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EVALUATION OF FILTRATE FLOW RATE USING CAPILLARY SUCTION TIME APPARATUS

Arimieari, L.W.[1*], Ademiluyi, J.O.[2]

***CORRESPONDING AUTHOR**

ABSTRACT

This study evaluates the filtrate flow rate using capillary suction time apparatus both the 14.5 mm and 20 mm internal diameters cylinders were used to assess the filterability of synthetic sludge. Sludge conditioning facilitates the separation of the solids from the liquid portion by dosing with inorganic salts ($CaCl_2$). Experimental results indicate that the filtrate flow rate increases with increase in the concentration of inorganic salt ($CaCl_2$) and CST decreases with increase between the circles for 15.1 mm and 21.1mm external diameters cylinders. The change in the internal diameter of cylinders 14.5 mm and 20 mm shows consistent increase in flow rate with increase in the external cylinder diameter as CST increases and reduced the slope of the graphs from 15.242 to 12.949. CST was found to reduce as the concentration of $CaCl_2$ increases due to the presence of coagulant in synthetic sludge. The results showed that the water front movement from the centre of the cylinder of larger diameter was faster than that of the smaller diameter.

KEYWORDS: Sludge Filterability Measure, Conditioning Characteristics, Wastewater Treatment.

1 INTRODUCTION

The main reason for dewatering sludge is to reduce its volume by eliminating water, which lowers transportation costs, and facilitates storage. Dewatering also helps to stabilize sludge. In addition, sludge structure is improved by dewatering, so that it can be made into a fertilizer or soil conditioner which can be spread by agricultural equipment [1]. The decision to select an environmentally sustainable approach to sludge dewatering can be used very effectively to review and correct point source polluting practices up-stream that should not be taking place. Sewage can contain pathogens or disease-causing organisms, minerals, metals, and nutrients such as ammonia and phosphorous. The techniques used in dewatering devices to remove moisture from waste water sludge include mechanical and non mechanical methods [2]. In mechanical method, mechanically assisted physical means are used to dewater the sludge which includes centrifugation, belt-filter press, filter presses and vacuum filtration. The non mechanical methods rely on natural evaporation and percolation to dewater the solids. In many countries, sewage sludge is a serious problem due to its high treatment costs and the risks to environment and human health based on the factor in the operation of wastewater treatment plants [3], [4], [5]. Sewage sludge quantities and characteristics depend not only on types and levels of wastewater treatments but also on the quality of the influent and effluent [6], [7]. Sludge Stabilization is used for reducing undesirable effects of sludge on environment, including the removal of pathogens and the reduction of volatile solids and offensive odours [8]. There are different ways to characterize the filterability of sludges.

1. **Department of Civil Engineering, Rivers State University, Port Harcourt, Nigeria.**
   luvi4real@yahoo.com

2. **Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria.**

The most common method to evaluate the filterability of sludges is to determine their filterability by measuring specific resistance to filtration (SRF) and capillary suction time (CST). The measurement of these parameters is based on the flow through a porous medium which are good indicators of the filterability. The Capillary suction time (CST) is the time taken for the filtrate to travel between two concentric and adjacent circles on the filter paper. Capillary suction time (CST) represents the filterability and has many advantages, such as easy operation, it is far from realistic since no pressure is applied and the easiness of removing moisture from slurry and sludge in numerous environmental and industrial applications [9]. Overdosing of sludge conditioning by polymers as a result of CST measurement has been reported [10]. A sludge sample that has high SRF and CST values is usually referred as difficult to dewater [11]. Sanin and Vesilind [12] developed a novel chemical surrogate for activated sludge, which they named synthetic sludge, to study sludge dewatering, settling and conditioning characteristics. Synthetic sludge is made up of non-living particles that resemble activated sludge components. Filtration has been defined as a mechanical method which is commonly applied for solid–liquid separation [13] while improving sludge cake filterability is one of the several ways to enhance biosludge dewaterability [14]. Sludge filtration theories and derived equations have been based on experimental assumptions and conditions, each researcher making effort to modify already existing theory in order to introduce a completely new concept for evaluating sludge filtration equation. A mathematical description of dewatering process has been developed based on the superposition of two models, the conventional filtration theory for the filtration phase and the BT-model for the drying phase [15]. The standard CST test was first developed by Gale and Baskerville [16]. The components include an open stainless steel cylindrical column or funnel with a Whatman filter paper at the base, multiple electrodes, which serve to sense the movement of filtrate across the paper, and a timer. A sample of sludge is poured into the column, and the filtrate is extracted by capillary suction through the paper, so that a cake is formed on the filter. The CST test is one of the most commonly used tests to determine sludge dewaterability [17]. The CST test is widely used because it is quick, reliable, simple and inexpensive. It does not require an external source of pressure or suction, and the automated CST test device is easy to use and portable, so that tests can be performed in any location. A short time indicates a highly filterable sludge; a long time suggests slow, problematic filtration. The purpose of using CST was to evaluate the filtrate flow in order to assess the dewaterability of synthetic sludge.

