SO_2 Removal by using Jordanian Oil shale ash

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Introduction

Air pollution is considered as one of the undesired changes in the environment associated with the development of chemicals and related to its industries. The main source of air pollution is the emission of toxic gases such as SO_2, H_2S, NO_X, CO, CO_2. The main source of these gases is the thermal conversion processing of liquid and solid fuels in power plants, refineries, and petrochemical industries and automobiles emission.

Sulfur dioxide is usually produced from desulphurization processes of petroleum fractions, coal and oil shale. The content of sulfur in petroleum ranges from less than 0.5 w% up to 2 % and more [1]. This value is as high as 7 -9 w% when using the oil extracted from Jordanian oil shale [2]. This sulfur, depending on the type of processing, is converted into H_2S and SO_2 .

Acidification of soil surface, poisoning of vegetation and living organism and corrosion are the negative actions of SO_2 contained in the atmosphere [4].

Adsorption is one of the widely used methods of SO_2 removal using different types of absorbents such as activated carbonaceous material like active coal impregnated with silica and alumina,[5] ,active coal treated with sulfuric acid [6], or with nickel and potassium compounds [7]. Alumina oxides and silica gel are commonly used as adsorbents of SO_2 [8]. Quick lime (CaO) and hydrated lime (CaO_2) are the most widely used adsorbent of SO_2 from hot flue gases [9]. Different types of natural and synthetic zeolites show a strong adsorption capacity of sulfur dioxide and hydrogen sulfide.

Oil shale ash which is obtained as by product of retorting and combustion of oil shale contains different types of metal oxides. Table (1) illustrates the composition of the Elajjoun oil shale (Jordan). The ash is considered as one the most important factors in selecting the suitable and more economical utilization technology for Jordanian oil shale. There is no available literature on the use of this ash as adsorbent of toxic gases.

OBJECTIVES

- The present work is a part of an ongoing project to study the characteristic of Jordanian oil shale ash and the possibility to be used as adsorbent of SO2 and other toxic gases.

EXPERIMENTAL INSTALLATION

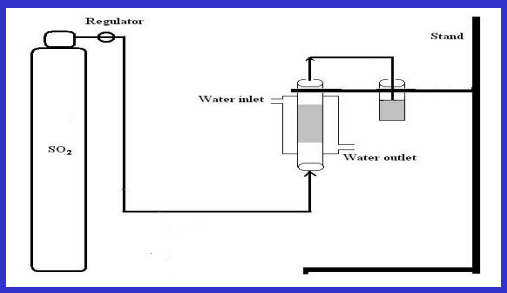

Figure 1. Fixed bed adsorption apparatus.

Sorption procedure was carried out by introducing of 200 ml deionized water containing 0.3 g of different particle sizes (45μm-1.2 mm) of oil shale ash in a glass tube (2.5 cm ID, 100 cm length). The tube is surrounded by a glass jacket and water is circulating through this jacket to maintain isothermal conditions (Figure 1). Pure SO_2 is allowed to enter the bed from the bottom of the column at a constant flow rate of 1.5 L/min, while the exit stream is connected to a deionized water reservoir having a pH meter. Samples of known volumes of pure SO_2 were introduced in the upstream at atmospheric pressure and room temperature (22±1 oC). The concentration of the SO_2 at the exit of the column was measured as a function of the difference in pH of deionized water. This procedure was repeated at different bed temperature values, masses and particle sizes of the ash and the acidity of the solution containing the ash.

Chemical composition of untreated oil shale from Lajoon area

Component	wt%
SiO_2	15.1
Al_2O_3	2.64
Fe_2O_3	1.2
P_2O_5	2.24
CaO	32
MgO	1.42
CO_2	20
S	2
TiO_2	0.2
Na_2O	0.07
Organic matter and others	23.13

- The samples show high content of silica, alumina and calcium oxide. These samples were then ashed at 950 °C for 8 hours to evaporate the water content and the organic matters percentage of ash content in all samples is 44.4 %.
- It appears that the ash contains several oxides of alkali and alkali earth which could play a significant role for absorption of acidic gases such as SO_2.

Results & Discussion

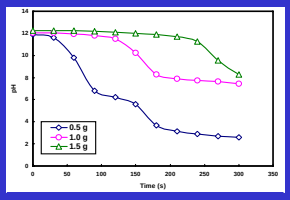

Figure 2 Effect of solution temperature on the Absorption of SO_2

Figure 2 shows the effect of ash concentration on the absorption kinetic of SO_2. It appears first as the amount of SO_2 injected into ash solution increases with increasing time; the pH of the detection solution is decreased. This is attributed to attaining the saturation value of SO_2 in the first solution containing ash. In all cases SO_2 react with water in the ash solution to produce sulfurous acid as:

$$SO_2 + H_2O \rightarrow H_2SO_3$$

Sulfurous acid then undergoes a series of either chemical reactions or adsorption with the metal oxides presented in ash or reacted with hydrated lime to produce calcium sulfide according

$$H_2SO_3 + Ca(OH)_2 \rightarrow CaSO_3 + H_2O$$

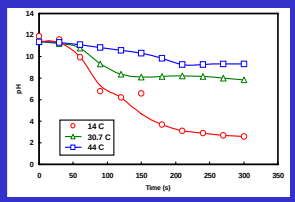

Figure 3. Effect of solution temperature on the absorption of SO_2

- ❑ The amount of sorbed SO_2 as a function of pH change in the solution at the exit stream
- ❑ It is obvious that increasing solution temperature favors sorbent uptake toward SO_2
- ❑ The maximum of SO_2 left over at the exit stream was increased with decreasing solution temperature. This decrease was moderate at elevated temperature values greater that 30 °C

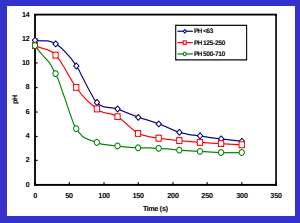

Figure 4. Effect of ash particle size of SO_2 uptake.

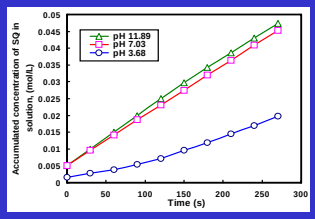

Figure 5. Effect of solution pH on SO_2 uptake.

→To predict the effect of solution acidity of ash on SO_2 uptake, three different solutions were initially prepared with the addition of either HCl or NaOH to obtained solution pH of 3.68, 7.03 and 11.89.
→For all solutions there was a linear increase in the amount of SO_2 sorbed at a fixed concentration of ash
→The rate of increase of SO_2 uptake in the acidic solution is lower than that of neutral and basic ones
→The following side reactions may take place as result of addition HCl or NaCl to the ash solution:

$$Ca(OH)_2 + HCl \rightarrow CaCl_2 + H_2O$$

$$NaOH + H_2SO_3 \rightarrow Na_2SO_3 + H_2O$$

CONCLUSIONS

- Sulfur dioxide gas stream was sweetened by passing through slurry of oil shale ash.
- The rate of uptake of SO_2 was directly affected by the amount of ash added to the solution mixture, the temperature of the solution, particle sizes of the ash and the solution acidity.
- This process is economical, safe and efficient.

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