A Comparative Study of the Influence of Varying Composition of Soil Samples on the Rate of Water Flow

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***Abstract*-This research investigates and compares the rate of flow of water through varying composition of soil samples collected from a sand dredging site at Amassoma community in Bayelsa State of Nigeria. The soil sample comprises of a mixture of two samples (sharp and medium) in different proportions. The different mixtures of soil samples were weighed and mixed by percentage and grouped into seven (Group A: 100% sharp sand and 0% medium sandy soil, Group A: 100% sharp sand and 0% medium sandy soil, Group A: 100% sharp sand and 0% medium sandy soil, Group B: 80% sharp sand and 20% medium sandy soil, Group C: 60% sharp sand and 40% medium sandy soil, Group D: 50% sharp sand and 50% medium sandy soil, Group E: 30% sharp sand and 70% medium sandy soil, Group F: 10% sharp sand and 90% medium sandy soil and Group G: 100% sharp sand and 0% medium sandy soil). Equal measured quantity of water was poured into a transparent PVC pipe containing the soil samples of each group and the time for the first drop and volume of water collected at an interval of 100mls were recorded. Results showed that the time of first drop differed with the different groups of soil samples and the values of the times of the volume of water collected were highly correlated. The results also showed no difference in the time for the volume of water collected for the dependent samples (dry and wet) for all groups and in most cases of the independent samples (both (dry and dry) and (wet and wet) cases) except for sample B (dry) and F (dry), sample C (dry) and D (dry) and sample E (dry) and G (dry).**

***Keywords:* Samples, Soil Samples, Flow of Water, Time of First Drop**

I. INTRODUCTION

Agriculture is the predominant economic activity in most part of Nigeria. Soil is a very important medium for the growth of plant and production of food (Fasina et al., 2007). It is the top layer of the earth's crust and is referred to as a general term for particles formed by the gradual wearing away of the parent rock material. The parent rock material largely defines the composition of the soil. Soil is composed of a mixture of minerals, organic matters, gases and liquids which work together to support life on earth. It serves as a means of water supply, storage and purification. The importance of the soil for the production of crop is dependent on the quality of the soil.

The properties of soil can be physical, chemical and biological. The characteristics of the soil give enough information on the understanding of the physical, chemical mineralogical and microbiological property of the soil (Ogunkunle, 2005). Some of the physical characteristics of soil particles include colour, size, shape etc. The chemical properties such as soil reactions and buffering action determine the quality of the soil (Adesunloye, 1989). It is usually said that most scientist assume that the soil samples are chemically unaffected by the environment.

The size of soil particles increases as one digs further into the earth, soil is usually not totally dry; the Soil has a proportion of water and air that fill gaps between the particles of the soil. This gives the soil a porous characteristic. It is natural that soil will swell and contract when the water content changes. In general, it is important that the moisture of the soil is measured since it's used to determine the properties of the soil. The measurement of the moisture can be done through weighing and drying in an oven. Soil can be considered porous if it has a matrix of voids throughout it. The porosity of soil varies depending on the size of the particles of the soil sample. It is required that the apparent and specific bulk density of a soil sample is known to calculate the porosity of the soil sample. It is also required that the soil permeability is measured; the permeability of the soil is a measure of how fast a fluid moves through it. The permeability of soil depends on the porosity of the soil since the air pores allow fluid or water to pass through the soil, for instance, a sandy soil will have more pores and a low resistance to the flow of water while a clay soil will have little or no pores and hence resist the flow of water. The characteristic of the pores affects almost everything that occurs in the soil including the movement of water, air e.t.c through the soil (Nimmo, 2004) and hence, the flow of water in the soil is interconnected through the void and the velocity of the flow which depends on the size of the pores. Therefore, this research work is aimed at determining and comparing the rate of flow of water through the mixture of two different soil samples. It will also discuss the retention capacity of the various mixtures of the soil samples.

It is required that researchers perform more careful analysis on soil samples to ensure accurate results. There are various characteristics and methods for measuring accurate properties of soil samples. Some of the methods and basic theories for measuring the properties of the soil are Darcy's law, Porosity or void ratio, apparent bulk density and dry bulk density.

Darcy's law: The Darcy's empirical law defines the permeability of soil which is limited to one dimensional flow of water through the soil (Craig, 1997). It states that the rate of fluid flow through a porous medium is proportional to the potential energy gradient within that fluid. The constant of proportionality is the Darcy's permeability of soil. The Darcy's law is given as

$$V = Ki = \frac{K\Delta h}{L} \qquad [1]$$

where;

V = Discharge velocity of superficial velocity

K = Coefficient of Permeability or Hydraulic conductivity

i = Hydraulic gradient

Δh = Fall in total head

L = Length of soil specimens.