2 MATERIALS AND METHODS

2.1 Capillary Suction Time (CST) Apparatus

Standard CST apparatus was not available; hence the procedure described below was followed to fabricate the apparatus used for this study from the work done by Ademiluyi and Onah [18].

Plate Fabrication

1. Two Perspex plates of sizes 150 mm×200 mm×5 mm were cut for the upper and lower plates respectively.
2. 3mm diameter holes were drilled at the four edges to pass the clamping bolts.
3. Centre of the upper plate was located.
4. Using a pair of divider and with the point located in 3 above as reference point circle equal in diameter to the external diameter of the test cylinder was drawn on the upper plate.
5. Concentric circles were drawn round the first circle with the same reference point used in 4 above by increasing the diameter by 10mm respectively until the plate surface is covered in order to measure the distance of the wet front advances.

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6. A hole was drilled on the upper plate with a help of a drilling machine and with the point located in 3 above as centre.
7. Using a drilling machine the diameter of the hole in 6 above was increased to the external diameter of the test cylinder so that it can be passed to rest directly on the filter paper.
8. The same procedures from 3 to 7 were followed to make upper plates for the different test cylinders used for the study. The CST experimental setup is shown below.

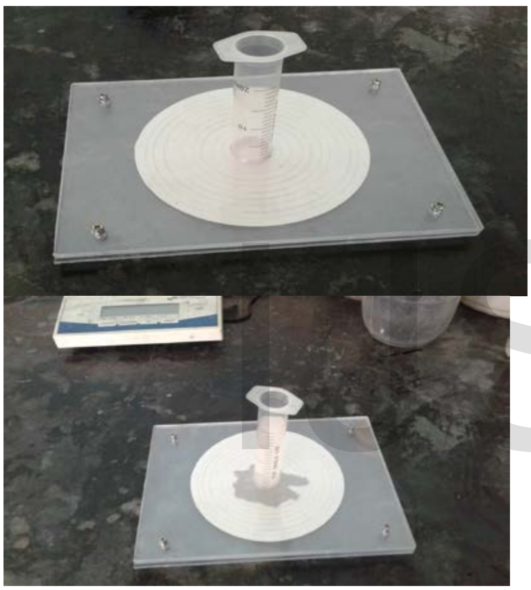

Plate 1: CST Experimental Setup (left) and CST Experimental Setup during Filtration (right).

Cylinder Fabrication

Two surgical syringes of internal and external diameters (14.5 mm, 15.1 mm) and (20 mm, 21.1 mm) were used for fabrication of the test cylinders. The closed end of the cylinder was cut off to make cylinder open at both ends.

Capillary Suction Time Paper

Whatman 1: Cat No 1001 - 125 was used for the CST test with a diameter of 12.5cm.

Synthetic Sludge Sample

Calcium chloride **(**$CaCl_2$**)** at various concentrations ranging from 10 – 18 g was used as a conditioner and mixed with 2 g of Borax, 2 g of Polyanionic Cellulose (PAC) and Carboxyl Methyl Cellulose (CMC) before filtration. The components were dissolved in a 320 ml of distilled water.

Data Reading System

Due to unavailability of computerized data acquisition system, a stop watch was used to take the readings as the filtrate moved across the filter paper and timing started when the wet front of the filtrate reached the starting point from the cylinder centre.

3 RESULTS AND DISCUSSION

3.1 Measurement of Filtrate Flow using Capillary Suction Time Apparatus

The capillary suction time apparatus was assembled as described earlier in this work; both the 14.5 mm and 20mm internal diameters cylinders were used for this text. Standard CST was measured as the time for the wet front to advance between points from the external diameters of the text cylinders. The filtration process was allowed to progress until the filter paper is completely saturated when the cake formation on the filter paper was noticed. The text was conducted using different concentrations of $CaCl_2$ as conditioner. Each calibration on the test cylinders is equal to 0.25 ml for 14.5 mm and 1ml for 20 mm internal diameters. The results are shown in Figs.1-4.

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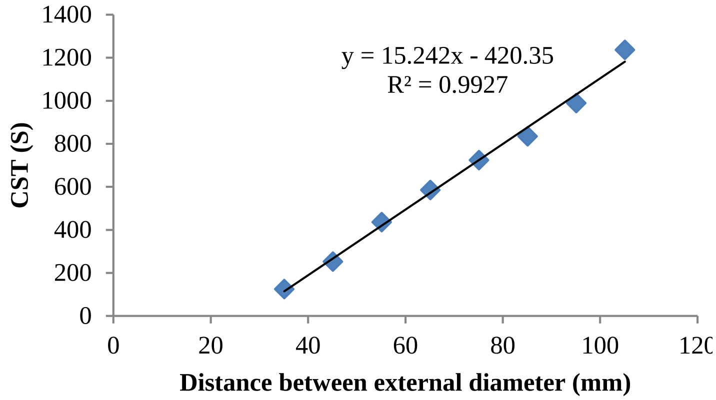

Fig. 1: Plot of CST against Distance between external diameters for 14.5 mm using 10g of $CaCl_2$.

