

# Determination of leaching parameter for calcined and uncalcined sample during industrial Production of Soda ash from Trona Ore

Ipeghan Jonathan Otaraku<sup>1</sup> and Anaele John Vitus<sup>2</sup>

<sup>1,2</sup>lecturer Department of Chemical Engineering University of Port Harcourt, Nigeria

**Abstract** Sodium carbonate (soda ash) is the neutral sodium salt of carbonic acid. It is one of the most important raw materials used in the chemical industry. This study was carried out to determine the leaching parameter for both calcined and uncalcined samples from Trona ore for the production of soda ash. The trona ore was grounded to a very finely size. The grounded trona was subjected to leaching process at a high temperature in order to maximize the amount of the trona ore dissolved. The temperature was maintained around 97-98oC which was close to the boiling point. The effect of two different leaching parameters; leaching time and leaching temperature on the leaching rate were examined in agitating leaching. The Results obtained shows leaching time to be around 5minutes and optimum leaching temperature to be around 80oC.

**Keywords:** Soda Ash, Leaching time, Leaching temperature, Trona Ore.

## I. INTRODUCTION

Sodium carbonate (soda ash) is the neutral sodium salt of carbonic acid. It has shown to be one of the main raw materials applied in manufacturing of other chemicals in the chemical industry. Sodium carbonate has many uses both in cleaning and glass manufacturing. Soda ash is a powdered material that is made up of 99 % sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) that is exported. The standard that is accepted for Soda ash is usually given in form of the total sodium oxide ( $\text{Na}_2\text{O}$ ) content. Therefore the commercial 58% soda ash contains up to 58% sodium oxide.

Soda ash is basic in nature, and due to the high pH value it causes eyes irritation, respiratory track and skin when it comes in contact with human being. Soda ash is manufactured principally in two grades; these are known as light soda ash and dense soda ash. The difference in these grades is in physical properties like size, bulk density and the geometry of the particles, and these affect the flow properties and repose angle. The bulk density of the dense soda ash is between 950 to 1100  $\text{kg/m}^3$ , and this may be responsible for the higher price it has when compare to the light soda, and it may also be the reason why it is chosen for glass manufacture as the light soda

causes frothing. The light soda ash has bulking density ranging from 520 to 600  $\text{kg/m}^3$ , and it is usually the manufacturing item direct from the calcining furnace and it is chosen for manufacturing of chemicals and detergents. Apart from the bulk density the other characteristics both physical and chemical characteristics are similar in the two grades (Ataman et.al., 1986). The available grades for commercial purposes are similar in chemical properties. The only difference between the two grades is the bulk density.

The production of glassware is one of the most important uses of sodium carbonate. When it is combined with silica ( $\text{SiO}_2$ ) and  $\text{CaCO}_3$  and heated to very high temperatures, then allowed to cool very fast, glass is produced. This type of glass produced in this process is called soda lime glass. Sodium carbonate is also used as a relatively strong base in various settings. For example, sodium carbonate is used as a pH regulator to maintain stable alkaline conditions necessary for some chemical agents' development. It is a common additive in municipal pools used to neutralize the acidic effects caused due to chlorine treatment and at same time raises the  $\text{p}^{\text{H}}$  of the pool.

Deposits of Trona show departures in geological and chemical properties. Where the Trona Deposits is located and site properties like specific energy resources, environmental issues, methods of distribution and trade restrictions are major concerns in chosen the best processing methods. Soda ash is manufactured from natural deposits or by synthetic methods, in history the methods are given as: (i) Le Blanc Process (ii) Solvay Process (iii) DUAL and NA Processes (iv) Monohydrate Process (v) Sesquicarbonate Process (vi) Carbonation Process (vii) Alkali Extraction method

Dense soda ash is manufactured from Trona by monohydrate process. The trona ore is transformed to crude soda ash by calcination process and after the transformation the resulting solution is then subjected to further operations as stated below:

Crushed trona is calcined in a rotary kiln to dissociate the ore and drive off the carbon dioxide and water.

