

Recovery and Utilization of Sulphur Dioxide from Exhaust Flue Gases to Control SO₂ Emission at Thermal Power Plant, Rajasthan

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Abstract: SO₂ 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 SO₂ 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 SO₂ monitoring kit of SO₂ measurement.

To find the optimum temperature of absorption of SO₂ in NaOH solution, the study was carried out at various temperatures. As is clear from Table 2 it is 20–25 °C which is the most appropriate for the maximum absorption of SO₂ by NaOH solution. Similar sets of experiments were carried out by varying the time intervals for absorption of SO₂ by NaOH solution. As is shown in Table 4 the increased absorption of SO₂ 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 SO₂ from stack gases but suffers from several following drawbacks:

1. Higher energy requirements

2. Penetration of SO₂ in the granule is difficult
3. Highly active absorbent surfaces cause oxidation of SO₂ to SO₃ 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 SO₂ 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 SO₂ 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 SO₂ (Butler et al., 2002; Dene, 2002; Buecker, 1986; Kohl and Nielsen, 1975; Slack and Hollindon, 1971).

Experimental

First SO₂ monitoring kit of SO₂ measurement was set up at chimney inlet for determination of concentration of SO₂ 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

SO₂ was provided in first impinger using a flexible pipe connected to the SO₂ monitoring kit. The flow of SO₂ was controlled using an inlet line rotameter and one end of flexible pipe was connected to chimney inlet for suction of SO₂ and other end of flexible pipe was connected to SO₂ 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 °C and 12.57, respectively. This reaction took place by passing of flue gases containing SO₂ 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 SO₂ absorption are given in Table 1.

Table 1: Operating condition of SO₂ absorption in sodium hydroxide solution

<i>S. No.</i>	<i>Operating Condition</i>	<i>Value</i>
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	135°C
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 SO₂

<i>S. No.</i>	<i>Temperature of NaOH solution</i>	<i>Initial Conc. of SO₂ (ppm)</i>	<i>Conc. of SO₂ after formation of sulphate (ppm)</i>	<i>Recovery (%)</i>
1	20–25 °C	3080	302	90.18
2	25–30 °C	3080	566	81.62
3	30–35 °C	3080	675	78.08

Table 3: Analysis results of precipitate which was prepared by different temperature of NaOH solution and SO₂

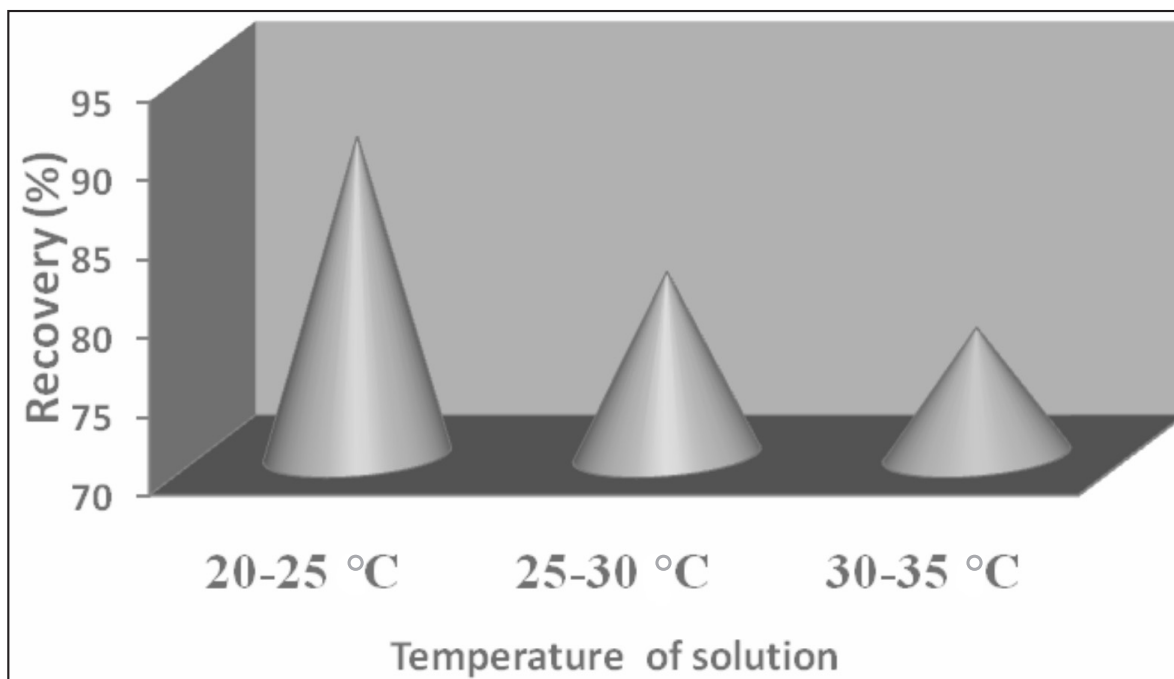
<i>S.No</i>	<i>Temperature of NaOH solution</i>	<i>Yield (g)</i>	<i>% SO₃</i>	<i>% SO₂</i>	<i>% Na₂SO₄</i>	<i>% Alkalinity</i>
1	20–25°C	9.77	0.62	38.72	1.100	1.68
2	25–30°C	9.25	0.42	31.92	0.745	1.80
3	30–35°C	9.06	0.22	17.87	0.390	1.95

