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Recovery of pure slaked lime from carbide sludge: Case study of Lagos state, Nigeria.

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Carbide sludge is the by-product of reaction between calcium carbide and water in the production of acetylene gas for welding purposes. This by-product is discarded as waste due to high content of impurities as a result of the reactants and reaction processes. In this research work an attempt was made at developing an appropriate process technology for the recovery of pure slaked lime from Nigeria's automobile welders' carbide sludge using solubilisation and evaporation process technology. The percentage purity of the slaked lime recovered through the process was 88%. The recovered slaked limes had pH of 11.93, were soluble in glycerol and dilute acid, insoluble in alcohol, and sparingly soluble in water. The optimum percentage yield was 78.2% at a ratio of 1:1000(w/v) of sludge to water held for 24 h at room temperature.

Key words: Carbide, recovery, evaporation, sludge, technology.

INTRODUCTION

Proper management of solid waste is critical to the health and well-being of urban residents (World Bank, 2003). The United Kingdom (UK) Environment Agency classifies waste as either controlled waste or non-controlled waste (Environment Agency, 1999). Controlled waste includes waste generated from households (municipal solid waste), commercial and industrial organizations and from construction and demolition. Non-controlled waste includes waste generated from agriculture, mines and quarries and from dredging operations. At all times, human activities have generated waste in various forms, that is, in gaseous (abattoirs), liquid and solid. These wastes have often been discarded because they were all considered as negative value goods. The more prevalent method of disposal of these wastes have been to first collect them from their source and then burn them in a landfill site or throw them in the surrounding deep erosion gullies (Ogwueleka, 2009). However, the steady increase of landfill site, deposition in the gullies, and waste generally has caused a lot of havoc to the potable water being extracted from downstream and ground water. Currently, the emergence and development of new public environmental consciousness have created a strong negative attitude toward landfill and deposition into gullies. In Nigeria the national and state regulation to protect the environment have increased the cost of developing new landfill and deposition in the gullies, also sitting has become increasingly difficult because the public oppose having such facilities nearby (Ogwueleka, 2009). Solid waste management has become a major concern in developing countries, like Nigeria. The ideal way to improve the situation would be, to reduce the generation of waste. But contrarily, this goes against the people's will to preserve their life style (Otti, 2011).

Solid waste is synonymous with garbage. As long as humans have been living in settled communities, solid waste, or garbage, has been an issue, and modern societies generate far more solid waste than early humans ever did. Daily life in industrialized nations can generate several kilograms of solid waste per consumer, not only

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directly in the home, but indirectly in factories that manufacture goods purchased by consumers.

Most developing countries, Nigeria, inclusive have solid waste management problems different from those found in industrialized countries in areas of composition, density, political, and economic framework, waste amount, access to waste for collection, awareness and attitude (Ogwueleka, 2009). In Lagos metropolis like most cities in Nigeria and the developing world, several tons of municipal solid waste is left uncollected on the streets each day, clogging drains, creating feeding ground for pests that spread disease and creating a myriad of related health and infrastructural problems (Aliyu, 2010). Nigeria is presently experimenting with the privatization of this sector. The Federal Government has instituted National Integrated Municipal Solid Waste Management Intervention Programme in seven cities of Nigeria. The seven cities are Maiduguri, Kano, Kaduna, Onitsha, Uyo, Ota, and Lagos. Lagos state government established municipal solid waste management policy to encompass private sector participation in waste collection and transfer to designated landfill sites.

The solid waste of interest here is carbide sludge. Calcium carbide is produced industrially in an electric arc furnace from a mixture of lime and coke at approximately 2000°C. This method has not changed since its invention in 1888.

$$CaO + 3\,C \rightarrow CaC_2 + CO \quad \rightarrow (1)$$

Calcium carbide sludge is generated during the process of reaction between calcium carbide and water in the production of acetylene for welding purposes.

The reaction of calcium carbide with water was discovered by Friedrich Wohler in 1962

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca\,(OH)_2. \quad \rightarrow (2)$$

This reaction is the basis for industrial manufacture of acetylene. The sludge has a pH of 12.2 and contains Cu, Pb, Fe, Mn, Ni and Zn ions (Bogner et al., 2002).

