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COMPARATIVE EFFECTIVENESS OF WATER, CALGON AND SODIUM HYDROXIDE IN SOIL DISPERSION UNDER TWO MECHANICAL AGITATION METHODS

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ABSTRACT

Distilled water, 5% calgon and sodium hydroxide were used as dispersion agents in the particle size analysis of surface and subsurface soils of five Nigerian soils. Sampling depths were 0 – 15, 15 – 30 and 30 – 45cm and concentrations of sodium hydroxide were 0.2N, 0.4N and 0.6N respectively. Agitation methods were high speed mechanical stirring for five minutes, and overnight shaking on a reciprocate shaker. Water was found to be least effective in soil dispersion, regardless of sampling depth or agitation method. There was no significant difference between the effectiveness of calgon and different concentrations of NaOH ($p = 0.2866$). There was also no significant difference between the two agitation methods within each soil depth. There was however highly significant interaction between soil depth and agitation method ($p<0.01$) and also between soil depth and dispersion agent ($p< 0.05$). Overnight shaking was more effective on soils of 0 –15 and 15 –30cm depth, but mechanical stirring for five minutes was more effective at 30 –45 cm depth. NaOH was as effective as calgon at 0 –15 and 15 – 30cm, but calgon was significantly more effective than NaOH at 30 – 45cm.

INTRODUCTION

The laboratory determination of soil texture or the mechanical analysis of soils includes three basic methods. These are: the Bouyoucos hydrometer method, the pipette method and the sieve method (Bouyoucos, 1951; Day, 1965). In these three methods, a common prerequisite to analysis is the initial dispersion of the soil before it is subjected to mechanical analysis, with the aid of chemical agents of dispersion, usually combined with some form of mechanical agitation of the soil suspension (Grohmann and Raij (1977).

Given the diverse nature of soils, no single dispersing agent has been found to be equally effective in all soils(Pinheiro and Schwertmann, 1996). However, those agents containing sodium have allowed the least flocculation, and therefore the greatest dispersion((Edwards and Bremner, 1967a, Curtin *et al.*, 1994). The Bouyoucos hydrometer method of particle size analysis is popular for its simplicity, rapidity and reasonable accuracy, and the use of sodium hexametaphosphate (calgon) has gained wide acceptability as an agent which needs no pretreatment of soils before dispersion (Baver *et al.*,1972, Singh, 1980).

Calgon, the most popular soil dispersion agent in Nigeria, has become rather expensive in recent times, as with cost and availability of other chemicals. However, results obtained from the use of water in soil dispersion for particle size analysis generally exaggerates percent sand content, and in subsoil analysis, results obtained for clay content are grossly underestimated, and very misleading. Baver et al.(1972) actually concluded that the use and comparison of a wide variety of dispersing agents be done on soils subjected to mechanical analysis, as their effectiveness varies with different soils. However, as this may not always be economically advisable, especially where there are large numbers of samples involved, there is need therefore to seek other effective agents in addition to calgon. Such alternatives should be commonly available, versatile in the sense that they can be useful for other laboratory analyses, yet without compromising effectiveness of dispersion.

The study aimed at

i. comparing the effectiveness of water and different concentrations of sodium hydroxide with calgon in the dispersion of surface and subsoils

ii. comparing high speed stirring and overnight shaking as mechanical agitation methods on soils for particle size analysis

iii. establishing an optimal combination of dispersion agent and agitation method in the dispersion of soils from different soil depths.

MATERIALS AND METHODS

Five soil types were used in this study, namely I – Alagba; II – Santigi; III – Ibadan; IV – Iwo; and V - Iju series. The textural classes of the soils used varied widely as follows. I-Alagba series (sandy clays); II-Santigi (deep sands); III-Ibadan (coarse sands); IV-Iwo (fairly clayey to clayey loam); and V-Iju series (sandy clays) (Smyth and Montgomery, 1962).

Each soil type was sampled at three depths of 0 – 15, 15 –30 and 30 –45cm using a screw auger. At each sampling depth, a composite of five spots were augered at a radial distance of 5m to form a bulk sample for each soil type.

The experiment was a 3*2*5*5 factorial, analysed as a randomized complete block design, with three sampling depths, two mechanical agitation methods, and five dispersion agents. Five soil types served as blocks.

