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Utilization of steam from thermal power plant to recover the caustic & alumina from red mud slurry

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Abstract

Earth's most powerful greenhouse gas– water vapor causes fast global climate change. Slight increase in the Earth's atmospheric water vapor concentration plays a far greater role in global warming than CO_2 or other minor gases. The highly energetic water vapor (waste steam) of thermal power plant forms brown cloud along with CO_2, CO, other gaseous pollutants, carbon particles, dust particles, light metal ions, etc. To prevent burning of earth, to some extent, steam is used in the laboratory scale as a source of energy and distilled water for the recovery of caustic and alumina from red mud slurry. The pH of highly alkaline red mud slurry decreased from 13.9 to 10.5 by this process and can be brought to standard environmental level (pH < 9) by addition of small amount of common salt. The recovered caustic, pH ≥ 13.5, can be used for the further digestion of bauxite ore. The use of steam led to many benefits, including conservation of distilled water, prevents the formation of brown cloud and reduces the cost of waste management.

Keywords: Global warming gases; Brown cloud; Red mud; Acid neutralizing capacity.

1. Introduction

Water vapor constitutes Earth's most significant greenhouse gas, accounting for about 95% of Earth's greenhouse effect. Interestingly, many "facts and figures' regarding global warming completely ignore the powerful effects of water vapor in the greenhouse system, perhaps, deliberately ignoring this impacts which is almost 20-fold than the effect other green house gases. Water vapor is 99.999% of natural origin. Other atmospheric greenhouse gases, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and miscellaneous other gases (CFC's, etc.), are also mostly of natural origin except for the latter, which is mostly man-made. Human activities contribute slightly to greenhouse gas concentrations through farming, manufacturing processes, power generation, and transportation as compare to natural process but the slight increase by these processes has a catastrophic effect on the environment because it increases the overall concentration of these green house gases. Primary causes of Global climate cycle change are due to Earth's rotation and variation in the Sun's energy out put. Secondary greenhouse effect stemming the warming atmosphere due to increasing concentrations of gases like water vapor (dominant player), CO_2, CH_4, N_2O, CFC's, etc.[1,2]. The highly energetic water vapor (waste steam) of thermal power plant forms brown cloud along with CO_2, CO, other gaseous pollutants, carbon particles, dust particles, light metal ions; etc. Brown clouds are much more responsible for rapid melting of glaciers and heating of lower atmosphere. When tiny soot particles get deposited on the large dust particles the light absorbing capacity increases dramatically. The average global temperature is 14˚C and its threshold temperature is 2˚C, above which the damages of global climate changes will be irreversible [1-5] . Hence it is an urgent requirement to save our earth by utilizing almost all greenhouse gases for economical benefits.

Red mud slurry is the main byproduct of bauxite processing for alumina extraction plant. Bayer's process is commonly used for digestion of bauxite ore in a solution of conc. NaOH at temperatures between 150-230˚C under pressure. During the digestion process, aluminum reacts with the NaOH to form soluble sodium aluminate, leaving red mud slurry. Red mud slurry is highly alkaline having pH > 13, due to presence of NaOH and Na_2CO_3 (1–6% w/w). These compounds are expressed in terms of Na_2O (2, 3). The main constituents of RM (%w/w) are: Fe_2O_3 (30-60%), Al_2O_3 (10-20%), SiO_2 (3-50%), Na_2O (2-10%), CaO (2-8 %), TiO_2 (trace -10%). The amount of red mud generated, per ton of alumina produced, varies greatly depending on the type of bauxite used, from 0.3 tons for high-grade bauxite to 2.5 tons for very low-grade [6]. Globally, there are approximately 70 million tones of red mud being produced every year. Red mud typically deposited as slurries (with 15–40% solids) in red mud pond situated much above the normal ground level. The problem related to storing the slurry causes leakage of alkaline supernatant and leachate into the ground water, overtopping of materials, dusting of dry surfaces which interfere with nearby rehabilitation. The contaminations of surrounding environment are a global environmental issue, which can be solved by neutralization of red mud and its utilization for environmental benefits. In this study, steam was taken as a source of energy and distilled water, for recovery of caustic and alumina from red mud slurry by simple addition and simultaneously using centrifuge filtration method.

