JEAS

JOURNAL OF ENGINEERING AND APPLIED SCIENCES

Journal of Engineering and Applied Sciences 8(1) (2012), 39-44

Beneficiation of water works sludge for environmental sustainability

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Abstract

Water Works Sludge collected from a water treatment plant was beneficiated for environmental sustainability. The steps considered were gravity thickening and air drying incorporating mechanical agitation. Results of tests conducted showed that the combined effects of temperature, relative humidity, wind speed and sun intensity affect the dying rate of sludge. Additionally, high solid content of 80% was achieved at a reduced time using drying bed which was high compared to the value from other dewatering processes. This study showed that water works sludge consists of typical oxides of alumina and silica, and can be properly managed in the environment through the manipulation of process parameters and incorporation of mechanical agitation that cushion the effect of sludge depth while improving the performance of drying bed. Considering the high potentials for resource utilization, sludge can be adopted as secondary raw material for building, construction and mining industries, while checking the menace of environmental degradation.

Keywords: Sludge; beneficiation; environmental sustainability; drying bed; dewatering.

1. Introduction

The quest for an effective means of improving the living standards of all Nigerians is the basis for the transformation agenda of the Federal government and the Millennium Development Goals (MDG's). Urbanisation has led to increase in provision of basic amenities like water, food, shelter, etc. with an appreciable increase in environmental degradation.

Generally, water treatment plants produce large quantities of sludge resulting from the treatment processes of raw water which include coagulation, flocculation and filtration. Water works sludge contains mostly water and small amount of solids consisting of different kinds of oxides, such as silicon oxide, calcium oxide, iron oxide, and aluminium oxide, as well as rich amounts of clay materials. Retrieval and reuse of these oxides from sludge and other applications is a direct way of treating sludge waste and indirectly reducing the demand for natural resources. Sludge moisture content is a critical parameter governing the feasibility of various final disposal routes, such as direct land application, composting and landfill. Therefore, applications for resource recovery of waterworks sludge become important.

The indiscriminate dumping of sludge has resulted to loss of valuable metal salts, pollution of aquatic environment and pollution of land and ground water. Keeping these in mind, therefore, beneficiation of waterworks sludge becomes important for resource utilisation and environmental sustainability. This will require different treatment processes that are flexible to local conditions, regulatory and economic constraints while assuring long-term and sustainable services.

The handling of sludge is one of the most significant challenges in water works management. In many countries, sludge is a serious problem due to its high treatment costs and the risks to environment and human health. Solid content of sludge is the key factor in determining the effectiveness of any dewatering method and its applicability.

Presently in Nigeria, most water works dispose sludge by returning it to water course or stock- pile in or around the treatment plants without further treatment which is against the local and international good practices for environmental sustainability.

Sludge could be more easily and economically handled if the volume were reduced by removing the water, resulting in a cake which could undergo further processing or be transported to its final disposal route. This can be achieved by natural or mechanical means.

Drying beds, drainage and evaporation have been utilized to achieve this result at a minimal cost (Paul, 1998). Mechanical devices have proven to speed this function with increase in operational and initial investment cost. Rainfall, solar radiation, wind speed, temperature, sludge depth and solid content are some of the major factors that combine to affect the drying rate of sludge with sludge depth as a dominant factor.

In consideration of some of the advantages of drying bed like, lower operational skill and attention, lower chemical and energy consumption, and higher cake-dry solids concentration, the major disadvantages are noted as large land area requirement and climate dependent. In Nigeria for example, the country is saddled with power challenges, of which natural drying method is the most economically feasible option because of its inherent advantages.

The composition of water treatment sludge and weather conditions differ from different sources and locations, therefore the need to investigate the performance of air-drying method on the basis of the solid content with other dewatering methods using sludge from a specific source i.e. Lower Usuma Dam Water Treatment Plant, Abuja, Nigeria become desirably feasible.

2. Material and Methods

2.1 Site Description

The Lower Usuma Dam Water Treatment Plant is located at Lower Usuma Dam in Bwari Area Council of FCT. The Federal Capital Territory (FCT) is located between latitude $8^0\ 25^1$ and $9^0\ 25^1$ North of the equator and longitude $6^0\ 45^1$ and $7^0\ 45^1$ East of Greenwich Meridian. The territory covers an area of 8,000 square kilometres and occupies about 0.87% of Nigeria. The territory is bordered by four states namely Niger to the West, and North West, Nassarawa to the East, Kogi to the South and Kaduna to the North of the territory (Balogun, 2001).