The three sampling depths (**Factor A**) used in the study were 0 –15cm; 15 –30cm and 30 –45cm respectively. The two agitation methods (**factor B**) were:

i. Mechanical, high speed stirring for five minutes (MS) and

ii. Overnight shaking for at least 16 hours on a reciprocating shaker (OS)

Factor C was made up of five dispersion agents, namely: water; 5% sodium- hexa-meta-phosphate (calgon); 0.2N NaOH; O.4N NaOH and 0.6N NaOH. Hydrometer readings for each treatment were taken three times, and the initial and final readings used in calculating percent sand, silt and clay are means across three readings each. Soil type was not a factor in this study, but served as blocks. This is because; soils naturally vary in clay- contents, depending on soil type. The dispersion indices of the various dispersion agents will therefore be different for different soil types, being a function of the clay content of each soil, and not necessarily indicating differences in effectiveness of different dispersion agents.

The use of dispersion index has been found to be very accurate by several workers, including Balks *et al.*, (1998), who used dispersion index to investigate the effects of increased sodicity on soil physical properties.

$$\text{Dispersion index, DI} = \frac{\%\ \text{clay}}{\%\ \text{sand} + \%\ \text{silt}}$$

First, particle size analysis was carried out on each sample by standard procedure according to Day, (1965). Hydrometer and temperature readings were taken after 40 seconds and three hours . After analyzing all the samples for their relative percentages of sand, silt and clay; dispersion index (DI) was then used as a measure of dispersion.

Sample Preparation

Each sample was air dried, crushed and sieved through a 2mm sieve. Samples were then subjected to different treatments as follows:

a. Addition of 100mls of distilled water

b. addition of 100mls of 5% sodium – hexa – meta- phosphate (calgon)

c. addition of 100mls of 0.2N NaOH solution

d. addition of 100mls of 0.4N NaOH solution

e. addition of 100mls of 0.6N NaOH solution

after which the samples were then subjected to mechanical agitation.

For the mechanical agitation, the two methods employed were:

i. one sample was allowed to stand for thirty minutes, occasionally stirring, then transferred to a dispersion cup and subjected to mechanical high speed stirring for five minutes

ii. the other was subjected to overnight shaking for at least 16 hours on a reciprocating shaker.

Statistical Analysis

Analysis of variance was carried out on the data, as a 3*2*5*5 factorial in randomized complete block design for factor A(soil depth), with agitation method (factor B) and dispersion agent(factor C) using MSTAT-C, with factors B and C tested with equal precision across all soil depths. The five soil types were blocks.

RESULTS AND DISCUSSION

The results of particle size analysis at different depths are presented in Table 1.Water was clearly the least effective dispersing agent on the soils used in the study. Water gave dispersion indices as low as 0.02 in 0 – 15cm depth of coarse sands like Ibadan series, for which 5% calgon and the various concentrations of NaOH gave DI between 0.07 and 0.10 respectively(Table 1).The weak dispersing ability of water became even more glaring at 30- 45cm depth, where it gave a dispersion index of 0.06 in Iju clay loam, whereas calgon gave as high as 0.59, and NaOH gave between 0.46 and 0.54 at the same depth.

Santigi (deep sands) and Ibadan (coarse sands) generally recorded high sand content at all depths, with increased sand content at 30 – 45cm depth above that at 15 –30cm. This may be due to the fact that at 30 –45cm depth, Santigi and Ibadan series had bigger, heavier particles in the profile, and so increased the hydrometer reading after 40 seconds (Table 1). On the other hand, Alagba (sandy clay) and Iju (clay loam) increased in clay content as depth increased, clearly reflecting inherent differences due to soil type.

All soils ranged from moderately acidic to fairly alkaline at 0 – 15 and 15 – 30cm depths (Table 2). Iju series (sandy clay) however had the lowest pH at all depths, actually rather acidic at 30 – 45 cm depth (pH 4.9). Iju series also had the highest organic matter content (3.72%), which may account for the lower pH. Santigi series (deep sand) had the highest pH at all depths (6.0 – 6.2). Ibadan series (coarse sand) was least in organic matter (1.85%), and it appeared that all five soils used were rather low in %total nitrogen, ranging from 0.06 in Ibadan series, to 0.27 in Iwo series. Baver et al., 1972 found that NaOH is very effective in the dispersion of H- saturated systems, while calgon is very effective with soils containing exchangeable calcium. The similar performance of both NaOH and calgon in the surface soils used in the study may be due to the fact that none could be termed as very acidic, while the superior performance of calgon at lower depths may be due to its ability to form an undissociated calcium metaphosphate complex, thus eliminating the Ca++ in solution (Baver *et al.*, 1972). Soils which are naturally high in clay content, like Iju series, also tended to have higher values for DI, while those with low clay content like Santigi and Ibadan series, had lower values for DI, being a measure of the ratio of clay to the sand and silt fractions. Thus, in the study, dispersion index consistently reflected peculiar soil type characteristics, across all treatments. This confirms the findings of Curtin *et al.* (1994), who found that total clay content, rather than soil management, was a more dominant factor in dispersibility when a wide range of soil types are considered.