Table 4: Effect of time intervals of reaction and recovery of SO₂

<i>S.No</i>	<i>Time for reaction (min)</i>	<i>Initial conc. of SO₂ (ppm)</i>	<i>Conc. of SO₂ after formation of SO₄ (ppm)</i>	<i>Recovery (%)</i>
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 SO₂

<i>S.No</i>	<i>Time of reaction (min)</i>	<i>Yield (g)</i>	<i>% SO₃</i>	<i>% SO₂</i>	<i>% Na₂SO₄</i>	<i>% Alkalinity</i>
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 SO₂.**

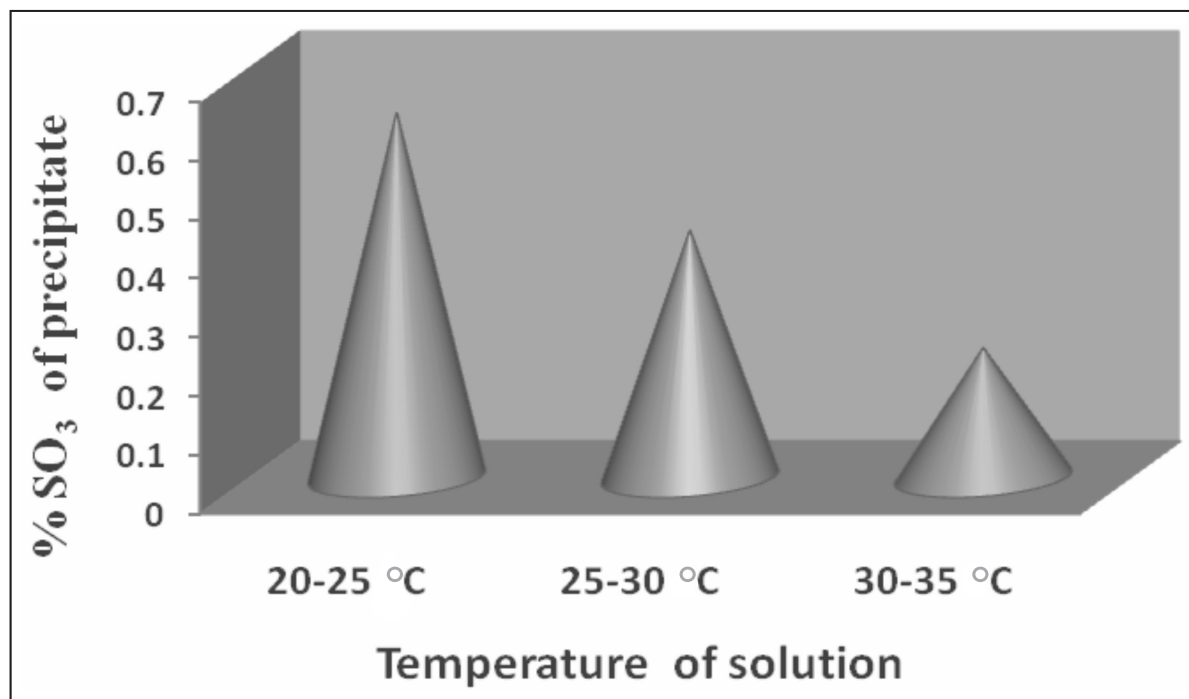


Figure 2: Effect of temperature of NaOH solution and % SO_3 (gravimetric) of ppt.