Abuja has features of a tropical wet and dry climate with three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season with a brief interlude of harmattan in between the two seasons. The rainy season falls between March and November, with its peak in September, during which abundant rainfall is received in the form of heavy downpours (Wikipedia, 2012).

2.2 Processing of Sludge from the Water Treatment Plant

Sludge collected from the desludging chamber of the clarifier using 20 litres plastic can was dewatered using gravitational thickening method. The dewatered sludge was dried in a bed made of concrete floor as shown in Figs.1 – 6.

Fig.1. Sludge Sampling from De-sludging Chamber

Fig. 2. Gravity Thickening Tank

Fig. 3. Drying Bed

Fig. 4. Liquid Sludge

Fig.5. Dewatered Sludge

Fig. 6. Dried Sludge

2.3 Bench Work

The experiment was conducted in an open environment of a weather monitoring station. Meteorological data from weather station was incorporated in the experiment at hourly intervals to determine the drying kinetics parameters.

The initial and final moisture and solid contents were measured to determine the effectiveness of natural drying method in Abuja, Nigeria. To accelerate the drying process, the solid was stirred at intervals (mechanical agitation) to increase its exposure to sun and air. The dried Sludge was milled and passed through a 200 mesh sieve for analysis. The chemical composition was subsequently determined with Minipal-4 PAnalytical X-ray fluorescence (XRF)machine.

3. Results and Discussion

3.1 Combined Effects of Drying Parameters on Drying Rate

From the results of effects of drying on sludge in Table 1 and Fig.7, it is obvious that the combined effects of temperature, relative humidity, wind speed and sun intensity affected the drying rate.

The drying rate increased with increase in temperature, wind speed and sun intensity but decreased with increase in relative humidity. As expected, the results showed a reduction in drying time during the dry season months than in the raining season months, thus Abuja natural environment favours drying of water works sludge with an average solid content of 80%.

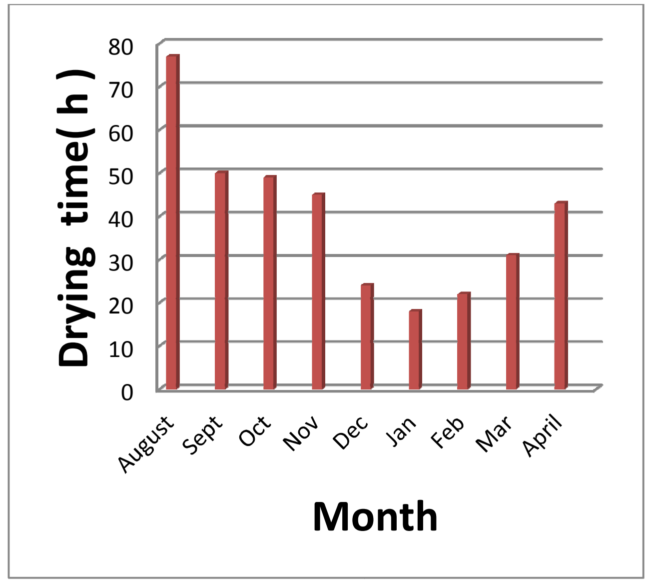

Fig.7. Performance Evaluation of Drying Time on Monthly Basis for Natural Drying on Sludge from Abuja Water Treatment Plant

Table 1
Result of Field-Trial Experiment

Month	Temp (^{0}C)	Relative Humidity (%)	Wind Speed (m/s)	Evaporation (mm)	Sun Intensity W/m^2	Initial Solid Content (%)	Initial Moisture Content (%)	Final Solid Content (%)	Final Moisture Content (%)	Drying Time (h)
Aug (19-22) 2011	25.5	88	3.0	2.2	447	5.03	94.97	80.01	19.99	77
Sept (17-29) 2011	25.5	85	4.0	2.2	785	5.43	95.57	79.69	20.31	50
Oct (29-30) 2011	24.0	86	3.7	3.3	948	4.83	95.17	79.5	20.05	49
Nov (12-14) 2011	25.9	70	3.7	5.1	901	5.04	94.96	80.13	19.87	45
Dec (14-15) 2011	24.6	39	2.4	9.2	809	4.68	95.32	80.46	19.54	24
Jan 16 2012	24.2	25	2.7	10.4	892	4.99	95.00	80.79	19.21	18