Porosity or Void Ration: The porosity is the fraction of the total soil volume that is taken up by the pore space. The porosity or void ratio is unity minus the ratio of the volume of soil alone to the volume of the sample.

It is defined as

$$P = I - \frac{V_{soil}}{V_{sample}} \qquad [2]$$

where

V_{soil} = volume of soil.

V_{sample} = volume of sample.

We will note that the porosity is generally expressed as percentage.

Apparent Bulk density

This is a measurement of the overall density of the soil sample including air or moisture present with the sample.

$$BD_A = \frac{M_{sample}}{V_{sample}} \ (measured\ in\ kg/m^3) \qquad [3]$$

M_{sample} = mass of sample

V_{sample} = volume of sample

Dry bulk Density: This can be measured using

$$BD_D = \frac{M_s}{V_t} \qquad [4]$$

Where BD is the Bulk density (gcm^{-3}).

M_s is the mass of soil (g).

V_t is the volume of Cylinder (cm^3).

II. MATERIALS AND METHODS

The materials used in this research include digital weigh balance, water, oven, thermometer, stop watch, beakers, transparent PVC pipe, sieve (1mm and 2mm), retort stand and measuring cylinder.

III. SOIL SAMPLES AND MEASUREMENT

This research is aimed at investigating the rate at which water flows through the mixture of two soil samples (sharp and medium) in different proportions. These soil samples were collected from a sand dredging site at Amassoma Community in Bayelsa State of Nigeria. The soil samples were heated in the oven for 30 minutes to a temperature of about 120^0C since it is required that soil needs to be dry for soil particles to be deflocculated to ensure accurate results. The heated samples were allowed to cool to a temperature of 30^0C. The cooled samples were sieved using different sizes of sieves (2mm for sharp sand and 1mm for medium sandy soil). The soil samples were then weighed and mixed by percentage and grouped into seven as shown in Table 1.

Table 1: Weighed and mixed soil samples in groups

Group	Sample mixture by percentage of sharp sand	Sample mixture by percentage of medium sandy soil
A	100%	0%
B	80%	20%
C	60%	40%
D	50%	50%
E	30%	70%
F	10%	90%
G	0%	100%

The soil samples of each group were poured into a transparent PVC pipe with one end close with a sieve. The initial height of the soil samples from each group was taken and 800mls of water was measured with a beaker. The 800mls of water was poured into each group of soil samples and the time for the first drop of water were recorded for each group against volume (ml) = 0. The time for the volume of water collected at an interval of 100mls were noted and recorded until the water stops to flow. The values were recorded as dry as given in Table 2 to Table 8. The height of each saturated sample of each group were recorded and another 800mls was allowed to flow through the saturated sample of each group and the time for the volume of water collected at an interval of 100mls was also noted and recorded until the water stops to drop. The values were recorded as wet as given in Table 2 to Table 8.

Table 2: Sample A

DRY		WET	
Volume (ml)	Time (secs)	Volume (ml)	Time (secs)
0	4	100	6
100	8	200	10
200	11	300	14
300	14	400	18
400	18	500	23
500	22	600	28
600	27	700	35
700	50	800	81
730	121	810	135

Table 3: Sample B

DRY		WET	
Volume (ml)	Time (secs)	Volume (ml)	Time (secs)
0	5	100	8
100	17	200	12
200	24	300	16
300	32	400	22
400	42	500	28
500	53	600	35
600	68	700	43
700	331	800	60
720		840	122

Table 4: Sample C

DRY		WET	
0	6	100	11
100	13	200	19
200	18	300	27
300	24	400	37
400	31	500	47
500	40	600	59
600	50	700	73
700	224	800	164
		810	368

Table 5: Sample D

DRY		WET	
Volume (ml)	Time (secs)	Volume (ml)	Time (secs)
0	7	100	13
100	15	200	22
200	21	300	32
300	28	400	44
400	37	500	56
500	46	600	71
600	58	700	86
700	189	800	141
		820	

Table 6: Sample E

DRY		WET	
Volume (ml)	Time (secs)	Volume (ml)	Time (secs)
0	9	100	15
100	16	200	25
200	23	300	35
300	31	400	49
400	40	500	62
500	50	600	80
600	64	700	120
700	300	800	180
		820	336

Table 7: Sample F

DRY		WET	
Volume (ml)	Time (secs)	Volume (ml)	Time (secs)
0	9	100	14
100	17	200	25
200	24	300	36
300	32	400	50
400	42	500	64
500	53	600	81
600	68	700	102
690	335	800	155
		820	279

