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An Experimental Study on the Use of Eggshell Powder as a pH Modifier: Production of Lime from Eggshells

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Abstract:- The use of pH modifiers in the mining and allied industries is very essential since certain reactions require certain pH to occur. Moreover, without the required pH, certain unwanted by-product of chemical reaction may occur which tend to make the atmosphere unsafe. Various works have been done to produce pH modifiers from certain waste products like the sea shell, oyster shell and the like. This work demonstrates an experimental study on the use of eggshell powder as a pH modifier. Eggshell contains about 94% calcium carbonate which when calcined produces quick lime (calcium oxide) which can be used as a pH modifier. In this work, eggshell powder was produced from dried eggshell and was sieved through 90µm. 100g of the sieved sample was then subjected to calcination at a temperature of 1000^{0}C for 2hours but observations were made at temperatures 600^{0}C, 700^{0}C, 800^{0}C and 900^{0}C. The calcined product was tested on a solution sample with natural pH of 9.71. Addition of 2g of the calcined sample increased the pH to 12.44.

Keywords:- *Calcination, Eggshell Powder, pH Modifier.*

I. INTRODUCTION

The rate of egg produced on a daily basis is always on the rise and as such about a million of hen eggs are broken daily in the food industry leading to the generation of eggshells which is considered as waste by this industry. In 2011, the amount of eggs produced by European countries were about 10 600 million tonnes of which about 2% was sent to the egg breaking industry.

Thus about 220 million tonnes of eggshell is produced annually as wastes by the European countries. Unfortunately, the disposal and handling of this waste generated has been considered a challenge for the food industry leading to the rapid growth microbes or pathogens (Russ and Meyer-Pittroff, 2004).

Eggshell waste finds relevance in the production of fertilizer and animal feed ingredients. Unfortunately, most this waste generated are deposited on landfills (Quina, M.J et al., 2013) giving rise to the breed of vermin due to the attached membrane and this poses a threat to the human health and the environment. Furthermore, when left in a garbage for a long time, eggshell waste tend to create some allergies and irritations.

The eggshell is predominantly made up of calcium carbonate ($CaCO_3$) since it is 95% $CaCO_3$. The remaining 5% include the organic layer which is below the shell and elements such as magnesium, aluminum, phosphorus, sodium and potassium. Eggshells have found significant applications in the construction industry.

A. J. Olarewaju et al, 2011 studied suitability of eggshell stabilized soil as subgrade material for road construction. Amu *et al.*,

2005 studied eggshell powder as a stabilizing material for improving soil properties. Eggshell shell powder when calcined at above 900^{0}C reveals chemical properties similar to that of ordinary Portland cement with CaO being predominant which can be used as lime. This work is aimed at producing calcium Oxide from waste eggshells to be used as a pH modifier.

➢ *Chemical Composition of ESP*

Component	Cement (%)	Eggshell Powder (%)
SiO2	21.8	0.08
Al2O3	6.6	0.03
Fe2O3	4.1	0.02
CaO	60.1	52.1
MgO	2.1	0.01
Na2O	0.4	0.15
K2O	0.4	-
SO3	2.2	0.62
Others	-	0.62
LOI	2.4	45.42

Table 1:- Chemical Composition of ESP and Cement

II. MATERIALS AND METHODS USED

➢ *Sample Collection and Preparation*

The eggshell used was locally obtained at the canteen of the University of Mines and technology. The eggshell was thoroughly washed with water and sun dried for a day after which it was manually broken into pieces in a container using a metal. The broken eggshell was further subjected to milling for 1 hour to obtain eggshell powder in a ball mill in the minerals laboratory of university of mines and technology. The eggshell powder was sieved using a

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90µm sieve size and all particles that passed through the sieve size was used for the project.

➢ *Calcination of the Eggshell Powder*

Generally, calcination of substances occur at or above their thermal decomposition temperature. The thermal decomposition temperature of substances is usually the temperature when the standard Gibb's free energy is equal to zero. The thermal decomposition reaction of any substance has its own standard Gibb's free energy equation.

In the case of calcination of limestone which is the same for that of eggshell, the decomposition reaction is given as $CaCO_3 = CaO + CO_2$. The standard Gibb's free energy equation for this reaction is given as $G^o r = 177{,}100 – 158T$ (J/mol) where T is the minimum thermal decomposition temperature. Thus the thermal decomposition temperature for the calcination of eggshell is 1121K or 848^{o}C. The calcination of the eggshell will begin above this temperature and it is usually between 850^{o}C and 1340^{o}C.