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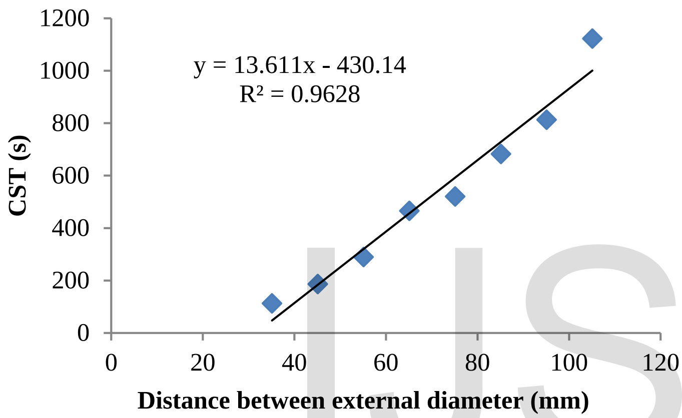

Fig. 2: Plot of CST against Distance between external diameters for 14.5 mm using 12g of $CaCl_2$.

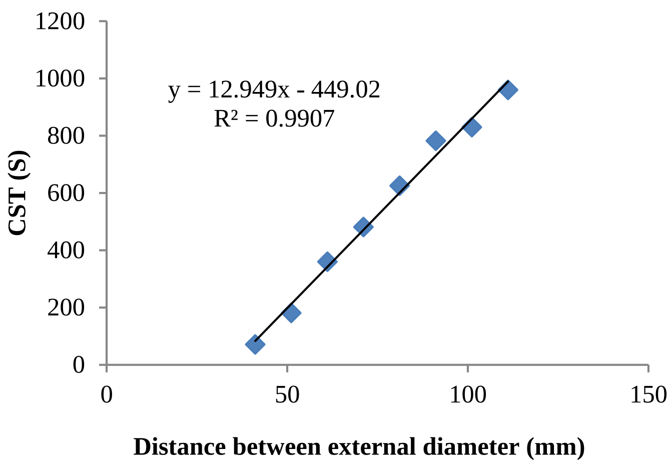

Fig. 3: Plot of CST against Distance between external diameters for 20 mm using 10g of $CaCl_2$.

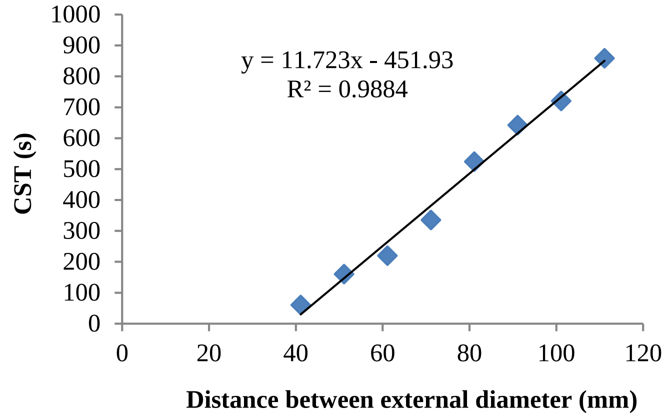

Fig. 4: Plot of CST against Distance between external diameters for 20 mm using 12g of $CaCl_2$.

The change in the internal diameter of cylinder 14.5 mm shows consistent increase in flow rate with increase in the external cylinder diameter as CST increases. The first two data were neglected for plotting of Figure 1- 4 as they are closed to the reference point whereby allowing the sludge to permeate through the filter medium.

4 CONCLUSION AND RECOMMENDATIONS

Standard CST was measured as the time for the wet front to advance between points from the external diameters of the text cylinders. CST for filterability estimates were computed from the results of the CST tests. The change in the internal diameters of cylinders 14.5 mm and 20 mm reduced the slope of the graphs showing consistent increase in flow rate with increase in the cylinder diameter. CST was found to reduce as the concentration of $CaCl_2$ increases due to the presence of coagulant in synthetic sludge. The results showed that the water front movement from the centre of the cylinder of larger diameter was faster than that of the smaller diameter for slow filtering sludge.

The results of this study for CST recommend larger diameter cylinder to be used to test heavy sludge because the larger

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cylinder significantly reduce the variability and the time taken to conduct the CST tests.

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