No sludge is a waste; all can be used judiciously as per its specification. While carbide sludge may not be considered as toxic, but hazardous material, adequate precaution should be taken to prevent unauthorized discharge.

The Nigerian Automobile Technicians Association (NATA) with average membership of twenty-five thousand panel beaters are scattered all over the country. Each panel beater produces an average of 30 kg of carbide sludge daily. The sludge generated by this activity (industry) has accumulated over the years. The sludge are dumped indiscriminately resulting in environmental problems and health hazard such as adverse effects on the fertility of land, as these wastes are deficient in plant nutrients, drainage problems, contamination of water resources. It also causes air pollution as the dry powder becomes air borne on windy days, wastage of valuable resources of calcium hydroxide (slaked lime) and handling and disposal problem (World Bank, 2003)

Calcium salts currently being marketed derive their calcium from some source which include limestone other than hydrated carbide lime. This is due in large part to the impurities in the hydrated carbide lime, such as metals, slag, minerals and carbon which come from the coal, coke and limestone used in the calcium carbide manufacturing process. These impurities have therefore rendered hydrated carbide lime unsuitable as a feed stock for the manufacture of many purified calcium products (Bunger et al., 1998).

In 2009, 449 metric tons of calcium hydroxide (slaked lime) valued at ₦19,520,000 was imported into the country while in 2010, 364 metric tons valued at ₦20,320,000 was also imported (US, GSM, 2010). If process technology for recovering slaked lime from carbide sludge is developed, this huge amount of money used for importation will be used for other developmental projects. Recovered slaked lime can be collected and reused for many applications such as in water treatment, road stabilization, acid neutralization and carbon dioxide removal. The recovered calcium hydroxide, if treated to a high temperature will decompose into quicklime and water (Halstead and Moore, 1987). Quicklime is a very important compound in our society today due to its many applications, such as in the production of calcium carbide for automobile welders:

$$2CaO \;+\; 4C \;\rightarrow\; 2CaC_2 + O_2 \quad \rightarrow (3)$$

Calcium hydroxide has many and varied uses due to its strong basic properties. The uses include as flocculants, in water and sewage treatment, improvement of acid soils, an ingredient in whitewash, mortar, and plaster, an alkali used as a lye substitute in non-lye hair relaxers, in the liming industry for neutralizing acid, the tanning of hides and skin Calcium hydroxide is used in endodontic (root-canal) dental applications (Mohammadi and Dummer, 2007).

The urgent need to manage this industrial waste in an environmentally friendly manner and also put it to beneficial use is the basis for this research.

MATERIALS AND METHODS

Samples and Chemicals

Carbide sludge samples were collected from twenty automobile welders' shops over a period of 12 months in four mechanic villages located at Ilupeju, Ladipo, Mazamaza and Agoo areas of Lagos mainland (Figure 1).

The chemiclas used in this study include hydrochloric acid, sulphuric acid, calcium hydroxide, glycerol, alcohol, cotton wool, plastic columns, hot plate and distilled water.

Methodology

The collected sludge samples were dried in the oven at 105°C for 1 h and then sieved with a fine mesh sieve of 80 µm. Representative samples were dissolved in the ratio of 1: 100; 1: 200; 1: 300; 1: 400;

Table 1. Physicochemical characteristics of the carbide sludge sample.

Parameter	Value
Moisture content(g)	2.06
Metals:	
Iron	0.9199
Zinc	0.4831
Cadmium	0.6745

Table 2. Determination of optimum percentage yield of slaked lime in a sludge solution for the 4 samples in 100 – 500mls of water.

Sludge(g)	Water (ml)	Ilupeju A (%)	Ladipo B (%)	Mazamaza C (%)	Agoo D (%)
1	100	27.2	27.7	26.0	27.0
1	200	48.2	41.7	39.3	38.9
1	300	55.2	43.3	42.7	44.84
1	400	54.2	49.0	60.7	47.6
1	500	61.7	55.5	58.9	56.4
Average yield		49.24	43.44	45.55	42.94

Table 3. Average yields of different volumes of water with 1g of sludge.

