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Particle size distribution by Bouyoucos in slightly alkaline soils from department of Cordoba, Colombia

Distribución del tamaño de partícula por Bouyoucos en suelos ligeramente alcalinos del departamento de Córdoba, Colombia

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Abstract

The aim of this study was to evaluate the Bouyoucos method, at different stirring times and using two chemical dispersants, for particle size determination and distribution in slightly alkaline soils of Córdoba, Colombia. Eight soils were mechanically dispersed applying a slow stirring; 60 rpm with five stirring times as follows: 2, 4, 6, 10 and 16 hours and a control experiment at 0 h. Chemical dispersion of samples was performed using two dispersants: Calgon (0.058 molL^{-1} $(NaPO_3)_6$ + 0.075 molL^{-1} Na_2CO_3) and a mixture of Calgon and 0.1 molL^{-1} $Na_4P_2O_7$ at pH 9.1, which was proposed by authors. In addition, particle size distribution was determined by Pipette method, which was used as reference method. Tests of means and regression models were performed for sand, silt and clay contents using SAS statistical software. According to the results, significant differences were not found between 10 and 16 h of stirring, therefore maximum state of dispersion had achieved at stirring time of 10 h. Content of sand fraction showed an exponential decreasing which can be described following model given by , with determination coefficients higher than 0.90. Clay fraction showed exponentially increasing behavior of first order given by with determination coefficients greater than 90%. Soil textural classification was performed by Bouyoucos method using the proposed dispersant at 10 h of stirring was 75% similar to that determined by Pipette method whereas for Calgon, was 62.5%.

Keywords: Stirring, clay, sand, chemical dispersants, silt, texture, timing.

Resumen

El objetivo de este estudio fue evaluar el método de Bouyoucos, a diferentes tiempos de agitación utilizando dos dispersantes químicos, para la determinación de la distribución de tamaño de partícula en suelos ligeramente alcalinos de Córdoba, Colombia. Para ello, ocho suelos fueron sometidos a un proceso de dispersión mecánica, que consistió en una agitación lenta, en un equipo tipo Wagner a 60 rpm con cinco tiempos de agitación 2, 4, 6, 10 y 16 horas y un testigo a 0 h. La dispersión química de las muestras se realizó utilizando dos dispersantes; Calgon ($(NaPO_3)_6$ 0.058 M + Na_2CO_3 0.075 M) y una mezcla compuesta de Calgon más pirofosfato ($(NaPO_3)_6$ + Na_2CO_3) + ($Na_4P_2O_7$)) 0.1 M a pH 9,1. Además, a las muestras se les determino la granulometría por el método de pipeta. Las pruebas de medias y modelos de regresión de los contenidos de arena, limo y arcilla fueron analizados usando el software estadístico SAS. De acuerdo a los resultados obtenidos, no se encontró diferencias significativas entre las 10 y 16 h de agitación, por lo tanto 10 h son suficientes para obtener un máximo estado de dispersión. El contenido de la fracción arena presentó un decrecimiento exponencial que siguió el modelo con coeficientes de determinación superiores a 0.90. La fracción de arcilla presentó un comportamiento exponencial creciente de primer orden, con coeficientes de determinación mayores del 90%. La clasificación textural por Bouyoucus con el dispersante propuesto a 10 h de agitación fue 75 % similar al determinado por el método de pipeta, y para el Calgon fue 62.5%.

Palabras clave: agitación, arcilla, arena, dispersantes químicos, limo, textura, tiempo.

Introduction

Soil can be defined as a complex system resulting from geological and topographical interactions and weather factors. These contribute with intrinsic characteristics of the evolutionary process and soil formation. One of the most important soil characteristic is the texture; this is understood as the particle size distribution and is an important aspect associated with soil fertility and hydro-geochemical processes.

De Sousa, De Figueiredo & Beutler (2009), indicated that knowledge of soil particle size distribution is important due to its close relationship with water dynamics, in addition to its important tool used in soil classification. Aparecida, Simões & Andrade (2012), stated that soil texture is based on various combinations of sand, silt and clay, being the particle size distribution of a soil sample defined by relative contents of these fractions.

Corá, Fernandes, Beraldo & Marcelo (2009), concluded that stability and size of soil aggregates increase mainly with concentrations of humic and fulvic acids, as well as with an increasing in oxides and hydroxides of Fe and Al. In addition, availability of polyvalent cations, such as Ca^{2+}, is an important factor as a binding agent, due to a promotion and formation of cationic bridges between soil organic matter and clay (Bronick & Lal, 2005).