Table 8: Sample G

DRY		WET	
Volume (ml)	Time (secs)	Volume (ml)	Time (secs)
0	10	100	13
100	18	200	24
200	25	300	37
300	34	400	50
400	44	500	61
500	55	600	79
600	70	700	100
690	277	800	150
		820	270

IV. METHOD OF DATA ANALSIS

We want to analysis the data collected in Table 2 to Table 8. First of all, we will want to check to find out if the time for the first drop (T_f) of water in each group is the same. Secondly, we will compare the time for the volume of water collected at intervals of 100mls for the samples in each group using the hypothesis testing about differences in both dependent and independent samples.

V. HYPOTHESIS TESTING ABOUT DIFFERENCES IN SAMPLES

We might want to find out if there are significant differences between two samples. We will consider two cases. In one case, the two samples will be dependent in the sense that each observation in one sample might be correlated with some particular observation in the other sample. For instance, in this research, we consider the rate of flow of water through a dry mixture of soil sample and wet mixture of the same soil composition. We will use hypothesis testing using t test for dependent samples (Tokunaga, 2016). We suppose that the null hypothesis H_0 is given as

H_0: There is no significant difference between the rate of flow of water between the dry and wet composition of the soil sample.

The alternative hypothesis H_1 is given as

H_1: There is significant difference between the rate of flow of water between the dry and wet composition of the soil sample.

The test statistics is given as

$$t = \frac{\bar{d}\sqrt{n}}{s_d} \qquad [5]$$

It has a t distribution with $n-1$ degree of freedom. We have that the difference between the values of the time of first drop (in seconds) of the dry soil sample, S_{d_i} and the corresponding values of the time of first drop (in seconds) of the wet sample S_{w_i} is

$$d_i = S_{d_i} - S_{w_i} \quad \text{for } i = 1,2,\ldots\ldots,n \qquad [6]$$

We also have that $\bar{d}$ is the sample mean difference and S_d is the sample standard deviation of the difference. The null hypothesis H_0 is rejected if the test statistics is greater than the t distribution with $n-1$ degree of freedom.

In the second case, we will be faced with problems such as finding out if there are any significant differences between the times of first drop of two different samples. Here, the samples are independent. The test statistics is given as

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} \qquad [7]$$

and has a t distribution with $n_1 + n_2 - 2$ degree of freedom. We have that S is the pooled variance.

The null hypothesis H_0 is rejected if the test statistics is greater than the t distribution with $n_1 + n_2 - 2$ degree of freedom. The p value can also be used.

VI. STATISTICAL ANALYSIS

The time for the first drop of water were recorded for each group against volume (ml) = 0. We present a plot of time for the first drop for the different groups of soil samples in Figure 1. We might want to compare the time for the volume of water collected at intervals of 100mls for the dry sample and that of the saturated sample (wet) of each group. We find the correlation or closeness in the relationship between the times of the volume of water collected at intervals of 100mls for all groups using R software (R Core Team, 2014). Table 9 gives the correlation matrix of the times of the volume of water collected at intervals of 100mls for some of the groups.

Figure 1: Plot of time of first drop against the different groups of soil samples

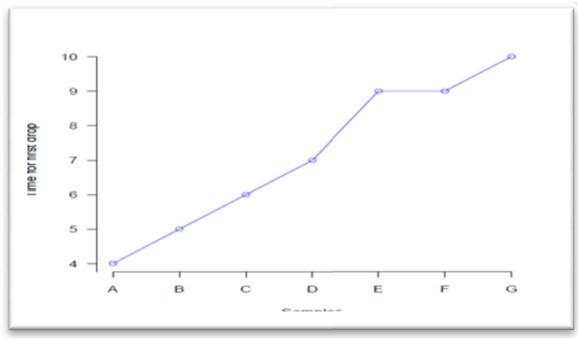

Table 9: The correlation matrix of the times of the volume of water collected at intervals of 100mls for some of the groups.