The calcined material is mixed with water to cause dissolution of the soda ash and to enable the

separation of the insoluble materials like shale by filtration or settling. In order to concentrate the resulting product it is subjected to evaporation process where the dissolved soda ash precipitates out as crystals of sodium carbonate monohydrate,  $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$ . While the remaining impurities like sodium chloride and others are left in the solution. The crystals and liquor are separated by centrifugation. The sodium carbonate monohydrate crystals are calcined a second time to remove water of crystallization. The final product is cooled, screened, and shipped by rail or truck. (Muraoka, 1985).

The major parameters in process selection are: the characteristics of the trona deposit, available forms of energy and its costs and the geographical market under consideration for soda ash and suitable derivatives. The process selected must be considered in conjunction with the new developments. Monohydrate and sesquicarbonate processes, are preferably applied in conventional trona mining. Both approaches, however, involve the basic steps of dissolving the ore, filtering to remove insoluble impurities, crystallizing a sodium carbonate compound, and calcining the drive off excess carbon dioxide and water.

#### **A. Leaching**

Leaching is the primary extractive operation in hydrometallurgical processing. The ore is brought into contact with an active chemical solution known as lixiviant or leaching solution. Although one of the simpler steps in processing trona, the leaching of the calcined ore never-the-less generated a moderate patent literature. The heat of solution is exothermic in addition to the high sensible heat of the hot calcined ore (Haynes, 1997).

The three important factors which influence the viability of a leaching operation are: (i) The degree of dissolution that can be achieved (ii) The selectivity of the leaching reactions (iii) The cost of the lixiviant used.

Various other considerations enter into the leaching circuit design. The size to which the ore is ground helps determine both the completeness of calcining and the rate at which the calcine dissolves. The calcined ore dissolves very rapidly in fine particle size, especially compared to raw ore or coarser calcined ore. However, in order to obtain fairly complete leaching efficiency the soda ash solution is never quite saturated, typically containing about 28.5 to 30.0 %  $\text{Na}_2\text{CO}_3$ . Raw trona ore is ground to a fairly fine size to increase the solubility. The ore then is leached at as high temperature as possible to maximize the amount dissolved. This temperature is generally reported to be near the boiling point.

#### **B. Crystallization**

Sodium carbonate is an incongruently dissolving double salt; that is, when dissolved in water, the sodium sesquicarbonate is not in equilibrium with water and attempted crystallization results in the production of a different salt. Therefore, when crude trona is dissolved in hot water, sodium sesquicarbonate cannot be crystallized from solution by cooling or evaporation. The temperature and the composition of the solution are prepared by using phase diagrams.

Crystallization of sesquicarbonate is more difficult than crystallization of sodium carbonate monohydrate as the trona tends to form needle-shaped, elongated crystals or clusters of such crystals. It is hard to settle and dewater these crystals well enough to obtain a solid product of the desired bulk density and purity. Crystal modifying additives can be used to improve the crystallization, as noted, but their effect is not perfect, they are expensive, and often secondary problems arise, such as foaming, inconsistent operation, additional colour drying and so forth. Even with the additive, however, dewatering still is somewhat more complicated than it would be if a large, better shaped crystal is produced. It is debatable whether filters or washing type centrifuges, but generally the latter are chosen. Some washing of the centrifuged cake is done to reduce the impurities with the product, and a moderate amount of sesquicarbonate brine is bled from the system both for  $\text{CO}_2$  control and to remove impurities.

Above 109 °C, at slightly elevated pressure, the evaporation of soda ash solutions will crystallize anhydrous sodium carbonate as the stable phase. Thus the water of hydration of the otherwise produced monohydrate could be removed in the evaporators with multiple-effect economy, rather than in the less thermally efficient dryers. The capacity of either gas fired or steam-tube dryers would be greatly increased and the water would be reclaimed in the evaporator condensate. In this paper the calcination of trona was extensively studied under the Muffle furnace type of calcination

## **II. Methodology**

#### **A. Calcination of the sample**

The calcination of the sample was carried out in a muffle furnace, the sample was heated at a set temperature of 150°C, and the initial sample weight was weighed to be 40 grams in each run. The calcination operation was terminated when weight loss was closed to 10 grams

#### **B. Leaching of Trona**

The trona ore was grounded to a very finely size. The grounded trona was subjected to leaching process at a high temperature in order to maximize the amount of the trona ore dissolved. The temperature was maintained around 97-98°C which

was close to the boiling point. The effect of two different leaching parameters; leaching time and leaching temperature on the leaching rate were examined in agitating leaching. Uncalcined and calcined samples were used during leaching experiments.