The methods of mechanical agitation were not significantly different. But, there was significant interaction between soil depth and agitation method, as well as between soil depth and dispersion agent (Tables 3 and 4). This is because any given soil tends to vary in clay content at different depths, generally increasing as one goes down the profile to lower depths, except in cases like deep or coarse sands. This increase in clay content thus plays an important role in the effectiveness of any method of agitation or dispersion agent, being a measure of the ratio of clay to the sand and silt fractions.

Soil depth * Agitation method

At 0 – 15cm and 15 – 30cm depths, overnight shaking gave the greater dispersion as shown in the mean separation (Table 3), confirming the work of So *et al* (1997), who found that increasing time of shaking with an end over end shaker led to greater dispersion of surface soils.

Table 1. Particle size distribution of soil types according to depth (%)

0 – 15cm	Water	5% calgon	0.2N NaOH	0.4N NaOH	0.6N NaOH	Water	5% calgon	0.2N NaOH	0.4N NaOH	0.6N NaOH
	M.S	O.S	M.S	O.S	M.S	O.S	M.S	O.S	M.S	O.S
Alagba sand	78.52	75.94	71.94	68.84	67.86	68.09	68.50	66.70	69.53	68.44
Silt	17.41	18.05	19.99	16.99	18.13	12.84	13.94	13.26	15.54	12.73
Clay	4.07	6.01	8.07	14.17	14.01	19.07	17.56	20.04	14.93	18.83
Dispersion index	0.04	0.06	0.09	0.17	0.16	0.24	0.21	0.25	0.18	0.23
Santigi Sand	79.11	78.56	75.59	75.64	77.55	74.33	79.14	77.41	79.23	70.00
Silt	17.05	20.41	13.83	14.20	14.96	12.97	13.26	11.23	12.96	15.74
Clay	3.84	1.03	10.58	10.16	7.49	12.70	7.60	11.36	7.81	14.26
Dispersion index	0.04	0.01	0.12	0.11	0.08	0.15	0.08	0.13	0.08	0.17
Ibadan Sand	81.54	79.45	76.59	75.93	77.55	77.85	76.60	78.15	72.1476.89	
Silt	16.45	16.59	15.99	17.74	15.64	15.37	16.32	14.05	18.29	16.28
Clay	2.01	3.96	7.42	6.33	7.24	6.78	7.08	7.80	9.57	6.83
Dispersion index	0.02	0.04	0.08	0.07	0.08	0.07	0.08	0.08	0.10	0.07
Iwo	Sand	75.14	76.26	66.45	66.83	74.00	72.48	77.83	72.40	75.14
Silt	20.80	21.70	23.40	25.85	19.98	17.00	16.07	17.54	18.23	18.24
Clay	4.06	2.04	10.15	7.32	6.02	10.52	6.10	10.06	6.63	10.85
Dispersion index	0.04	0.02	0.11	0.08	0.06	0.12	0.06	0.11	0.07	0.12
Iju	Sand	72.64	70.72	64.09	64.48	67.45	65.80	66.60	66.43	
Silt	21.39	23.74	18.49	20.01	13.94	15.95	16.32	14.99	18.11	
Clay	5.97	5.54	17.42	15.51	18.61	18.25	17.08	18.58	12.93	
Dispersion index	0.06	0.06	0.21	0.18	0.23	0.22	0.21	0.23	0.15	
15-30										
Alagba Sand	74.77	73.90	74.29	67.24	65.49	65.71	68.28	67.22	68.56	64.04
Silt	21.20	28.37	12.66	12.09	15.49	14.43	15.84	16.90	16.51	14.17
Clay	4.03	7.73	13.05	20.67	19.02	19.86	15.88	15.88	14.93	20.79
Dispersion index	0.04	0.08	0.15	0.26	0.23	0.25	0.19	0.19	0.18	0.26
Santigi Sand	78.94	77.04	75.16	74.27	76.78	76.55	76.65	77.19	74.73	69.14
Silt	17.02	19.90	15.39	17.42	15.73	15.68	16.42	15.38	16.01	22.31
Clay	4.04	3.06	9.45	8.31	7.49	7.77	6.92	7.43	9.26	8.55
Dispersion index	0.04	0.03	0.10	0.09	0.08	0.08	0.07	0.08	0.10	0.09
Ibadan Sand	78.87	79.12	76.08	75.50	77.57	76.93	76.19	72.36	74.36	73.41
Silt	17.99	16.93	15.58	15.46	14.89	16.15	16.73	15.82	17.21	13.38
Clay	3.14	3.94	8.34	9.04	7.54	6.92	7.08	11.82	8.43	13.21
Dispersion index	0.03	0.04	0.09	0.10	0.08	0.07	0.08	0.13	0.09	0.15
Iwo	Sand	70.87	74.29	66.06	66.05	70.80	68.21	70.60	70.09	71.20
Silt	24.06	18.26	16.99	18.06	14.42	16.40	16.07	15.36	15.58	16.75
Clay	5.07	7.45	16.95	15.89	14.78	15.38	13.33	14.55	13.22	13.97