2. Materials and methods

2.1. Materias. Red mud slurry used in this study was obtained from R & D Laboratory of National Aluminum Company Ltd. NALCO, Damanjodi, Orissa, India.

2.2. Characterization. The pH measurements were made using a calibrated Orion pH meter. The mineralogy of powder red mud samples was determined with a Phillips X-ray diffractometer (XRD) having a nickel-filtered Cu Kα radiation source and digital data processing. Chemical composition of major oxides was determined by X-ray fluorescence (XRF). The micro-morphology of materials was investigated using a JOEL JSM-6480LV Scanning Electron Microscope (SEM).

2.3. Methods. The experiments were performed in gas tight conical flask with an inlet for steam and an outlet to vent the pressure. The steam was passed through the 2-g of red mud slurry at a constant pressure of 1 atm and a flow rate of 40mL /min and room temperature 20- 23 ˚C for 10, 20, 30, and 60 min. The steam was passed through a narrow jet pipe and stirred the solution through a magnetic stirrer, to increases the solubility of steam.

3. Results and discussion

3.1. Change of mineral composition

The red mud samples are analysed before and after the recovery process, the composition of which are represented in Table 1, iron oxides, aluminium hydroxides, aluminosilicate minerals dominate the composition of red mud after recovery . Most of the soluble minerals from the red mud slurry pass into the filtrate during centrifuge filtration.

Table 1. Major mineral composition of Red mud and Red mud after recovery of caustic as determined by X-ray diffraction

Mineral phases	Formula	
	Red mud	Red mud after recovery
Hematite	Fe_2O_3	Fe_2O_3
Goethite	FeO(OH)	FeO(OH)
Gibsite	$Al(OH)_3$	$Al(OH)_3$
Calcite	$CaCO_3$	$CaCO_3$
Rutile	TiO_2	TiO_2
Sodalite	$1.08Na_2OAl_2O_31.68SiO_21.8H_2O$	$1.08Na_2OAl_2O_31.68SiO_21.8H_2O$
Quartz	SiO_2	SiO_2

3.2. Change of chemical composition

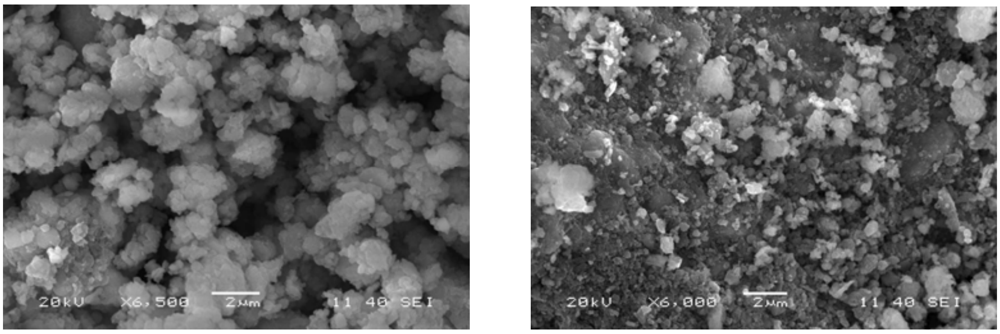
The chemical composition of red mud is analyzed by XRF the results of which are presented in Table 2.The results in Table 2 indicates that, addition of steam and centrifuge filtration causes changes in the ratio of soluble salts. The composition of major oxide decreased in the red mud after recovery, the exchange phase is predominantly by NaOH and soluble $NaAlO_2$.

Table 2. XRF Chemical composition – major oxides analysis of red mud, red mud after recovery of caustic, recovered caustic

Major oxides	Red mud %(w/w)	Red mud after recovery %(w/w)	Recovered caustic %(w/w)
Fe_2O_3	52.42	51.72	1.29
Al_2O_3	14.34	11.25	3.05
TiO_2	3.19	3.17	--
SiO_2	8.05	6.56	2.56
Na_2O	5.45	2.87	19.37

3.3. Change of physical characteristics

Scanning electron microscope images, Fig. 1(a) of red mud, and Fig. 1(b) of red mud after recovery, show compositional features of the materials. The smaller particle size in the red mud after recovery is due to the mechanical stresses imposed by stirring for proper dissolution of steam in the red mud slurry.