	A (dry)	A (wet)	B (dry)	B (wet)	C (dry)	C (wet)	D (dry)	D (wet)	E (dry)	E (wet)	F (dry)	F (wet)	G (dry)	G (wet)
A (dry)	1.00	0.94	0.95	0.94	0.95	0.94	0.99	0.93	0.95	0.98	0.95	0.94	0.96	0.94
A (wet)	0.94	1.00	0.79	0.99	0.80	0.99	0.84	0.99	0.79	0.99	0.79	0.99	0.81	0.99
B (dry)	0.95	0.79	1.00	0.79	0.99	0.78	0.99	0.77	0.99	0.88	0.99	0.79	0.99	0.99
B (wet)	0.94	0.99	0.79	1.00	0.80	0.99	0.84	0.99	0.79	0.99	0.79	0.99	0.81	0.99
C (dry)	0.95	0.80	0.99	0.80	1.00	0.79	0.99	0.78	0.99	0.88	0.99	0.80	0.99	0.80
C (wet)	0.94	0.99	0.78	0.99	0.79	1.00	0.83	0.99	0.79	0.99	0.78	0.99	0.80	0.99
D (dry)	0.97	0.84	0.99	0.84	0.99	0.83	1.00	0.83	0.99	0.92	0.99	0.84	0.99	0.84
D (wet)	0.93	0.99	0.77	0.99	0.78	0.99	0.83	1.00	0.77	0.98	0.77	0.99	0.80	0.99
E (dry)	0.95	0.79	0.99	0.79	0.99	0.79	0.99	0.77	1.00	0.88	0.99	0.79	0.99	0.80
E (wet)	0.98	0.99	0.88	0.99	0.88	0.99	0.92	0.98	0.88	1.00	0.88	0.99	0.90	0.99
F (dry)	0.95	0.79	0.99	0.79	0.99	0.78	0.99	0.77	0.99	0.88	1.00	0.79	0.99	0.79
F (wet)	0.94	0.99	0.79	0.99	0.80	0.99	0.84	0.99	0.79	0.99	0.79	1.00	0.81	0.99
G (dry)	0.96	0.81	0.99	0.81	0.99	0.81	0.99	0.80	0.99	0.90	0.99	0.81	1.00	0.82
G (wet)	0.94	0.99	0.79	0.99	0.80	0.99	0.84	0.99	0.79	0.99	0.79	0.99	0.82	1.00

Table 10: Hypothesis testing about differences in times of dependent sample

Sample	P value	T value	Decision
Sample A (dry) and A (wet)	0.165	1.0596	Accept H_0
Sample B (dry) and B (wet)	0.09	1.4944	Accept H_0
Sample C (dry) and C (wet)	0.2224	0.8177	Accept H_0
Sample D (dry) and D (wet)	0.2729	0.6402	Accept H_0
Sample E (dry) and E (wet)	0.2449	0.7354	Accept H_0
Sample F (dry) and F (wet)	0.2186	0.8322	Accept H_0
Sample G (dry) and G (wet)	0.2061	0.8812	Accept H_0

Table 11: Hypothesis testing about differences in times of independent samples

Sample	P value	T value	Decision
Sample A (dry) and B (dry)	0.9067	-1.4011	Accept H_0
Sample A (dry) and C (dry)	0.8813	-1.2434	Accept H_0
Sample A (dry) and D (dry)	0.9187	-1.488	Accept H_0
Sample A (dry) and E (dry)	0.9053	-1.3915	Accept H_0
Sample A (dry) and F (dry)	0.906	-1.3962	Accept H_0
Sample A (dry) and G (dry)	0.9243	-1.5318	Accept H_0
Sample A (wet) and B (wet)	0.7502	-0.6960	Accept H_0
Sample A (wet) and C (wet)	0.9737	-2.1505	Accept H_0
Sample A (wet) and D (wet)	0.9869	-2.5342	Accept H_0
Sample A (wet) and E (wet)	0.9869	-2.536	Accept H_0
Sample A (wet) and F (wet)	0.9908	-2.7252	Accept H_0
Sample A (wet) and G (wet)	0.9901	-2.6877	Accept H_0
Sample B (dry) and C (dry)	0.4701	0.3234	Accept H_0
Sample B (dry) and D (dry)	0.5154	0.3078	Accept H_0
Sample B (dry) and E (dry)	0.1082	0.4578	Accept H_0
Sample B (dry) and F (dry)	-0.0095	0.5037	Reject H_0
Sample B (dry) and G (dry)	0.1155	0.455	Accept H_0
Sample B (wet) and C (wet)	-1.6127	0.9336	Accept H_0
Sample B (wet) and D (wet)	-2.0635	0.9693	Accept H_0
Sample B (wet) and E (wet)	-2.1912	0.9755	Accept H_0
Sample B (wet) and F (wet)	-2.3229	0.9807	Accept H_0
Sample B (wet) and G (wet)	-2.2772	0.9791	Accept H_0
Sample C (dry) and D (dry)	0.0236	0.4908	Reject H_0
Sample C (dry) and E (dry)	0.2741	0.6426	Accept H_0
Sample C (dry) and F (dry)	-0.4769	0.679	Accept H_0
Sample C (dry) and G (dry)	-0.3951	0.6502	Accept H_0
Sample C (wet) and D (wet)	-0.5587	0.7067	Accept H_0
Sample C (wet) and E (wet)	-1.0073	0.8332	Accept H_0
Sample C (wet) and F (wet)	-0.9737	0.8253	Accept H_0
Sample C (wet) and G (wet)	-0.9085	0.8092	Accept H_0
Sample D (dry) and E (dry)	-0.4189	0.6586	Accept H_0
Sample D (dry) and F (dry)	-0.5219	0.6944	Accept H_0
Sample D (dry) and G (dry)	-0.4468	0.6685	Accept H_0
Sample D (wet) and E (wet)	-0.5235	0.6949	Accept H_0
Sample D (wet) and F (wet)	-0.4422	0.6669	Accept H_0
Sample D (wet) and G (wet)	-0.3734	0.6423	Accept H_0
Sample E (dry) and F (dry)	-0.1174	0.5457	Accept H_0
Sample E (dry) and G (dry)	0.0028	0.4989	Reject H_0
Sample E (wet) and F (wet)	0.1106	0.4569	Accept H_0
Sample E (wet) and G (wet)	0.4754	0.4318	Accept H_0
Sample F (dry) and G (dry)	0.0689	0.4731	Accept H_0
Sample F (wet) and G (wet)	0.0689	0.4731	Accept H_0