### III. Result and discussion

The effect of leaching time was studied starting from 1 minute leaching and ending at 5 minutes. The leaching results are shown graphically in figure 1

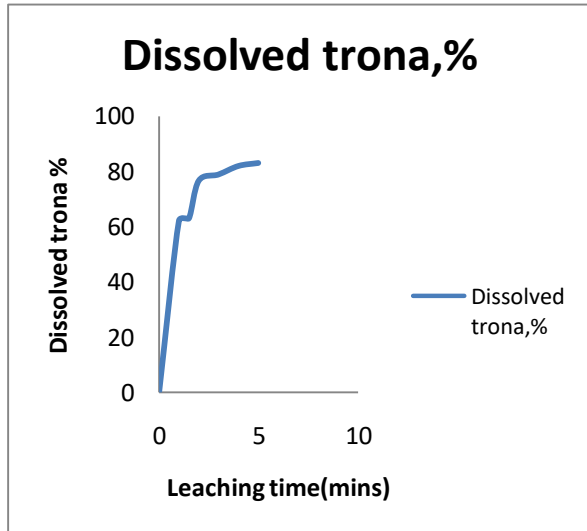


Fig. 1: Effect of leaching time on the dissolution of raw trona

From Fig. 1, leach recovery is increasing with increasing leaching time. The first 2 minutes of leaching was occurring very fast. The recovery reached 80 % values in 4 minutes at room temperature. The leaching time of trona was very short which means that trona has a high solubility in water.

#### a) Effect of Leaching Temperature on dissolution of trona

In order to see the effect of leaching temperature, experiments conducted at temperatures of 20 °C, 40 °C, 60 °C, and 80 °C. During these tests, leaching time of 3 minutes was maintained. The effect of leaching temperature on dissolution of raw trona is shown in Fig. 2.

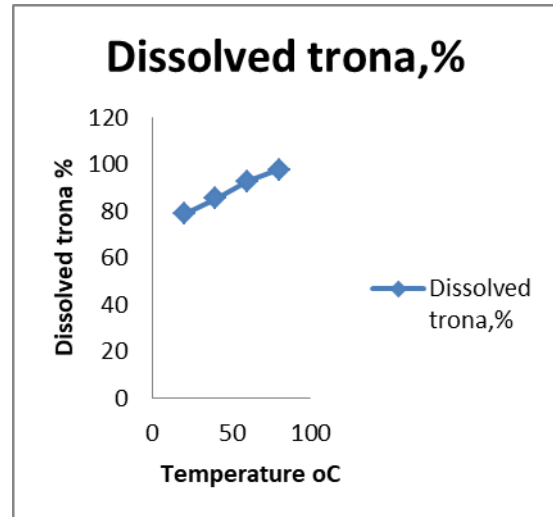


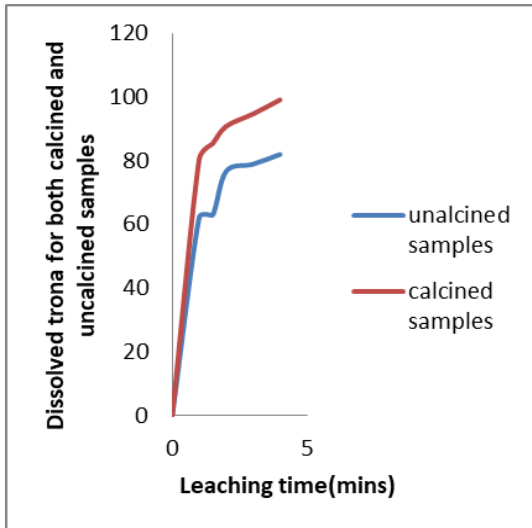
Fig. 2: Effect of leaching temperature on dissolution of raw trona

In general, high temperature has a positive effect on leaching rate and kinetics. This effect is also observed in trona leaching experiments, dissolved trona is increasing with increasing leaching temperature. Although the rate of dissolution of trona is rather high at room temperature, some other higher temperature levels were examined and complete dissolution was obtained at slightly above 85°C.