Water (ml)	Yield (g)	Yield (%)
100	0.2699	27.0
200	0.4204	42.0
300	0.4651	46.5
400	0.5288	52.9
500	0.5812	58.1
600	0.6900	69.0
700	0.7434	74.3
800	0.7654	76.5
900	0.7810	78.1
1000	0.7815	78.2
1100	0.7815	78.2
1200	0.7815	78.2
1300	0.7810	78.1
1400	0.7788	77.9
1500	0.7788	77.9

1: 500; 1: 600; 1: 700; 1: 800; 1: 900; 1: 1000 (w/v) sludge to water for 6, 12, 24, 48 and 72 h per batch (Figure 2). This process was repeated three times. At the end of each process the solution was filtered and the filtrate evaporated to get the calcium hydroxide (slaked lime) (Figure 3).

Percentage purity was calculated using molarity formulae

RESULTS AND DISCUSSION

Table 1 shows physicochemical properties of the carbide sludge which include the metal and moisture content. The metal content of the sludge is still within the acceptable limit for discharge into the environment by FME (formally FEPA, 1992) standard.

Table 2 shows the determination of Optimum Percentage yield of Slaked Lime in a sludge solution for the 4 samples in 100 – 500 mls of water.

Table 3 shows the determination of optimum yield of calcium hydroxide using 1 g of sludge in different volumes of water. The highest average yield of 78.2% at a ratio of 1:1000(w/v) of sludge to water held for 24 h at room temperature was obtained. There was some slimy yellowish deposit in the flask when 1300 mls of water was used in the determination. When the slaked lime was scoped, it was found to be less than the previous ones and the same thing occurred with 1400 and 1500 mls. May be part of the slaked lime formed the slimy deposit resulting in the reduction of the quantity recovered. Further research need to be conducted into the occur-rence.

Tables 4 to 8 show the determination of optimum solubilisation time for the 4 samples at different periods at room temperature. The average yield of calcium hydroxide from each sampling location at different periods was determined.

Table 9 shows the average yield of calcium hydroxide at different period of time. From the table it was observed that the optimum yield was obtained when the sludge is solubilised for 24 h at room temperature.

Table 10 shows the physicochemical properties of the recovered calcium hydroxide. Using the calculated molarity of the recovered slaked lime, the percentage purity of the recovered slaked lime is 88%. The pH from the literature is 12.08 while the recovered calcium hydroxide has 11.93 and with this it can be concluded product is highly

Table 4. Determination of optimum percentage yield of slaked lime for the 4 samples in at a 6-hour solubilisation period.

Location	Sludge (g)	Water (ml)	Yield (g)	Yield (%)
A	1	1000	0.2830	28.3
B	1	1000	0.2410	24.1
C	1	1000	0.2560	25.6
D	1	1000	0.4689	46.9

Average yield =0.3872 = 38.72%.

Table 5. Determination of optimum percentage yield of slaked lime for the 4 samples in at a 12-hour solubilisation period.

Location	Sludge (g)	Water (mls)	Yield (g)	Yield (%)
A	1	1000	0.323	32.3
B	1	1000	0.2490	24.9
C	1	1000	0.4188	41.88
D	1	1000	0.5484	54.84

Average yield =0.3848g = 38.48%.

Table 6. Determination of optimum percentage yield of slaked lime for the 4 samples in at a 24-hour solubilisation period.

Location	Sludge (g)	Water (mls)	Yield (g)	Yield (%)
A	1	1000	0.6972	69.7
B	1	1000	0.8830	88.3
C	1	1000	0.9275	92.8
D	1	1000	0.6182	61.8

Average yield =0.7815g = 78.2%

Table 7. Determination of optimum percentage yield of slaked lime for the 4 samples in at a 48-hour solubilisation period.

Location	Sludge (g)	Water (mls)	Yield (g)	Yield (%)
A	1	1000	0.607	60.7
B	1	1000	0.535	53.5
C	1	1000	0.5494	54.9
D	1	1000	0.5031	50.3

Average yield =0.54863g = 54.9%

Table 8. Determination of optimum percentage yield of slaked lime for the 4 samples in at a 72-hour solubilisation period.

