INTERNATIONAL JOURNAL OF ENGINEERING
AND APPLIED SCIENCE
ISSN 2709-8117
MAR. 2022 VOL. 3, NO. 1

Effects of Inorganic Chemicals $AlCl_3$, $CaCl_2$, $MgCl_2$, $Ca(OH)_2$ and $CaCO_3$ on Soil Erosion

Opara Alexander, Onwuka A.Tijani
Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

ABSTRACT

This study attempted to study the effect of stabilizing the eroded soil of Oba (a town in Anambra State) by using some inorganic chemicals. Soil erosion has become a serious issue on a vast scale around the world. The soil samples from the site contain a large amount of sandy soil and a low clay content to determine the reason for their erosive properties. The following inorganic chemicals were used to stabilize the eroded soil :Ca(OH)2, CaCO3, MgCl2, CaCl2 and AlCl3; The results show that AlCl3 and CaCl2 have the strongest effect on the complete stability of soil samples. Their ability to stabilize was tested with a small penetrator, an engineering instrument that measures the unconfined compressive strength (UCS) of soil.

KEYWORDS

Erosion; Penetrometer; Inorganic; Chemicals.

1. Introduction

It is hard to imagine an aspect of our world which covers such an enormous measure of scale in both time and space as erosion of the earth's surface (Nearing et. al., 2017). Erosion is one of the surface processes that deface the earth's landscape and constitutes one of the global environmental problems (Abdulfatai et. al., 2014).

Erosion of soils, is becoming a serious problem because of the substantial economic loss it causes to the society at large, world over (Pandea et. al., 2013).

Anambra (a State in Nigeria) is well-known with its gullies in towns of Agulu, Nanka, Oko and Ekwulobia in the State. The gullies in this area in the State have been recorded to be about 120m deep and 2km wide. In Anambra State, erosion is a peculiar environmental problem. Virtually all communities are affected by one form of erosion or the other in Anambra State (Obi and Okekeogbu, 2017).

With economic development, the need for road construction generally increases (Dong et. al., 2012), and as cities are being developed, large-scale ground excavation works in urban area have rapidly increased (Han and Yoo, 2017); because excavation and reclamation of soil are essential steps for infrastructure development (Katsumi, 2015).

Unfortunately the Oba excavation site, in which the research was carried out, happens to be erosive.
This study therefore seeks to find out the effect of stabilizing the erosive soils of the excavation site using some inorganic chemicals.

1.1 Study Area

Oba is a town in Anambra State, Nigeria, which lies approximately 7 kilometres south of Onitsha along the old Owerri-Onitsha Trunk A Road. Oba is located 6o4′N 6o50′E/ 6.067oN 6.833°E (https://en.m.wikipedia.org/wiki/Oba,_Anambra, Date Accessed, 14/11/2019)

Figure 1. Oba Excavation Site (Photo shot by the researchers), date taken: 02/02/2017

Figure 2. Oba Excavation Site (Photo shot by the researchers), date taken: 02/02/2017

2. Literature Underpinning

Durán Zuazo and Rodríguez Pleguezuelo (2008) wrote a review article on the soil-erosion and runoff prevention by plant covers; and said that "ne of the most effective measures for erosion control and regeneration of the degraded former soil is the establishment of plant covers" and also that "Soil erosion can be controlled through a process of assessment at regional scales for the development and restoration of the plant cover, and the introduction of conservation measures in the areas at greatest risk".

Another review articles was written by Seutloali and Beckedahl (2015) on a review of road– related soil erosion: an assessment of causes, evaluation techniques and available control measures, in which they made the following statements as part of their concluding remarks: "It has been shown in the literature that soil erosion control techniques have the potential to reduce runoff and soil loss. Numerous studies that have investigated the effectiveness of soil erosion control techniques utilised on roadside embankments showed that the most effective methods are those that promote revegetation and reduce both velocity and quantity of runoff".

Zhao et. al. (2014) conducted a research on the effects of chemical stabilizers on an expansive clay. The work investigated the effect of chemical agents on an expansive soil from Texas through a laboratory injection method. The following agents were used: lime, potassium based agents, and a group of ionic agents. Swelling tests, chemical tests, and soil suction tests were utilized in assessing the stabilizing effects of those chemical agents. The results showed that potassium based stabilizer was an effective agent to control the swelling potential of the expansive clay. The chemical tests on the injected Texas clay indicated that the stabilizing mechanism of the ionic agents was possibly through the cations' exchange and the increase of the cations' concentrations in the soil pore water.

In a research undertaken by Eires et. al. (2017) on enhancing water resistance of earth buildings with quicklime and oil, with the main aim of improving the compressed soil against rainwater action. The main result obtained from the study showed that quicklime led to increased performance in compressive strength and significantly reduced erosion in the accelerated test of rain simulation.