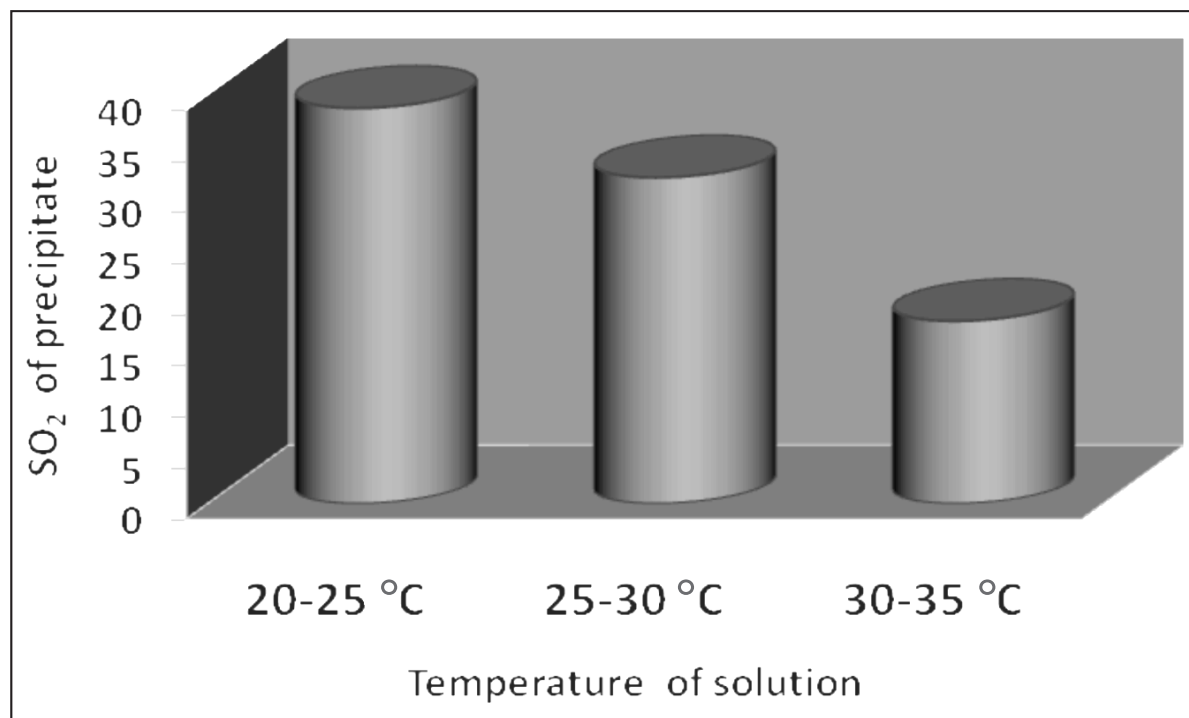


Figure 3: Effect of temperature of NaOH solution and % SO_2 (volumetric) of ppt.