Feb 5 2012	30.6	34	3.6	9.4	903	5.01	94.99	80.13	19.87	22
Mar (7-8) 2012	30.2	43	2.4	9.1	960	4.78	95.222	80.00	20.00	31
Apr (4-5) 2012	30.1	57	2.2	4.9	729	4.97	95.03	79.98	20.02	43

3.2 Effect of Sludge Depth with Time

From the results in Table 2 and Fig. 8, it is noted that the higher the sludge depth the longer the drying time. Sludge depth produces a determinant effect when combined with other factors affecting the drying rate.

Table 2
The Effect of Sludge Depth with Time

Depth(cm)	**1**	**2**	**3**	**4**
Time(h)	**18**	**40**	**64**	**90**

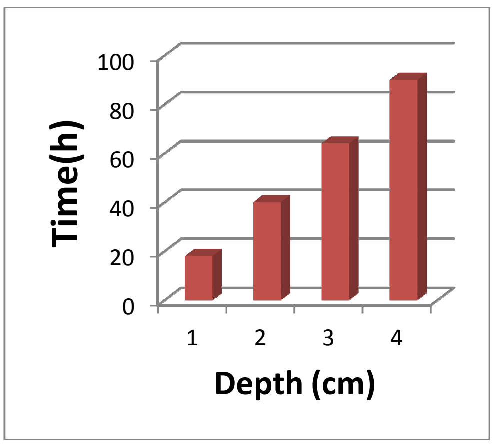

Fig. 8. Changes in Drying Rate with Time on Sludge Depth in 3D

3.3 Effect of Stirring (Mechanical Agitation) on Drying Rate and Time

From Table 3 and Fig. 11, it is observed that the incorporation of stirring (mechanical agitation) increased the exposure of sludge to sun and air, which further increased the drying rate with attendant reduction in the drying time as compared to normal drying process as in Figs. 9 and 10.

Fig.9. Normal Drying

Fig. 10. Aided (Stirred) Drying

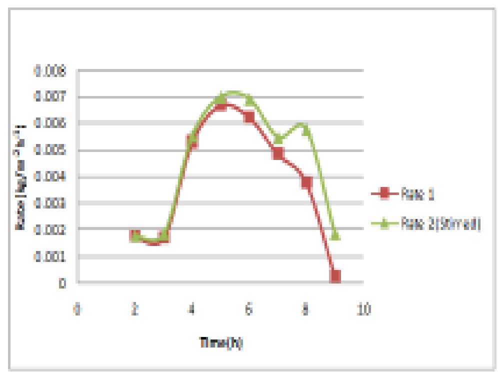

Fig. 11. Changes in Drying Rate with Time for Natural Drying and Effects of Stirring on Drying Rate

3.4 The Chemical Characterization of Sludge

From Table 4 of the chemical composition of water works sludge, there is evidence of high silica and alumina contents, whose oxide total content exceeds 58% by weight.

3.5 Performance Evaluation

From Table 6, it is observed that the evaluation performance of sludge showed a high solid content of 80% inferring that dewatering method in the drying bed application is a better suite.

Table 3
Result of the Effect of Mechanical Agitation (stirring) on Drying Rate and Time

Time	Weight 1 (g)	Weight 2 (stirred) (g)	Time(h)	Rate 1 ($kgm^{-2}h^{-1}$)	Rate 2 (Stirred) ($kgm^{-2}h^{-1}$)
7am	83.4	88.4	0	0	0
9am	78.9	83.8	2	0.001724138	0.001762452
10am	76.7	81.4	3	0.001685824	0.00183908
11am	69.8	74.2	4	0.005287356	0.005517241
12noon	61.1	65.1	5	0.006666667	0.00697318
1pm	53	56.1	6	0.006206897	0.006896552
2pm	46.7	49	7	0.004827586	0.005440613
3pm	41.8	41.5	8	0.003754789	0.005747126
4pm	41.5	39.1	9	0.000229885	0.00183908