(a) Red mud (b) Red mud after recovery of caustic

Fig. 1. SEM of (a) red mud, and (b) red mud after recovery of caustic

Rounded shape of red mud particles is responsible for extremely high friction angles, most of minerals are cubic or prismatic shapes. The cementing/aggregating agent is hydroxysodalite. Hydroxysodalite is only very slightly soluble in water, but becomes more soluble in alkaline conditions [6]. The dissociation of hydroxysodalite is responsible for decrease of rounded shape and aggregation of red mud Fig. 1 (a,b). NaOH, Al_2O_3 are predominantly recovered, white powered crystals easily being produced when they were dried.

Table 3: pH of Red mud slurry, red mud after recovery of filtrate and recovered caustic

	pH ± 0.1
Red mud slurry	13.94
Red mud after recovery	10.51
Recovered caustic	13.63

3.4. Acid neutralizing capacity (ANC)

The ANC is the amount of acid that can be added to a kilogram of red mud such that the equilibrium pH of the mixture remains above 5.5. Red mud slurry & red mud after recovery of caustic were titrated with standardized 0.1 M HCl solutions indicates that the ANC had about 12, 7 mol/kg respectively (Fig. 2). The ANC of red mud slurry was higher than that of the red mud after recovery. This is due to removal of NaOH, $NaAlO_2$ from red mud slurry during steam addition and centrifuge filtration.

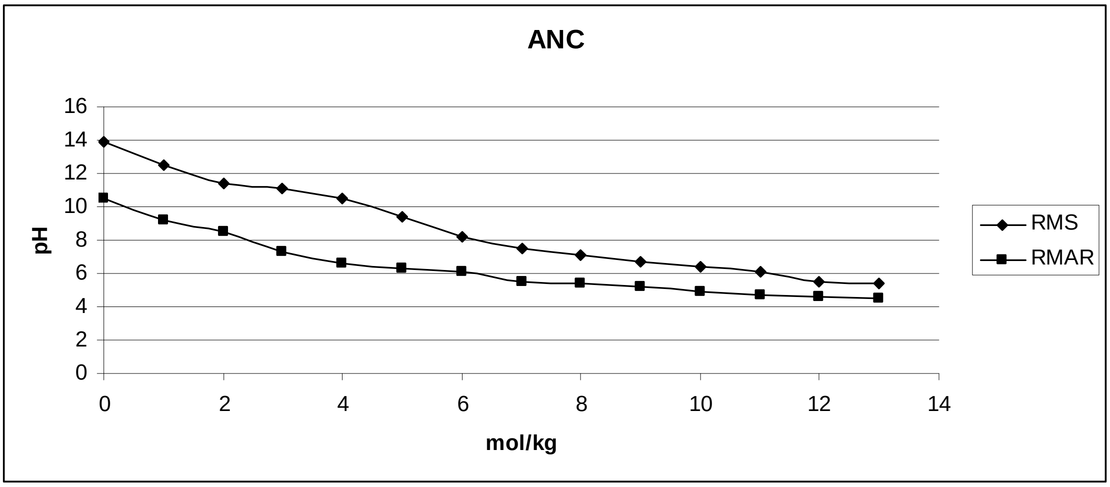


Fig. 2. ANC of red mud slurry and red mud after recovery of caustic filtrate were obtained by slow titration with standardized 0.1 mol/L HCl solution

4. Conclusions

Every waste is a resource if we give science & technology to it. Hence, we can minimize global warming gases by their utilization in various economical processes. If we use almost all steam of thermal power plant as a source of energy, then we can minimize brown cloud formation which is a boon to prevent the melting of glaciers. This experiments show recovery of some caustic and alumina from highly caustic red mud slurry which prevent the water pollution. The findings of this study show that steam has excellent potential for recovery of caustic and alumina; but further wok is needed to increase their recovery.

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