It is very obvious from Table 9 that the values of the times for the volume of water collected or recorded at intervals of 100mls are very much correlated.

We will use the test of hypothesis about differences for dependent samples since the samples are dependent on each other (dry and wet samples). Again, the R software was used to conduct the hypothesis testing about the differences in the values of the dry and wet. The values of the t distribution and p values are recorded in Table 10. We conduct the hypothesis testing about the differences in the times of the independent samples of all groups (for instance, dry of Group A and dry of Group B, etc). The values of the t distribution and p values are recorded in Table 11.

VII. RESULTS AND DISCUSSION

The values of the time recorded in Table 9 shows that the times of the volume of water collected at an interval of 100mls are highly correlated. Figure 1 shows that the time of first drop differs with the different groups of soil samples. It increases across the groups and is steady for group E and F. Table 10 shows that the null hypothesis H_0 in all cases was accepted in the dependent samples. For instance, a comparison of the times of the volume of water collected at an interval of 100mls for sample A (dry) and the saturated sample A (wet) gives a p value of 0.165. This value is greater than 0.05 and so we accept the null hypothesis that the time for the volume of water collected at an interval of 100mls for the dry sample is the same for that collected for the wet sample. The same is the case for all samples in each group.

Table 11 also shows that the null hypothesis H_0 was accepted in most cases in the independent samples. The null hypothesis was rejected in the comparison of sample B (dry) and F (dry), sample C (dry) and D (dry) and sample E (dry) and G (dry). For instance, a comparison of the times of the volume of water collected at an interval of 100mls for sample A (dry) and sample B (dry) gives a p value of 0.9067. This value is greater than 0.05 and so we accept the null hypothesis that the time for the volume of water collected at an interval of 100mls for sample A (dry sample) is the same for that collected for the sample B (dry). The comparison of the times of the volume of water collected at an interval of 100mls for sample C (dry) and sample D (dry) gives a p value of 0.0236. This value is less than 0.05 and so we reject the null hypothesis that the time for the volume of water collected at an interval of 100mls for sample C (dry sample) is not the same for that collected for the sample D (dry).

VIII. CONCLUSION

The results obtained in this research indicate that water percolation or the time for the first drop differs with the different groups of soil samples. The value of the time for the first drop decreases gradually from sample A to sample G with the percentage increase in medium sand. Consequently, our data analysis shows that there is no difference in the time for the volume of water collected at intervals of 100mls for the dependent samples (dry and wet). It is obvious that the rate of flow of water through the soil samples is the same after the time of the first drop has been recorded. The time for the volume of water collected at intervals for the different samples are the same for both dependent (dry and wet) and for most cases of the independent (both (dry and dry) and (wet and wet)) cases) except for sample B (dry) and F (dry), sample C (dry) and D (dry) and sample E (dry) and G (dry).

We notice that that the time till the first drop varies for both dry and wet samples. This is due to the difference in grain size and particle arrangement. It might also be that for the dry sample, the soil is well disturbed than that of the wet sample. The rate of flow is the same after some water has passed through the samples. The packing arrangement reduces the voids because medium sand with relatively small size tends to occupy the void spaces between the sharp and medium sand mixture, thereby reducing the number of voids and as well as affecting the possible connectively between voids.

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