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Research Article

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Characterization and Experimental Analysis and Conversion of Solid Waste into Structural Materials

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Abstract The generation of solid waste has become a growing problem, not only because of the population increase but also because of the dynamics of consumption that the societies in the world present. In this study, solid waste from various industries has been collected and characterized. Based on the nature and composition of solid waste, the possible chemical composition is evaluated and value added products are prepared. Methods for conversion of solid wastes into building materials such as bricks and concrete blocks have been described. Mixing of solid waste in various proportions with red soil also carried out as pot experiment. From the results of various tests on final product, it is concluded that solid waste can be used suitably to produce bricks with 25-30% of sludge, for concrete blocks with 45-50% of sludge. By applying this type of alternative, solid waste could be disposed off in a better way without affecting the health of the residence in the existing environment with better economic leaving standard in the area.

Keywords Solid waste, Characterization, Chemical analysis, Conversion, and Experimentation

1. Introduction

Municipal solid waste (MSW) is a composition of both organic and inorganic materials generated from series of human activities in industrial sites, domestic households, commercial centers and other institutional workshops (Raviprasath *et al,* 2019)**.** The presence of MSW in a society is a great problem if not well managed due to its ability to induce environmental degradation. In the past few years, Lagos metropolis witnessed rapid industrialization and demographic expansion. These twin developments have been responsible for the increase in volume of waste generations in the city. The high quantity of waste generation in Lagos metropolis symbolizes a greater opportunity for experimentation and a conversion process in the form of alternative for building materials from bio-waste resource (Raviprasath *et al,* 2019)**.**

Based on the quality of liquid effluent, textile house is one of the leading and most polluting industrial sectors in India. To treat this waste water, adsorption and coagulation techniques are used by the most of textile effluent treatment plants. The textile solid waste, brownish in color, contains mainly iron, chloride, sulphate and a few traces of other substances, all coming from different sections and type of dyes used in the textile industries. The solid waste form the glass industries will be grey in color. In general, sludge generation and accumulation are the most serious problems faced by the treatment plants. Due to its chemical and mineral content, these industrial solid wastes are found to be hazardous in the view of environmental consideration (Khan, 2017). Unsafe disposal

of the solid waste may cause harmful effects on the environment and human beings (Giri and Bhattacharya, 2020). Hence, solid waste management should be given primary importance before things becomes too convoluted. The conventional techniques for sludge disposal like compositing, land filling, agricultural utility, open dumping and thermal techniques are found to have some drawbacks such as land losing its fertility, possible contamination of under-ground water, requirement large surface area for storage and high cost of disposal(Raviprasath *et al*, 2019). To overcome the drawbacks of the existing sludge disposal methods, an attempt has been made to dispose the solid sludge waste from textile house, glass industry and thermal industries in Nigeria. The employment of waste sludge to produce valuable products is considered to be the most advanced trend in solid waste management for the environmental damages can be reduced or overcome and the cost can be considerably reduced without necessitating heavy establishments (Kumaravelan and Anandan, 2023). The present work analyses the feasibility of producing building materials like bricks and concrete blocks. The experimental work was carried out, and the solid wastes collected are subjected to chemical analysis to get the nature and chemical composition of thesludge. This research aimed at attempt to study the possibility of mixing solid wastes in various proportions with red soil or other conventional raw materials to produce the building materials in Nigeria.
Objectively, mixing solid wastes in various proportions withred soil was carried out as pot experiments. To obtain the quality of bricks compressive strength, water holding capacityand efflorescence test were carried out.

2. Materials and Methods

2.1 Materials

Sludge after the solar evaporation was taken from textile house, glass and thermal industry. All the reagents used for finding the characteristics of the sludge are of A.R.Grade.

2.2 Analysis of Sludge

The solid waste was evaluated based on its various characteristics of loss of ignition and insoluble residue; iron, sulphate, calcium, aluminium and silica were analyzed as per the standard methods (Arnold *et. al*, 2022).

2.3 Manufacture of bricks

The most common bricks are one of the oldest building materials and it is extensively used at present as a leading material of construction because of its durability, strength, low cost and easy availability of raw materials. The conventional bricks are manufactured by four distinct operations like preparation of clay, molding, drying and burning. The sludge was dried in order to remove the moisture. Then it was mixed with various binding materials and water in the ratio 1:0.25. Fly ash was used as binding materials. In preparation of brick, the composition of textile house sludge, glass industry sludge, thermal industry waste (fly ash) and red soil were made in various proportions. The sludge was mixed in various proportions with the red soil forming a murrite. The mixture was then made in to brick shape using a brick mold made of cast iron having the dimensions 22 cm x 10 cm x 6 cm. The wet brick was put in the open air for atmospheric drying for about 8 days. Then the bricks were arranged and burnt in a lime kiln at a temperature around950-1200ºC.The burnt bricks were then subjected to various tests.

2.4 Manufacture of concrete blocks

Normally 8kg of coarse aggregates, 4kg of sand, 2kg of cement and sufficient amount of water were mixed with water-cement ratio of 0.45 and 0.5. The concrete mixture was filled in the mould in layers approximately 5cm deep. The mixture was tamped with the help of a standard rod. The specimens were kept in cold water for 24 hours. After the mould is removed, the specimen is subjected to curing for about 3-7days. In the present study, 4kg of aggregates was replaced by waste concrete aggregates, 2 kg of sand was replaced by glass industry waste and 1kg of cement was replaced by fly ash and powder solid glass waste.

2.5 Tests on Burnt Bricks

Various properties of burnt bricks like compressive strength, water holding capacity, efflorescence test, flexural strength and compacting factor test for concrete blocks were carried out as per the standard procedures (Rangola, 2022).

