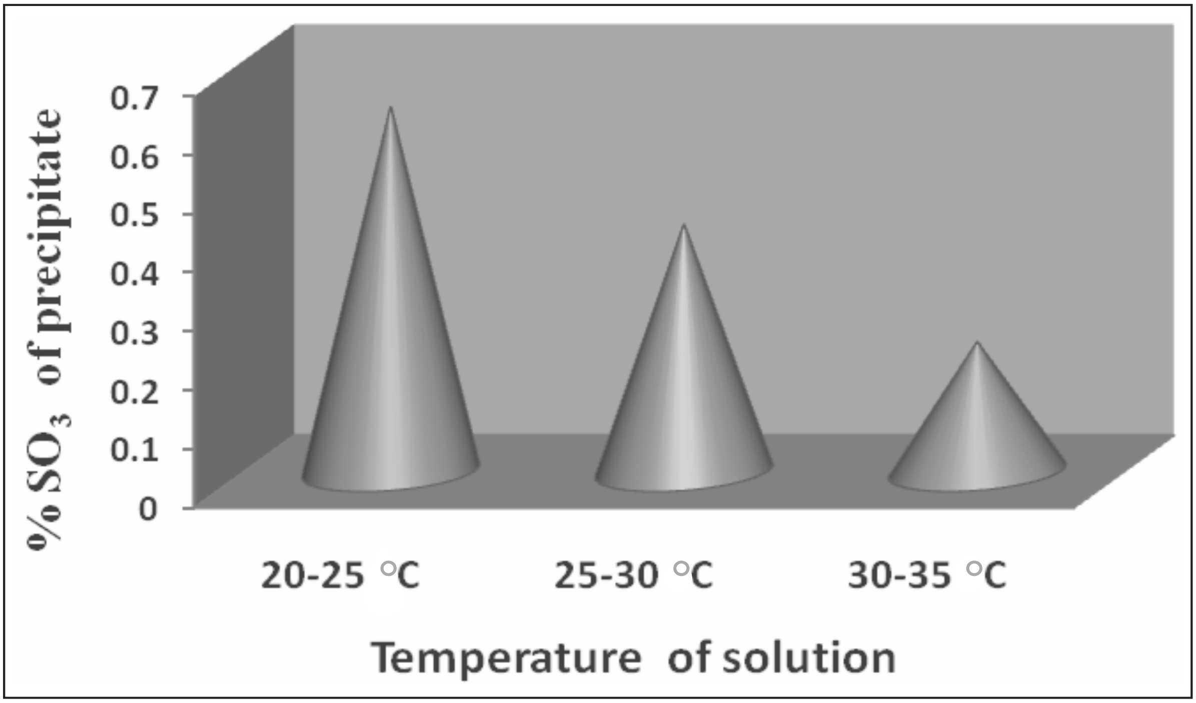

Figure 2: Effect of temperature of NaOH solution and % SO_3 (gravimetric) of ppt.