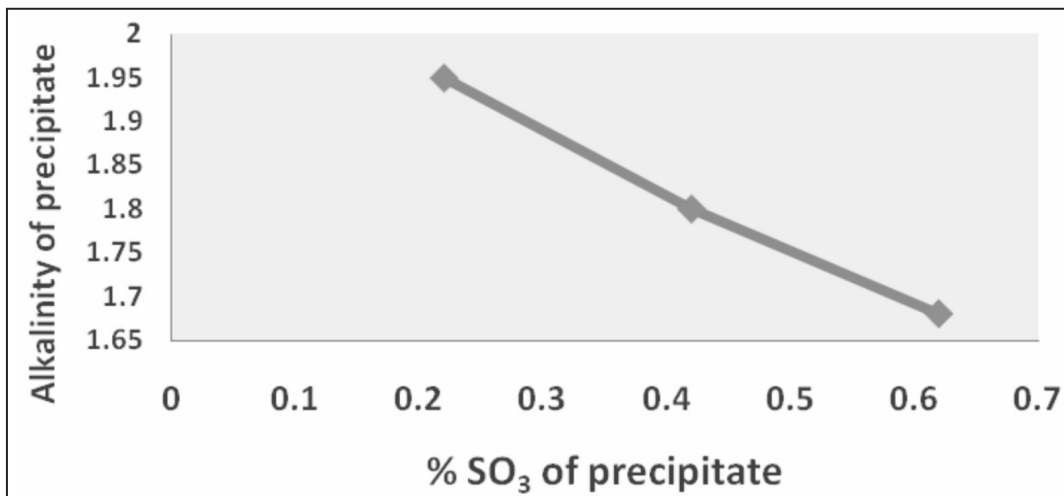


Figure 4 : Relation between % SO₃ and alkalinity of precipitate.

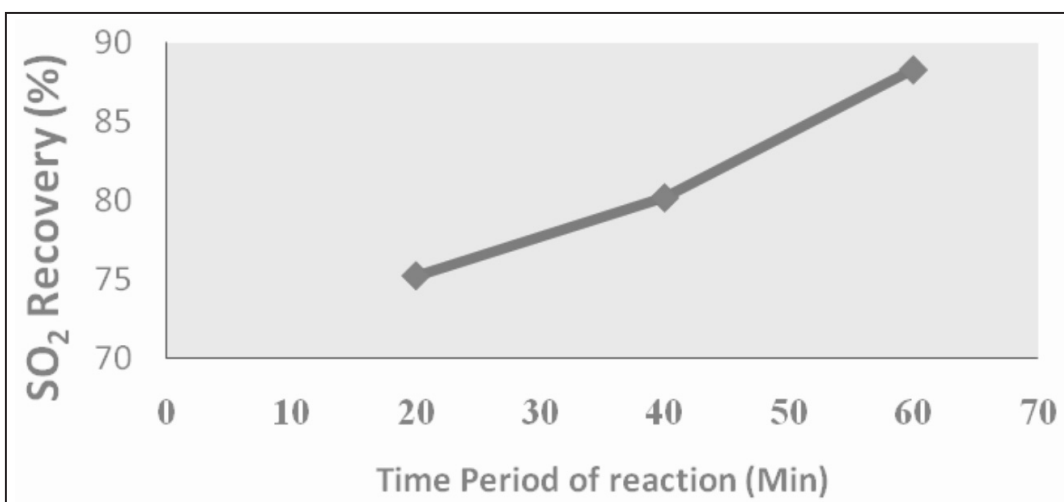


Figure 5: Effect of time period for reaction and recovery of SO₂.

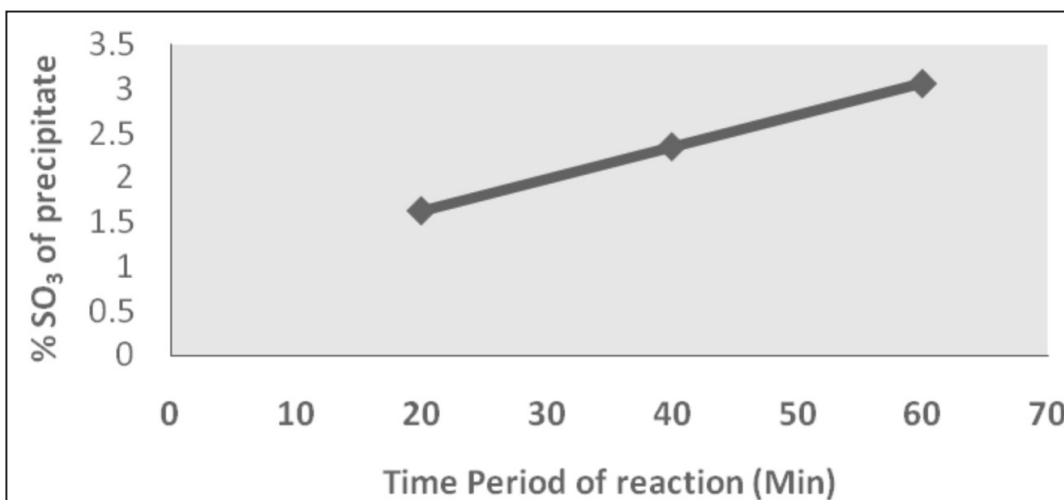


Figure 6: Relation of time period of the reaction and % of SO₃ of precipitate.