2.6 Recovery of Iron Oxide

Since, in the textile waste sludge, the amount of Iron Oxide present is 30.18 %, an attempt has been made to recover this. 0.250kg of the textile solid sludge was taken in 1000ml beaker and 1:1 Hydrochloric acid (HCl) was added in such a way that the level of the acid was 0.05m above the solid. The contents were boiled for 10-15 minutes and allowed to settle. The supernatant liquid was filtered. The above procedure was repeated 5 to 6 times to leach the iron completely and Iron was precipitated in the filtrate by Hydroxide Method (Vogel, 2019). The precipitate was dried and ignited. This iron may be used in paint industry.

3. Results and Discussion

For bricks manufactured from individual and combination of various industrial sludge, various tests like compressive strength, water holding capacity, flexural strength; efflorescence test and for concrete blocks compacting factor test were conducted and results have given in Table 2, 3, 4, and 5. Maximum allowable values for the bricks are given in Table 6. From the analysis results of various solid wastes (given in Table 1), it was found that these sludge is considered to be suitable for the production of building materials such as bricks and concrete blocks. The work mainly focused on using sludge to replace red soil/clay in the manufacture of bricks and sand/ aggregates/cement in the manufacture of concrete blocks. From the tabulated results it is clear that sludge can be replaced up to 25-30% in the manufacture of bricks that does not affect physical and chemical properties of bricks. But in the manufacture of concrete blocks, compaction factor test results (Flexural strength of concrete blocks: Breaking point of concrete block = 0.22m) and flexural strength of concrete blocks shows that 45-50% of sludge can be replaced.

4. Conclusion

Solid waste from various industries (textile house, glass and thermal industry) has been collected and characterized. These solid wastes that were obtained can be utilized in the production of building materials. From the results, it is concluded that solid waste sludge can be replaced up to 25-30% to produce bricks and 45-50% to produce concrete blocks. The bricks produced with 25-30% sludge were observed to have good compressive strength and water holding capacity, which meets the specifications recommended. As the present disposal methods are found to be hazardous, a highly eco-friendly method has been formulated for the conversion of solid wastes into value-added products like building bricks and concrete blocks. This promising alternate disposal method thus paves a better way to dispose the solid wastes from various industries on one side and provides a means to utilize the solid wastes for a useful purpose.

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APPENDIX

Table 1: Composition of the various industrial sludge (wt %)

Element	Red soil	Textile house sludge	Glassindustry sludge	Thermalplant waste	Cement
Alumina	27.0	2.0	0.0002	30.36	6.0
Calcium	-	26.67	-	3.04	55.0
Ferric oxide	01.0	30.18	0.0002	3.34	3.5
Magnesium	05.0	3.5	-	0.93	7.5
Org. matter	05.0	-	-	-	-
Silica	62.0	5.0	45.13	50.41	22.0
Sodium	-	3.65	12.96	3.07	1.0
Sulphate	-	1.714	-	1.71	2.0
Others	-	27.286	41.9098	7.14	3.0

Table 2: Analysis of textile house waste- red soil blended bricks (wt. %)

Textile house waste%	%	Compressive strength (N/mm2)	Water holding capacity (%)	Efflorescence	%	Compressive strength (N/mm2)	water holding capacity (%)
80	20	-	15.90	Slight	20	0.925	14.50
70	30	-	15.50	Slight	30	0.875	15.95
60	40	0.52	14.85	Slight	40	-	>18
50	50	0.81	14.00	Slight	50	-	>18
40	60	1.20	13.75	Slight	-	-	-
30	70	4.55	12.95	Slight	-	-	-

*For all Fly ash composition efflorescence test is: serious

Table 3: Compaction factor and flexural strength test on concrete blocks

Water- cement ratio	**Compaction factor**	**Flexural strength**
0.4	0.73	Breaking point = 0.22 m
0.45	0.74	

Table 4: Analysis of textile house sludge-glass industry sludge-red soil blended bricks

Textile housewaste%	Glassindustry waste%	Redsoil%	Compressive strength (N/mm2)	Waterholding capacity(%)	Efflorescence
5	5	90	9.225	8.95	Nil
5	10	85	8.995	10.50	Nil
5	15	80	8.125	10.95	Slight
5	20	75	6.850	11.25	Slight
10	10	80	7.125	10.25	Nil
10	5	85	8.850	10.15	Nil
10	15	75	6.225	11.50	Slight
10	20	70	5.445	11.25	Slight
15	10	75	4.125	11.50	Slight
15	15	70	3.850	11.95	Slight

Table 5: Analysis of industrial wastes of textile-glass -thermal-red soil blended bricks

Textile waste %	Glass waste %	thermal waste%	Red soil%	Compressive strength (N/mm^2)	Water holding capacity (%)	Efflorescence
5	5	5	85	9.885	8.22	Nil
5	5	10	80	10.150	8.62	Nil
5	10	5	80	9.50	8.79	Nil
10	10	10	70	7.55	10.11	Slight
10	5	5	80	8.15	9.15	Nil
10	10	5	75	7.125	9.92	Nil
10	5	10	75	7.75	9.87	Nil
15	5	5	75	7.17	9.90	Nil
15	10	5	70	6.99	11.10	Slight
15	15	5	65	5.20	11.95	Slight
15	10	10	65	5.35	11.04	Slight
20	5	5	70	5.55	9.94	Nil

Table 6: Maximum allowable values for the bricks

S/N	Test Type	Maximum Allowable Value
1	Compressive Strength	7 to 14 N/mm^2 (BIS-1077-1957)
2	Water Absorption	20% dried brick wt.
3	Hardness	Sufficiently Hard
4	Structure	Homogenous free from defects
5	Efflorescence Test	White deposit on surface up to 10% slight, up to 50% moderate, and greater than 50% serious