Location	Sludge (g)	Water (mls)	Yield (g)	Yield (%)
A	1	1000	0.4324	43.2
B	1	1000	0.2932	29.3
C	1	1000	0.4539	45.4
D	1	1000	0.6003	60.0

Average yield =0.4450 g = 44.5%.

Table 9. Average percentage yield of slaked Lime for different solubilisation periods.

Time (h)	Yield (g)	Yield (%)
6	0.3872	38.72
12	0.3848	38.48
24	0.7815	78.15
48	0.5486	54.86
72	0.4450	44.50

Table 10. Physicochemical characteristics of the recovered slaked lime.

Parameter	Literature	Recovered slaked lime
Density	2.211	2.12
pH	12.08	11.93
Purity (%)		88
Solubility		
Water	Sparingly soluble	Sparingly soluble
Alcohol	Insoluble	Insoluble
Glycerol	Insoluble	Insoluble
Acid	Completely soluble	Completely soluble
Odour	Odourless	Odourless
Appearance	Soft white powder	Soft white powder
Metals	**Sludge**	**Recovered slaked lime**
Iron	0.9199	ND
Zinc	0.4831	0.0454
Cadmium	0.6745	ND

alkaline. The literature has the density of 2.211 g/cm^3 while the recovered slaked line has density of 2.12 g/cm^3. The solubility tests conducted agree with literature. The metal content, though within the limit were reduced more after the recovery.

Bunger et al. (1998) was able to recover slake lime from carbide sludge into solution with subsequent reacting of the solution with carbondioxide to form calcium carbonate. Also Musa et al. (2005) obtained calcium hydroxide from Nigeria limestone and then passed chlorine into the suspension to get calcium hypochlorite. Recovering of slaked lime in solution will limit its usage, because as mentioned above its varied application can only be maximized when it is in powdered form which the present research has actualized.

Production of slaked lime from limestone is a cumbersome process and requires substantial energy to convert the limestone ($CaCO_3$) to lime (CaO) which will then be hydrated. The slaked lime recovered will be of high market value and solves the problem with disposal of low-value hydrated carbide lime from acetylene processes. Calcium hydroxide generally has low solubility in water which is worsened by presence of under/over bur-ning of rocks or impurities that had escaped calcinations during production from limestone (Musa et al., 2005).

The research served dual purpose of preserving the environment as well as making slaked lime available for its many applications. The significant application of slaked lime is as a flocculants, in water and sewage treatment. It forms a fluffy charged solid that aids in the removal of smaller particles from water, resulting in a clearer product. This application is enabled by the low cost and low toxicity of slaked lime. It is also used in fresh water treatment for raising the pH of the water so pipes will not corrode where the base water is acidic because it is self-regulating and does not raise the pH too much. Another large application is in the paper industry, where it is used in the production of sodium hydroxide. This conversion is a component of the Kraft process.

There is no cost analysis but survey was conducted on slaked lime vendors and users in Lagos. Twenty-five (25) copies of questionnaires were distributed to the vendors and users of slaked lime to determine quantity of sales per week, product source, price range and quality requirequirement of their buyers. Twelve (12) questionnaires were retrieved and the analysis of the survey shows that nine of the vendors deal on slaked lime representing 75% of the local vendors, two (2) deals on limbux lime while one (1) did not give any information. The summary of the analysis showed that nine (9) of the vendors obtain their product from China and Great Britain while only two (2) source their own locally with so much difficulty. The vendors sell maximum of seventy-five bags in a week at a price range of between N76, 000 and N122, 500. It was discovered from the survey that slaked lime vendors import their products due to its scarcity locally.

CONCLUSION

The recovered product proved to be calcium hydroxide through the analysis carried out. The 88% purity and 78.1% yield of the recovered slaked lime seems promising for slaked lime recovery from automobile welder’s carbide sludge. The dissolution period of 24 h is also not too long to convert the waste to wealth.

The technology needs to be developed so that the problems carbide sludge is causing to the environment will be tackled. There is also need to conduct cost benefit analysis of the process.

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