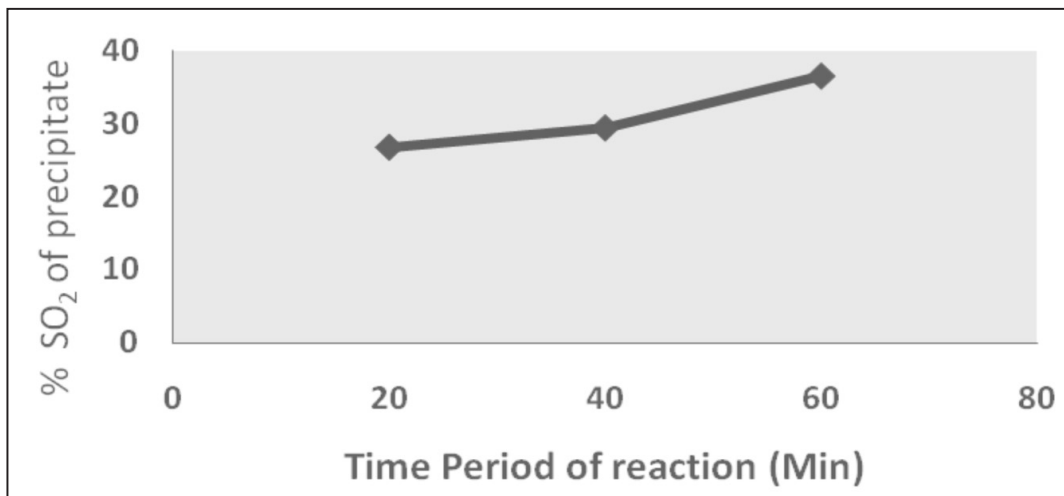


Figure 7 : Relation of time period of the reaction and % of SO₂ of precipitate.

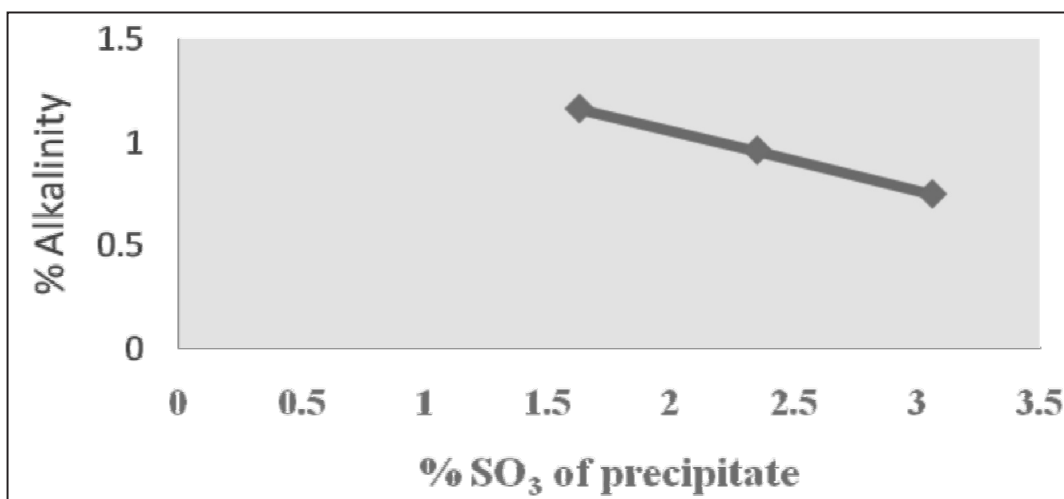


Figure 8: Relation between % SO₃ and % alkalinity of ppt.



Figure 9: Experimental Set Up by using SO₂ monitoring kit for absorption of SO₂.

Results and Discussion

Figure 1 and Table 2 shows the relation between recovery of SO₂ at different ranges of temperature of NaOH and it is confirmed that maximum recovery of SO₂ was observed at lower temperature, i.e., 20–25 °C. Figures 2 and 3 and Table 3 show analytical results of ppt (% SO₃ and % SO₂). As it is seen from the table that the ppt which was prepared at lower temperature of NaOH have maximum % SO₃ and SO₂.