A study was also carried out by Vannoppen et. al. (2017) with the primary aim of assessing the erosion-reducing potential of both fibrous and tap roots in sandy soils. Furthermore, they examined potential effects of root diameter, soil texture and dry soil bulk density on erosionreducing potential of roots. Flume experiments carried out on sandy soils were compared with those on sandy loam and silt loam soils (using the same experimental set up). Results showed that plant roots were very effective in reducing concentrated flow erosion rates in sandy soils compared to root-free bare soils. Furthermore, their results confirmed that fibrous roots were more effective compared to (thick) tap roots.

3. References

After the soil sample was collected below 10 feet in the Oba Site, it was taken to the lab for the following analysis:

3.1 Determination of percentage Silt, Clay, Sand (Particle size analysis).

30g of the soil sample was weighed into a 250 mL beaker. A beaker was filled with distilled water to 200 mL mark.

•The soil was washed for four times with distilled water.

•25% sodium hexametaphosphate solution was prepared.

•20 mL of the solution and 200 mL of distilled water was added to the washed sand, and then allowed to stand for 16hrs (i.e. overnight).

•The soil sample was transferred into 0.1μm sieve. During sieving, the sample that was left on the sieve was the sand while the sample that passed through the sieve was the silt. The sample was then dried to a constant weight [AOAC, 1973]

$$\%\text{Sand} = \frac{\text{Residue wt.} \times 100}{\text{sample wt.}}$$

$$\%\text{Silt} = \frac{\text{Residue wt.} \times 100}{\text{sample wt.}}$$

%Clay = 100 – (% Silt + % Sand)

3.2 Chemical Stabilization determination Preparation of the stabilizing chemicals

The following inorganic chemicals were used to stabilize the soil: Aluminium Chloride (AlCl3), Magnesium Chloride (MgCl2), Calcium Chloride (CaCl2), Calcium Hydroxide (Ca(OH)2) and Calcium Trioxocarbonate(IV) (CaCO3). Their solution were each prepared by putting 20g each of their solutes in 200mL of water.

3.3 Preparation of the Soil Sample

The erosive soil sample was sun-dried for more than 20 hours, to remove some moisture from the soil particles. Then it was oven-dried for 1 hour to remove the remaining moisture.

3.4 Fabrication of Metallic Pipes for the Sample Stabilization

A flat bottomed metallic pipes of about 25mm diameter and 60mm high each were fabricated

3.5 Steps for the Stabilization Process

· 10 g of the soil sample that has been oven-dried was weighed into the fabricated pipe, and 2 mL of the AlCl3 was poured into the pipe.

· The pipe, which contains the soil/chemical mixture, was placed on an electric heater for 7-10 minutes to allow for evaporation of the water solvent, leaving behind only the soil and the chemical solute; after which the pipe was brought down from the heater.

· The above experiment was conducted for the other individual chemicals.

· Also entire experiment was repeated using 15 g of the soil sample

3.6 Confirmation of the Soil Particles Compaction Test Procedures Using a Pocket Penetrometer

Penetrometer is an instrument used to measure the resistance offered by the soil penetration. The resistance offered by the soil is in proportion to soil strength (Jaiswal, 2003). Penetrometer was used to determine the unconfined compressive strength (UCS).

The penetrometer was used as follows:

· The tip of the penetrometer was placed on the soil surface, making a right angle with the soil surface

· Then the handle of the penetrometer was slowly pushed to penetrate the soil with the needle tip of the penetrometer.

· As the pressure of the handle of the penetrometer is released, the handle reverts smoothly to its initial position leaving behind the plastic ring on the needle (i.e. steel rod) which is calibrated (Jaiswal, 2003)

4 Results/Findings

After the lab analyses, the following results were obtained:

Table 1. Percentage of the particle sizes distribution of the soil

Parameters	% of Particle Sizes
Clay	6.60
Silt	34.70
Sand	58.70

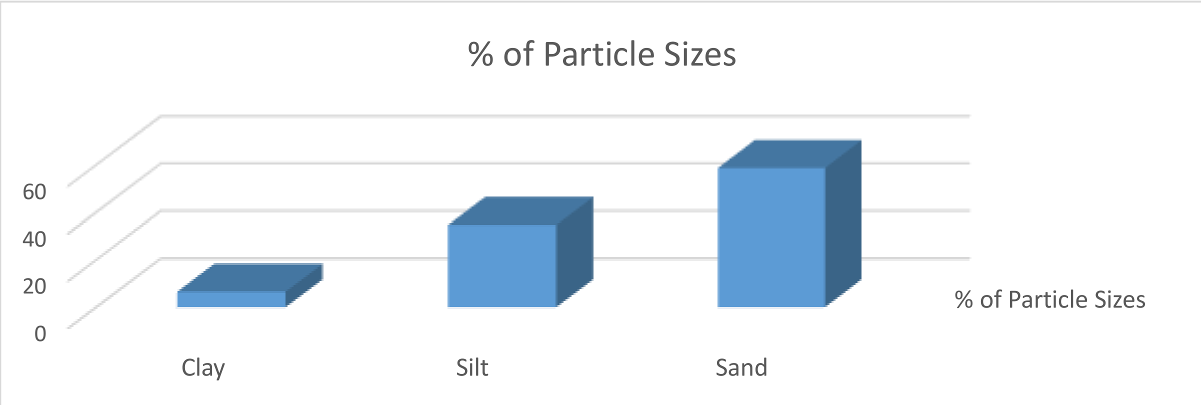

Figure 3. Percentage of the particle sizes distribution of the soil Table 2: Penetrometer confirmation (in kg/cm2) of the stabilization of 10g and 15g each of the erosive soil using the chemicals

	$AlCl_3$	$MgCl_2$	$CaCl_2$	$Ca(OH)_2$	$CaCO_3$
10g	5.00	3.80	5.00	1.30	1.70
15g	5.00	5.00	5.00	2.52	3.65

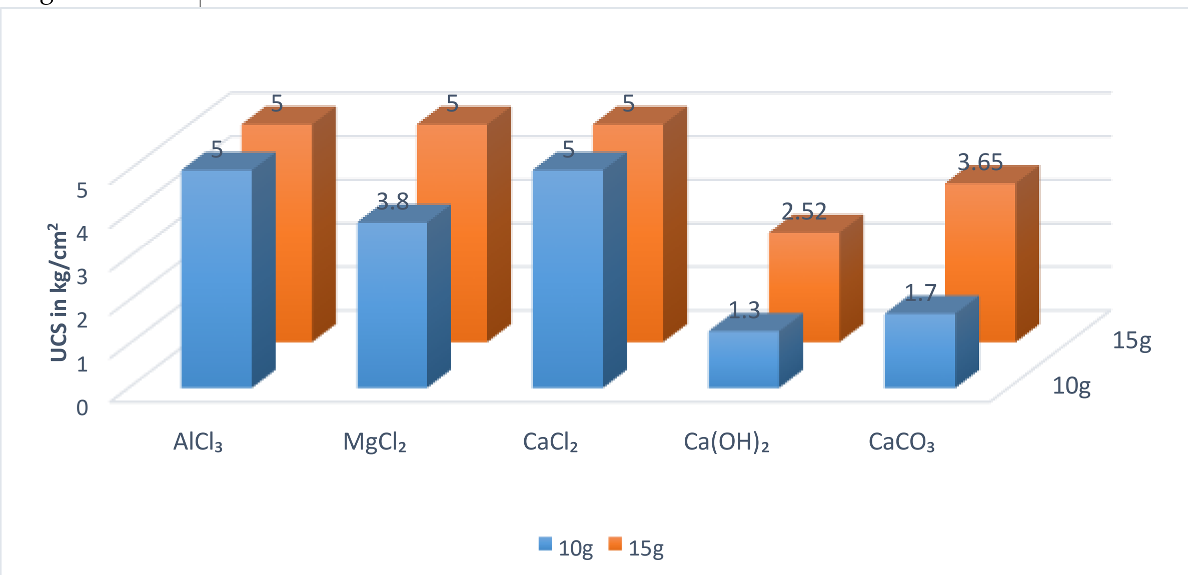

Figure 4. Penetrometer confirmation (in kg/cm2) of the stabilization of 10g and 15g each of the erosive soil using the chemicals DISCUSSION Particle size distribution

From Table 1 and Figure 3, the values for the percentage sand, silt and clay particles were 58.7, 34.70 and 6.60, respectively. From the values it was observed that the soil contained more of the sandy soil particles than the silt (which was in turn higher than that of the clay particles). According to Yang, et. al. (2019), “Silty sand can be prone to erosion because it is short of stability cementation materials”. Therefore the soil, since it contains a high percentage of sand particles will be erosion-prone.

4.1 Confirmation of the Soil Particle Compaction with Pocket Penetrometer

From Table 2, Figure 4 the variation in the mass of the stabilized soil samples, the following were observed for the effect of the following chemicals:

AlCl3 and CaCl2, gave UCS values of 5.00kg/cm2, respectively, for both 10 and 15g soil samples while MgCl2 gave 5.00kg/cm2 for 15g soil sample, and 3.80kg for 10g soil sample. Ca(OH)2 gave UCS of 2.52kg/cm2 for 15g sample and 1.3kg/cm2 for 10g sample. CaCO3 gave UCS values of 3.65kg/cm2 for 15g soil sample, and 1.7kg/cm2 for 10g soil sample

From these values AlCl3 and CaCl2 chemicals were best suitable for stabilizing the soil sample, while Ca(OH)2 was the least chemical for stabilizing the soil particles.