* M.S (mechanical stirring); O.S. (overnight shaking)

Table 1. Particle size distribution of soil types according to depth (%) contd.

15-30	Water M.S	5% calgon O.S	0.2N NaOH M.S	0.4N NaOH O.S	0.6N NaOH M.S	Water O.S	5% calgon M.S	0.2N NaOH O.S	0.4N NaOH M.S	0.6N NaOH O.S
Dispersion index	0.05	0.08	0.20	0.19	0.17	0.18	0.15	0.17	0.15	0.16
Iju	Sand	67.35	67.60	63.52	64.70	62.52	64.06	63.74	64.50	66.07
Silt	24.94	24.78	13.28	13.52	16.13	16.52	16.23	16.12	15.62	16.27
Clay	7.71	7.62	23.20	21.78	21.35	19.42	20.03	19.38	18.31	18.65
Dispersion index	0.08	0.08	0.30	0.28	0.27	0.24	0.25	0.24	0.22	0.23
30 – 45cm										
Alagba Sand	69.64	72.65	56.04	56.97	58.76	59.21	57.62	66.63	56.63	65.59
Silt	27.17	25.31	11.03	15.29	11.23	14.91	11.23	14.63	13.69	19.79
Clay	3.19	2.04	32.93	27.74	30.01	25.88	31.15	18.74	29.68	14.62
Dispersion index	0.03	0.02	0.49	0.38	0.43	0.35	0.45	0.23	0.42	0.17
Santigi Sand	76.60	78.87	72.82	76.10	76.78	77.19	75.90	78.05	74.89	72.90
Silt	19.32	18.05	15.41	15.59	15.78	15.99	15.55	16.11	15.40	17.16
Clay	4.08	3.08	11.77	8.31	7.44	6.82	8.55	5.84	9.26	9.94
Dispersion index	0.04	0.03	0.13	0.09	0.08	0.07	0.09	0.06	0.10	0.08
Ibadan Sand	79.94	80.56	75.31	75.14	75.27	76.07	76.09	74.03	71.78	
Silt	14.91	13.42	15.42	17.43	19.65	16.58	15.65	17.63	19.01	
Clay	5.15	6.02	9.27	7.43	5.08	7.35	8.26	8.34	9.21	
Dispersion index	0.05	0.06	0.10	0.08	0.05	0.08	0.09	0.09	0.09	
Iwo	Sand	68.34	65.97	64.73	62.68	68.28	65.79	65.07	65.69	64.98
Silt	28.29	28.21	24.43	28.04	24.07	26.60	28.02	28.29	27.24	28.24
Clay	3.37	5.82	10.84	9.28	5.15	7.61	6.91	6.02	7.78	5.79
Dispersion index	0.03	0.06	0.12	0.10	0.05	0.08	0.07	0.06	0.08	0.06
Iju	Sand	67.34	66.26	52.35	52.56	56.74	57.39	56.55	56.68	57.01
Silt	26.82	28.73	10.68	11.39	10.25	10.44	11.82	10.03	10.11	12.39
Clay	5.84	5.01	36.97	36.05	33.01	32.17	31.63	33.29	32.88	35.03
Dispersion index	0.06	0.05	0.59	0.58	0.49	0.47	0.46	0.50	0.49	0.54

* M.S (mechanical stirring); O.S. (overnight shaking)

This may be due to the fact that in surface soils, organic matter acts as cementing agents, which tend to impede rapid dispersion. In most soils, secondary soil particles, or aggregates, are formed by the union of primary particles into units of varying stability. These aggregates may be held together rather loosely, or they may be resistant to dispersion because of cementing agents like organic matter, colloidal clay, and the dehydrated colloidal oxides of iron alumna (Hinds and Lowe, 1980). A longer period of agitation, especially at moderate speed, would therefore enhance the separation of surface soils into the natural separate soil fractions. At 30 – 45cm however, high speed mechanical stirring led to greater dispersion. This may be explained by the fact that in subsoils, soil aggregation is mainly due to clay content, which is peculiar to soil type. Therefore, subsurface soils are dispersed faster than surface soils because of lower organic matter content. This implies that high speed stirring may be more appropriate at increasing soil depth.