The effect of temperature on dissolution mechanism of trona could be vital for the solution mining of trona. While trona dissolves in water, adverse effect of crystallization would be seen if appropriate temperature and concentration were not taken into consideration carefully. It is difficult to obtain on an industrial scale a saturated solution at a temperature around 90 °C. This temperature may lead to an undesirable crystallization in the production wells (Saygili, 2003).

#### b) Leaching of Calcined Samples

Leaching experiments were carried out at ambient temperature (20 °C) with samples of 6.35 mm particle size and pulp density of 25 % solid by weight. Experimental results are shown in Fig. 3.



**Fig. 3. The comparison of calcined and uncalcined samples of leaching**

Comparison of dissolution rate of calcined and uncalcined samples for the same operating conditions showed that there is a significant improvement in trona dissolution for calcined sample. From Fig. 3, it is observed that leaching operation is completed for calcined trona sample in a very short time, 4 minute, whereas the uncalcined leach recovery was about only 80 % in the same leaching time.

#### IV. CONCLUSIONS

- Close to 100 % leach recovery was observed with calcined within 5 minutes, while leach recovery was about 80% for the uncalcined sample at the same leaching conditions.

- Leaching experiments demonstrated that highest dissolution rate for trona was obtained at 80 °C

#### V. References

- [1] Ataman, G., Tuncer S. and Güngör, N. Remarks on Different Methods for Analyzing Trona and Soda Samples. Bulletin of the Mineral Research and Exploration, 1986, No: 105-106, pp. 57-67.
- [2] Ball, M.C., Snelling M.C., Strachan, A.N. and Strachan, R.M. Thermal Decomposition of Solid Sodium Sesquicarbonate,  $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot \text{H}_2\text{O}$ . J. Chem. Soc. Faraday Trans. Vol. 88, No. 4, 1992, pp. 631-636
- [3] Doğan, M., Güldür, Ç., Doğu, G. and Doğu, T. Soda Ash Production from Trona in Spray Dryer. J. Chem. Tech. Biotechnol., 68, 1997, pp. 157-162.
- [4] Demirbaş, A. Production of Sodium Carbonate from Soda Ash via Flash Calcination in Drop Tube Furnace. Chemical Engineering and Processing, 41, 2002, pp. 215-221.
- [5] Eggman, T. Sodium Carbonate. Kirk-Othmer Encyclopedia of Chemical Technology, 2001.
- [6] Hartman, M., Vesely, V. Svoboda, K., Trmka, O. and Beran, Z. Dehydration of Sodium Carbonate Decahydrate to Monohydrate in a Fluidized Bed. AIChE Journal, 2001, Vol. 47, No. 10, pp. 2333-2340.
- [7] Haynes, H.W. Solution Mining of Trona. In Situ, 21 (4), 1997, pp. 357-394
- [8] Hu, W., Smith, J.M., Doğu, T. and Doğu G. Kinetics of Sodium Bicarbonate Decomposition. AIChE Journal, 1986, Vol. 32, No. 9, pp. 1483-1490.
- [9] Muraoka, D. Monohydrate Process for Soda Ash from Wyoming Trona. Minerals and Metallurgical Processing, Vol. 36, 1985, pp. 236-240
- [10] Saygılı, G.N.(2003) Effect of Temperature on Dissolution of Turkish Trona. Hydrometallurgy, 68, 2003, pp. 43-49.
- [11] Thieme, C. Sodium Carbonates. Ullmann's Encyclopedia of Industrial Chemistry, 1993, Vol. A24, pp. 299-316.
- [12] SiBEL, Ö.(2003) Evaluation of Soda Ash Production Parameters from Beypazari Trona Ore (Size 8) S. M. Metev and V. P. Veiko, *Laser Assisted Microtechnology*, 2nd ed., R. M. Osgood, Jr., Ed. Berlin, Germany: Springer-Verlag, 1998.