From the overall results, the increase in the rate of stabilization of the following chemicals as it relates to the Oba erosive soil sample are as follows:

Ca(OH)2 < CaCO3 < MgCl2 < CaCl2 < AlCl3

4.2 Implication of Research and Practice

The research will help to prevent underuse or excessive use of these inorganic chemicals, as they may negatively affect the soils’ nutrients or the underground water.

5 Results/Findings

The research tried to establish the reason for the erosive nature of Oba excavation site by showing that the soil sample in this site contains high amount of sandy soil (which is a huge factor to high soil particles dispersion), and a low clay content.

The research also went ahead to use the following inorganic chemicals to try to stabilize the erosive soil: Ca(OH)2, CaCO3, MgCl2, CaCl2 and AlCl3; which when applied to the different mass ratios of the soil sample, showed that AlCl3 and CaCl2 are great in completely stabilizing the soil sample, followed by CaCO3 and Ca(OH)2. Their stabilization capacity was tested using a pocket penetrometer
(an engineering instrument for testing for the unconfined compressive strength (UCS) of soils).

The extent of their stabilization capacity in the following increasing order: Ca(OH)2 < CaCO3 < MgCl2 < CaCl2 < AlCl3.

This then means that the use of inorganic chemicals can be employed for the stabilization of erosive soils in Anambra State, when used at their proper ratios.

5.1 Future Research

It will be wise to use other inorganic salts for the soil stabilization, in order to find out whether they will give a better yield than the ones that have been used in this study.

References

AOAC. Collaborative study of the cation exchange capacity of peat minerals. Journal of Association of Official Analytical Chemists (AOAC), 56(1), 1973, 154–157, https://doi.org/10.1093/jaoac/56.1.154

Abdulfatai, I. A., Okunlola, I. A., Akande, W. G., Momoh, L. O. and Ibrahim, K. O. (2014) Review of Gully Erosion in Nigeria: Causes, Impacts and Possible Solutions. Journal of Geosciences and Geomatics, 2(3), pp. 125-129.

Durán Zuazo, V.H. and Rodríguez Pleguezuelo, C.R. Soil-erosion and runoff prevention by plant covers. A review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2008, 28 (1):65-86.

Dong, J., Zhang K. and Guo, Z. Runoff and soil erosion from highway construction spoil deposits: A rainfall simulation study. Transportation Research Part D, 2012, 17:8-14

Eires, R., Camoes, A. and Jalali, S. Enhancing water resistance of earthen building with quicklime and oil. Journal of Cleaner production, 2017, 142(4):3281-3292

Han, Y. and Yoo, K. Analysis of the Ground Sinking around an Excavation Site using GPR Exploration. Int'l Journal of Research in Chemical, Metallurgical and Civil Engg. (IJRCMCE), 2017, 4(1):94-97.

Jaiswal, P.C. Soil, Plant and Water Analysis. Kalyani Publishers, New Delhi-110 002, India, 2003, pp. 26-28

Katsumi, T. Soil Excavation and Reclamation in Civil Engineering: Environmental Aspects. Soil Science and Plant Nutrition, 2015, 61(1):22-29

Oba, Anambra. https://en.m.wikipedia.org/wiki/Oba, Anambra. Date Assessed, 14/11/2019

Obi, N.I. and Okekeogbu, C.J. Erosion Problems and Their Impacts in Anambra State of Nigeria: (A Case of Nanka Community). International Journal of Environment and Pollution Research, 2017, 5(1):24-37.

Pandea, V.C., Kurothea, R.S., Singha, H.B., Tiwarib, S.P., Kumara, G., Raoa, B.K., Vishwakarmaa, A.K. and Bagdia, G.L. Economic Assessment of Soil Erosion Damage on Smallholder Farms in Marginal Lands of Mahi Ravines in Gujarat. Agricultural Economics Research Review, 2013, 26(1):63-71.

Seutloali, K.E. and Beckedahl, H.R. A Review Of Road–Related Soil Erosion: An Assessment of Causes, Evaluation Techniques and Available Control Measures. Earth Science Research Journal, 2015, 19(1):73-80.

Vannopen, W., De Baets, S., Keeble, J., Dong, Y. and Poesena, J. How do roots and soil characteristics affect the erosion-reducing potential of plant species? Ecological Engineering, http://www.sciencedirect.com/science/article/pii/S0925857417304615, Date Accessed, 11/09/2017.

Yang, Q., Pei, X. and Huang R. Impact of polymer mixtures on the stabilization and erosion control of silty sand slope. Journal of Mountain Science, 2019, 16:470-485.

Zhao, H., Ge, L., Petry, T.M. and Sun, Y. Effects of chemical stabilizers on an expansive clay. KSCE Journal of Civil Engineering, 2014, 18(4):1009-1017.

Copyrights