*Soil depth * Dispersion agent*

There was a markedly inferior performance of water when compared with that of calgon and sodium hydroxide (Table4). This is because in soils, cementing agents, which possess both positive and negative charges, hold particles. They are thus attracted to each other and act as a bridge between soil particles to hold them together. This bridge is not easily broken by water, and because a small cluster of many particles grouped together will behave in the same way as a large particle, higher percentages of sand may be recorded when water is used as a dispersion agent. The main component responsible for dispersion in soils is Na+ (Baver *et al.*, 1972). It strongly attaches itself to the negatively charged clays and organic matter, thus effectively breaking the bonds they create, causing the soil to be separated into its different fractions. Therefore, both calgon and NaOH, both containing Na, are more effective than water in soil dispersion, even in sandy soils.

Table 2. Some chemical properties of soils used in the study

	Depth	Location				
		Alagba	Santigi	Ibadan	Iwo	Iju
pH ($CaCl_2$)	0-15	6.0	6.2	6.2	6.0	5.7
	15-30	5.8	6.0	5.9	5.8	5.0
	30-45	5.7	6.0	5.8	5.6	4.9
Available P (ug / g)	0-15	18.56	18.01	8.68	21.04	23.84
	15-30	16.34	17.85	6.55	14.15	11.91
	30-45	17.09	17.89	5.78	13.39	11.48
% Organic matter	0-15	2.61	2.03	1.85	3.24	3.72
Exch.cations (meq/100g)						
Ca	0-15	0-15	2.73	1.62	1.89	3.85
Mg		"	1.60	0.88	1.07	2.84
K		"	0.13	0.12	0.09	0.25
Na		"	0.22	0.17	0.12	0.33

Table 3. Effect of soil depth and agitation method on soil dispersion index (A*B interaction)

Soil depth(cm)	Agitation method	
	Mechanical stirring	Overnight shaking
0 – 15	0.122 e	0.152 d
15 – 30	0.159 cd	0.177 c
30 – 45	0.208 b	0.244 a

LSD = 0.01989 at alpha 0.05

*Means followed by the same letters are not statistically different at P 0.05 level

Table 4. Effect of soil depth and dispersion agent on soil dispersion index(B*C interaction)

Soil depth(cm)	Dispersion agent				
	Water	5% calgon	0.2N NaOH	0.4N NaOH	0.6N NaOH
0 – 15	0.039f	0.122e	0.144de	0.144 de	0.140de
15 – 30	0.055f	0.177c	0.164cd	0.161cd	0.169cd
30 – 45	0.043f	0.266a	0.215b	0.210b	0.211b

LSD = 0.02812 at alpha 0.05

*Means followed by the same letters are not statistically different at P 0.05 level

At 0 – 15cm, dispersion by the three concentrations of NaOH was higher than calgon, (Table4). The difference between the effectiveness of calgon and the different concentrations of NaOH was however not statistically significant. At 15 – 30cm, dispersion by calgon was higher, but was not significantly different from any of the concentrations of NaOH, and again, that by water was least. This may be due to the fact that both calgon and NaOH have the ability to break aggregate bonds due to organic matter, with the added advantage of doing this without dissolving the organic matter, and organic matter increases the stability of the soil suspension after dispersion has been achieved (Emerson, 1971). At 30 – 45cm depth however, dispersion by 5% calgon was distinctively higher than the various concentrations of NaOH. This suggests that 5% calgon may be more effective in the dispersion of sub- surface soils, while NaOH is as effective as calgon in the dispersion of surface soils.

CONCLUSIONS

The study showed that

i Sodium hydroxide is equally effective as the conventional calgon in the dispersion of surface soils, and 0.4 N – 0.6N NaOH is recommended for use in particle size analysis of soils ranging from 0 – 15, and 15 - 30cm depth, as a possible alternative to calgon

ii. 5% calgon is significantly more effective as a dispersion agent at 30 – 45cm depth

iii. overnight shaking was more effective in the dispersion of soils at 0 – 15cm and 15 –30cm depth, therefore a longer period of agitation is required in the effective dispersion of surface soils

iv. dispersion in water is not complete, therefore, it can only serve as a general guide to indicate soil texture, not an accurate analysis

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