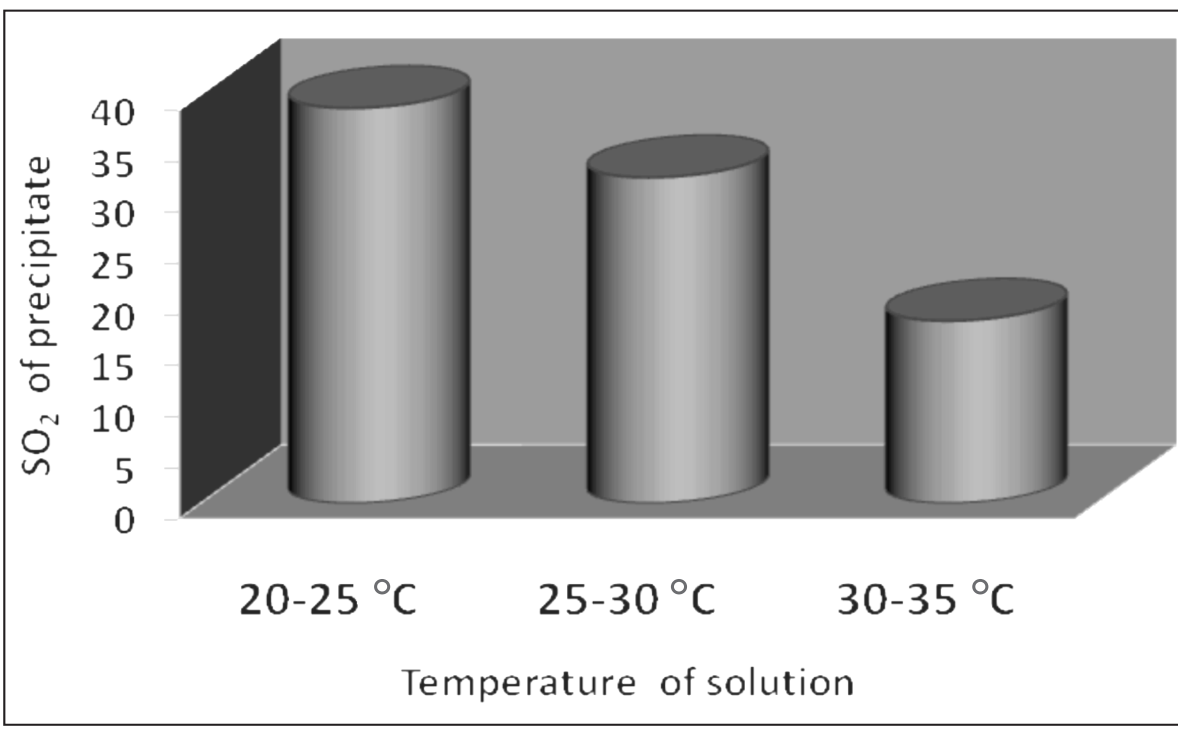

Figure 3: Effect of temperature of NaOH solution and % SO_2 (volumetric) of ppt.

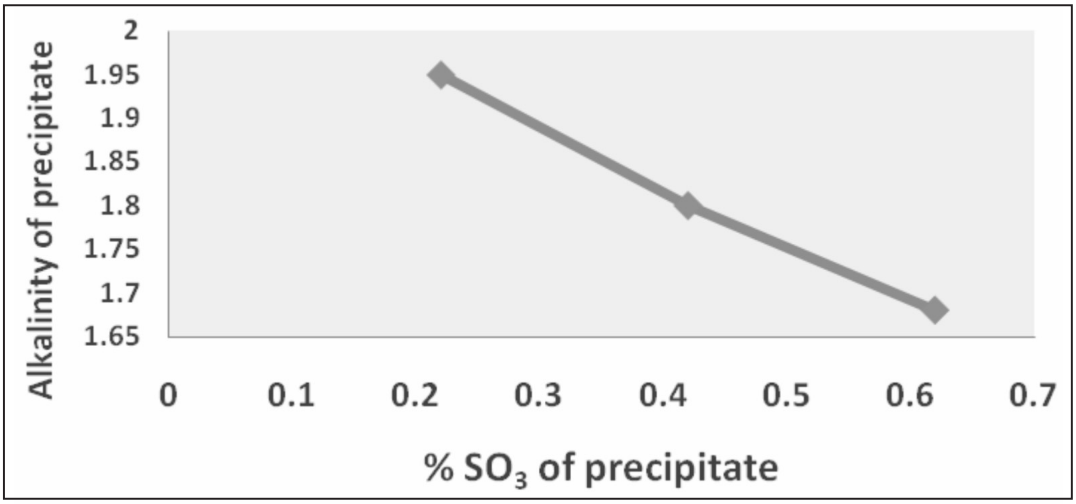

Figure 4 : Relation between % SO_3 and alkalinity of precipitate.