Figure 4 reports that when % SO₃ increases then % alkalinity decreases in the precipitate.

Figure 5 and Table 4 show results of recovery of SO₂ with different times of intervals. As is clear from this figure that maximum recovery of SO₂ 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 SO₂ and NaOH at different time intervals and confirmed that the ppt which was made at longer time period. The ppt have got maximum of SO₃ and SO₂. Figure 8 represents when % SO₃ 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 SO₂ is found at the temperature in the range of 20–25 °C 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 SO₂ in sodium hydroxide solution depends upon time period of the reaction.
4. The maximum recovery of SO₂ was obtained when the reaction took place for a longer time period.
5. Prepared Na₂SO₄ can be used as a home laundry detergent, and also used in paper production. In the laboratory Na₂SO₄ is used as an inert drying agent, for removing traces of water from organic solutions.

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References

- Buecker, B. (1986). Gypsum seed recycle in lime stone scrubber. *Power Engineering*, **110**: 10–12.
- Buecker, B. (2006). Wet lime stone Scrubbing fundamentals. *Power Engineering*, **110**: 32–37.
- Butler, A.D., Maohong, F. and R.C. Brown (2002). Comparison of polymeric and conventional coagulants in arsenic removal. *J. Env. Engg.*, **74**: 308–313.
- Dene, C. (2002). FGD chemistry and analytical methods handbook. *Power Engineering*, **2**: 48–55.
- Gosavi, Ram S. (2005). Flue gas desulphurization – an overview of system and technologies. *Env. Poll. Cont. J.*, **8**: 5–8.
- IS 11255 (Part 2) 1985 and IS 5182 (Part 2) (2001). Indian standard method for measurement of emission from stationary sources.
- IS 248 (1987). Indian standard methods of sodium bi sulphite technical (fourth revision).
- IS 252 (1991). Indian standard methods of Caustic soda, pure and technical (third revision).
- IS No 1760 Part 3 (1992). Indian standard methods of chemical analysis of limestone, dolomite and allied materials: determination of iron oxide, calcium oxide and magnesia (First revision).
- IS No. 1514. Indian standard methods of sampling and test for quicklime and hydrated lime (first revision).
- Kohl, A. and R.B. Nielsen (1975). Gas Purification, fifth edition. Gulf Publishing Company. **10**: 42–49.
- Maohong, Fan and C. Brown (2002). A process for synthesizing polymeric ferric sulphate using sulphur dioxide from coal combustion. *Int. J. Env. Poll.*, **17**: 102–109.
- Sheth, K.N., Patel and Neha J. Patel (2006). Effect of concentration in absorption of sulphur dioxide with sodium hydroxide. *Env. Poll. Cont. J.*, **9**: 14–18.
- Slack, A.V. and G.A. Hollindon, (1971). Sulphur dioxide removal from stake gases, second edition. Noyes Data Corporation. **11**: 45–55.
- Sung, Shih-Wu and R.C. Brown (2002). Synthesis, characterization and coagulation performance of polymeric ferric sulphate. *Int. J. Env. Poll.*, **128**: 483–490.

Asian Journal of Water, Environment and Pollution



Aims and Scope

Asia, as a whole region, faces severe stress on water availability, primarily due to high population density. Many regions of the continent face severe problems of water pollution on local as well as regional scale and these have to be tackled with a pan-Asian approach. However, the available literature on the subject is generally based on research done in Europe and North America. Therefore, there is an urgent and strong need for an Asian journal with its focus on the region and wherein the region specific problems are addressed in an intelligent manner. In Asia, besides water, there are several other issues related to environment, such as; global warming and its impact; intense land/use and shifting pattern of agriculture; issues related to fertilizer applications and pesticide residues in soil and water; and solid and liquid waste management particularly in industrial and urban areas.

Asia is also a region with intense mining activities whereby serious environmental problems related to land/use, loss of top soil, water pollution and acid mine drainage are faced by various communities.

Essentially, Asians are confronted with environmental problems on many fronts. Many pressing issues in the region interlink various aspects of environmental problems faced by population in this densely habited region in the world. Pollution is one such serious issue for many countries since there are many transnational water bodies that spread the pollutants across the entire region. Water, environment and pollution together constitute a three axial problem that all concerned people in the region would like to focus on.

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