Table 4
Chemical Composition of Beneficiated Sludge

Component	Al_20_3	SiO_2	K_2O	CaO	TiO_2	MnO	Fe_2O_3	MgO	Na_2O	Loss on Ignition
Composition (%)	28.28	30.3	0.90	1.55	0.89	3.11	9.17	0.33	0.41	20.78

Table 5
Comparison of Results of LUD, Abuja Dried Sludge with Some Clay Samples in Nigeria

Clay	**Location (State)**	**Al_2O_3 (%)**	**SiO_3 (%)**	**Fe_2O_3 (%)**	**CaO+MgO (%)**	**Loss on ignition**
Oshielle *	Abeokuta (OG)	28.30	53.40	1.35	0.88	15
Ozubulu *	Nnewi (AN)	19.31	58.30	1.55	1.25	14.16
Enugu *	Enugu (EN)	22.71	55.00	2.42	1.95	16.35
Nsu *	Okigwe (IM)	30.22	50.60	1.92	1.08	10.54
Okpekpe *	Auchi (ED)	24.30	53.20	1.45	1.30	16.86
Kankara *	Kankara (KT)	38.64	44.50	NIL	1.30	16.70
Giro *	Giro(SO)	38.72	41.26	2.10	1.48	14.00
Warram *	Warram (PL)	37.13	43.54	1.15	0.58	14.20
Sabon Gida *	Jos (PL)	26.88	25.32	13.10	3.20	18.36
Alkaleri *	Bauchi(BA)	25.43	54.30	1.05	1.00	15.73
LUD sludge	Abuja	28.28	30.8	9.17	2.97	22.6

*** Source:** Ahmed (1986)

Table 6.
Comparison of Result of Drying Bed with other Dewatering Methods

S/N	Process	Solid Concentration (%)
1.	Gravity Thickening *	3 - 4
2.	Scroll Centrifuge *	20 - 30
3.	Belt Filter Press *	20 - 25
4.	Vacuum Filter *	25 - 35
5.	Pressure Filter *	35 - 45
6.	Diaphragm Filter Press*	30 - 40
7.	Sand Drying Bed *	20 - 25
8.	Storage Lagoons *	7 - 15
9.	Natural Drying Bed	80

***Source:** **(**USEPA, 1996)

4. Conclusion

It is evident from the results;

1. That suitable condition is demonstrated for the beneficiation of sludge for environmental sustainability. The result has demonstrated the suitable process parameters that can improve the performance of drying bed by the solid content for environmental sustainability.
2. That drying bed proved to have high solid content of 80%, than other dewatering methods.
3. That the chemical composition of sludge consists of typical oxides of alumina and silica, that are similar to those of some clay deposits in Nigeria.
4. That, the FCTWB Sludge has potentials for resource utilization especially as secondary raw material for building, construction and mining industries.

For practical interests, this work will widen the knowledge on air drying of waterworks sludge which will assist in reducing environmental pollution challenges of improper disposal of sludge, including the conservation of non- renewable resources for environmental sustainability.

Acknowledgement

The authors would like to acknowledge the following institutions and Organizations for using their facilities and equipment; Ahmadu Bello University, Zaria, Nigeria; Federal Capital Territory Water Board, Abuja, Nigeria; Centre for Energy Research and Training, Zaria, Nigeria; National Geological Research Laboratory, Kaduna, Nigeria; Nigerian Meteorological Agency (NIMET), Abuja, Nigeria.

References

Ahmed, K. S., 1986. Development of Phosphate bonded fireclay Refractory Castables. MSc Thesis, Ahmadu Bello University, Zaria.

Balogun, O., 2001. The Federal Capital Territory of Nigeria. (Ed) Geography of Its Development. Ibadan, Ibadan University Press.

http://en.wikipedia.org/wiki/Abuja. Abuja-Wikipedia, the free encyclopedia. Retrieved on February 26, 2012.

Paul, M. R., 1998. From Conventional Drying Beds to High Rate, High Capacity Vacuum Dewatering Beds, The Water Environment Federation 12th Annual Residuals & Biosolids Management Conference Bellevue, Washington, July 12 - 15, 1998.

USEPA., 1996. Technology Transfer Handbook-Management of Water Treatment Plant Residual, American Water Works Association, New York.