Figure 5: Effect of time period for reaction and recovery of SO_2.

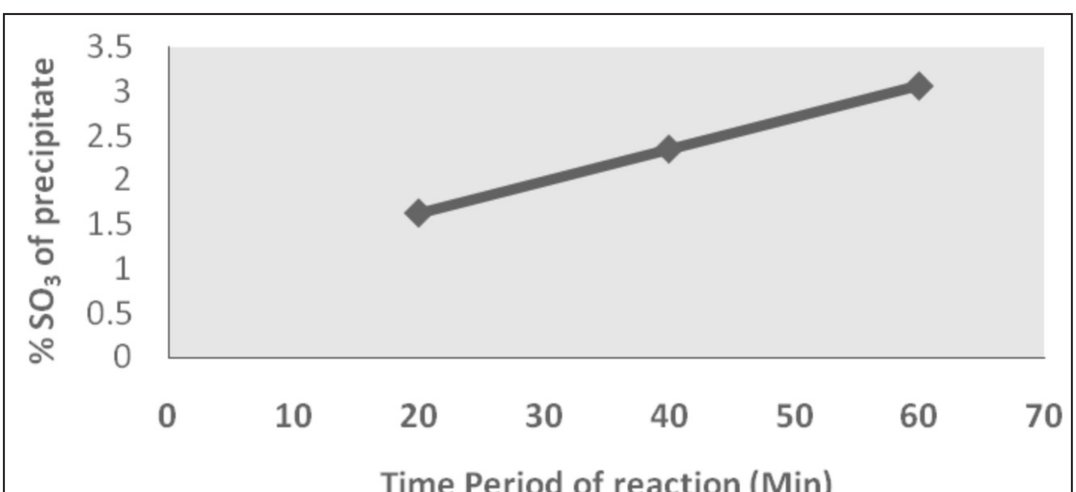

Figure 6: Relation of time period of the reaction and % of SO_3 of precipitate.

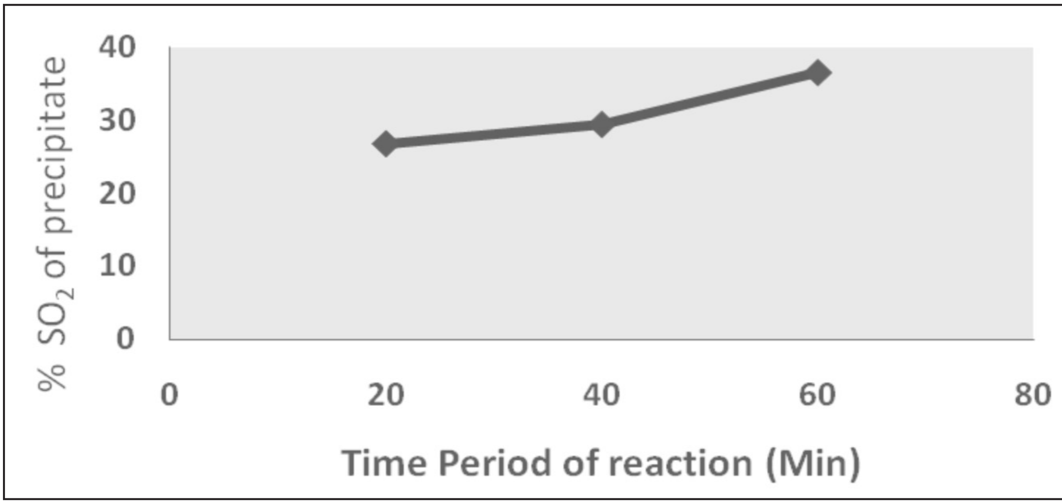

Figure 7 : Relation of time period of the reaction and % of SO_2 of precipitate.