This temperature range must be maintained throughout the entire decomposition process. Carbon dioxide is evolved during the decomposition process and a porous layer of calcium oxide remains.

In this work, an amount of 100g of the eggshell powder that passed through the 90µm sieve was calcined at a temperature of 1000^{0}C for 2 hours using a locally made furnace known as "Sika Bukyia". Various observations were made during the calcination at temperatures 600^{0}C, 700^{0}C, 800^{0}C and 900^{0}C.

Fig 1:- Sika Bukyia Furnice

➢ *Test on the Calcined Eggshell Powder*

After calcination of the eggshell powder, 2g of the calcined material was tested on a slurry of natural pH of 9.71 in order to ascertain its effect on the pH of the slurry. The result was compared to that of the same experiment repeated for laboratory lime of the same mass.

III. RESULTS AND DISCUSSION

➢ *Effect of Calcination Temperature*

The eggshell powder that was decomposed in the furnace at different temperatures 600ºC, 700 ºC, 800 ºC, 900 ºC, and 1000 ºC were shown physically different in colour to the eggshell powder before calcined. Calcination at temperature of 600 ºC produced powder in black colour, at 700 ºC produced black powder mixed with gray, at 800 ºC formed solid gray, at 900 ºC calcination obtained white solid with little gray, and at 1000°C obtained white solid. The higher calcination temperature, the more metal oxide was formed indicated from the change of the colour of the chicken eggshell powder became white. Picture of chicken eggshell and eggshell after decomposed at various temperatures are presented in Figure 1.

The results also have differences lost weight of the samples before and after calcination. The $CaCO_3$ which is the main component of eggshells are known to have a decomposition temperature at 900 ºC. At temperature of 600 ºC and 700 ºC the samples reduction in weight ranged up to 5%, this is due to the loss of organic compounds contained of eggshell which known to have about 4% in the eggshell. Organic compounds are easily damaged and lost at temperatures above 100 ºC. In the both of calcination temperature above is not yet formed metal oxide CaO, while at 800 ºC the sample weight was reduced by 26%, perhaps at this temperature the $CaCO_3$ has been converted into CaO and CO_2, but only in slightly amounts.

At temperature 900 ºC, there was a reduction in the sample's original weight by 46% indicating the decomposition temperature of $CaCO_3$ to CaO and CO_2. At calcination temperature 1000 ºC the sample weight reduced by 52.8%, the sample weight becomes lowest as it converted into CaO and gas- phase CO_2.

Fig 2:- Eggshell Powder Before Calcined (a) and Eggshell Powder After Calcined at Various Temperature (b) 600 ºC, (c) 700 ºC, (d) 800 ºC, (e) 900 ºC, and (f) 1000 ºC.

➢ *Effect of Calcined ESP on pH of Slurry*

Table 2 shows the result obtained after carrying a test to ascertain the pH modifying effect of the calcined eggshell powder on a slurry of natural pH of 9.71. The same test was repeated for laboratory lime on the same fresh slurry and the two results compared.

Natural PH of slurry	Mass of calcined ESP added	PH after addition of calcined ESP	Mass of laboratory lime added	PH after addition of Laboratory lime
9.71	2g	12.44	2g	12.40

Table 2:- Comparison between pH of slurry after addition of calcined ESP and laboratory lime

IV. CONCLUSIONS AND RECOMMENDATIONS

A laboratory investigation has been conducted on the possibility of using eggshell powder as a pH modifier by calcining the eggshell powder to produce lime (CaO). Major findings of this investigation are:

- Calcination at temperature of 600 ℃ produced powder in black colour.
- Calcination at temperature of 700 ℃ produced black powder mixed with gray.
- Calcination at temperature of 800 ℃ formed solid gray.
- Calcination at temperature of 900 ℃ calcination obtained white solid with little gray.
- Calcination at temperature of 1000℃ obtained white solid.
- At temperature of 600 ℃ and 700 ℃ the samples reduction in weight ranged up to 5% while at 800 ℃ the sample weight was reduced by 26%. The calcination temperature at 900 ℃ reduced the sample weight by 46% while at calcination temperature 1000 ℃ the sample weight reduced by 53%
- Complete calcination of the eggshell powder was achieved at 900 ℃.

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