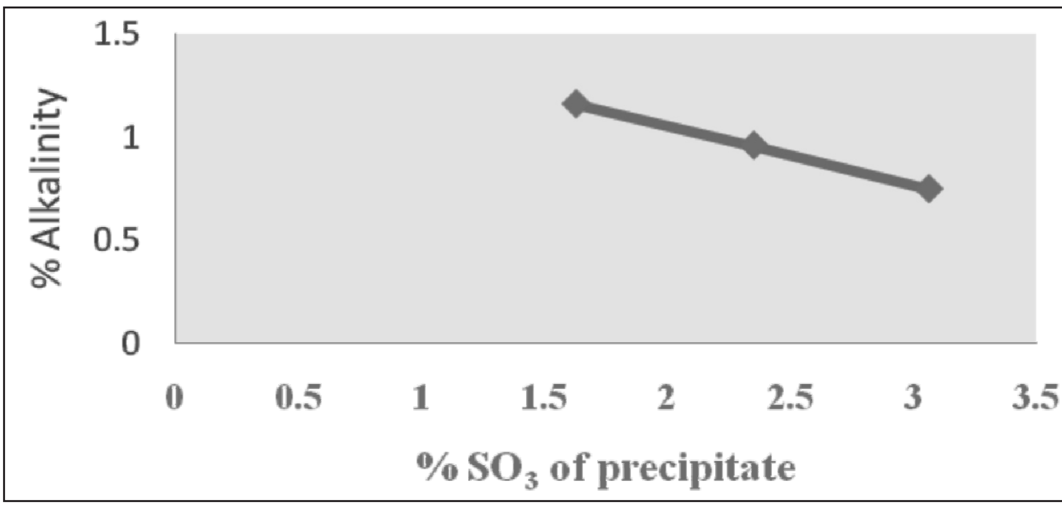

Figure 8: Relation between % SO_3 and % alkalinity of ppt.

Figure 9: Experimental Set Up by using SO_2 monitoring kit for absorption of SO_2.

Results and Discussion

Figure 1 and Table 2 shows the relation between recovery of SO_2 at different ranges of temperature of NaOH and it is confirmed that maximum recovery of SO_2 was observed at lower temperature, i.e., 20–25 ºC. Figures 2 and 3 and Table 3 show analytical results of ppt (% SO_3 and % SO_2). As it is seen from the table that the ppt which was prepared at lower temperature of NaOH have maximum % SO_3 and SO_2.

Figure 4 reports that when % SO_3 increases then % alkalinity decreases in the precipitate.

Figure 5 and Table 4 show results of recovery of SO_2 with different times of intervals. As is clear from this figure that maximum recovery of SO_2 is observed for longer time period of reaction. Figures 6 and 7 and Table 5 report analytical results of ppt which were prepared by using SO_2 and NaOH at different time intervals and confirmed that the ppt which was made at longer time period. The ppt have got maximum of SO_3 and SO_2. Figure 8 represents when % SO_3 decreases then % of alkalinity increases.

Conclusion

1. Absorption and precipitation of sulphate is a temperature sensitive reaction. At higher temperature the sodium sulphate is formed but remains soluble as solubility increases with the increasing temperature. The maximum recovery of SO_2 is found at the temperature in the range of 20–25 ºC and this seems to be optimum temperature.
2. At higher temperature the reversible reaction may take place and partially formed sodium sulphate, may be changed into NaOH.
3. The absorption of SO_2 in sodium hydroxide solution depends upon time period of the reaction.
4. The maximum recovery of SO_2 was obtained when the reaction took place for a longer time period.
5. Prepared Na_2SO_4 can be used as a home laundry detergent, and also used in paper production. In the laboratory Na_2SO_4 is used as an inert drying agent, for removing traces of water from organic solutions.

Acknowledgement

Authors are thankful to Principal and Head, Department of Chemistry, S.D. Govt. College, for facilities provided. One of the authors Arun Sharma is highly thankful to members of thermal power plant for their support and contribution during research.

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