Several authors have developed a series of mechanical stirring-based methodologies. Oliveira, Júnior, Vitorino, Ferreira, Sá & Lima (2002), found that slow stirring for 3 h causes a greatest dispersion. De Sousa, De Figueiredo & Beutler (2009), compared different mechanical dispersion methodologies and found that total dispersion of soil samples had achieved using stirring at 50 rpm for 12 hours.

Currently, there are few studies on mechanical stirring of soil samples in Colombia, and in consequence, during textural analysis, some laboratories use stirring times that do not generate an adequate dispersion. This lack of information have allowed an incorrect results directly related with stirring time required to obtain maximum mechanical dispersion.

Chemical dispersion of soil structures are based on an increasing in repulsion among soil particles, which occurs as consequence of negative charges in the suspension, causing a repulsion effect among soil fractions. This repulsive interaction promotes the separation of soil aggregates by a decreasing in bonding forces.

Given these concerns, the aim of this study was to evaluate the Bouyoucos method, at different stirring times and using two chemical dispersants, for determination of particle size distribution in slightly alkaline soils of Córdoba, Colombia.

Material and methods

This research was carried out in Soil and Water Laboratory of the Faculty of Agricultural Sciences, Universidad de Córdoba, Colombia. For this study, eight soil samples from the department of Córdoba were collected, chemically analyzed and mineralogically characterized according to standard protocols established by IGAC (2006).

For chemical characterization of soil samples, following methodologies were performed as follows: pH analysis in a water: soil suspension with 1:1 ratio and quantified using potentiometric method. Interchangeable bases (Na^{+}, K^{+}, Ca^{2+} and Mg^{2+}) were determined by ammonium acetate method (1 $molL^{-1}$ at pH 7.0) and quantified by atomic absorption spectroscopy using a Pelkin Elmer 3110. Soil Organic matter (SOM) was determined by Walkley-Black method; available phosphorous content was analyzed by Bray II method and available sulfur was extracted with 0.008 $molL^{-1}$ calcium monophosphate solution and quantified by molecular absorption spectroscopy using a Perkin Elmer Lambda XLS+ at a wavelength of 420 nm (IGAC, 2006).

In order to obtain particle size fractions, 60 g of each soil sample was dried, ground and sieved by a 2 mm sieve. Subsequently, 10 mL of chemical dispersant and 400 mL of water were added to pre-treated samples previously deposited in a glass beaker. Dispersants used were sodium Calgon (0.058 $molL^{-1}$ $(NaPO_3)_6$ + 0.075 $molL^{-1}$ Na_2CO_3) and a mixture proposed by authors (a mixture of Calgon and 0.1 $molL^{-1}$ $Na_4P_2O_7$ at pH 9.1). $Na_4P_2O_7$ is used as buffer agent, an emulsifier, a dispersing agent, and a thickening agent, in addition, is friendly environmentally and non-toxic substance.

For mechanical dispersion by slow stirring, soil: dispersant mixture was deposited in a plastic container of 600 mL and have allowed to stand during 24 hours. Subsequently, each of treatment was subjected to mechanical stirring on a Wagner type stirrer at 60 rpm at different times of 2, 4, 6, 10 and 16 hours and a 0 h control.

For quantification of particle size fractions, mixtures contained in plastic container were deposited in glass cylinders within a hydrometer with a capacity of 1000 mL; therefore, volume was completed by distilled water addition. These suspensions were shaken manually and reading was recorded at 40 seconds and at 2 hours. Determination of particle size fractions for each treatment was carried out by Bouyoucos method (IGAC 2006), for all stirring times in triplicate. In addition, soil subsamples were sent to IGAC with the aim to determine clay, silt and sand contents according to Pipette method. Data were analyzed using SAS statistical software to compare the mean values of treatments and regression models to sand, silt and clay contents to identify significant difference among treatments and statistical significance for all comparisons was made at $p<0.05$.

Results

Average pH values for soil samples was 7.0, and in consequence, these soils can be classified as slightly alkaline. In addition, soils showed contents of soil organic matter lower than 2%. Average values of Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} were 33.7, 9.4, 0.3 and 0.5 cmolkg^{-1}, respectively. Low contents of Cu^{2+}, Fe^{2+}, Mn^{2+} and Zn^{2+} were found.

Table 1. Chemical characterization of slightly alkaline soil samples collected from Córdoba, Colombia.

Soils	pH	MO	S	P	Ca	Mg	K	Na	CICE	Cu	Fe	Zn	Mn	B
	01:01	%	- mgkg^{-1} -		------------------ cmol+kg $^{-1}$ ----------------						--------- mg kg^{-1} -----------			
1	7.52	0.51	20.5	7.2	18.4	6.8	0.22	0.23	40.4	1.8	40.4	1.6	48	0.14
2	8.11	0.17	8.4	44.4	46.5	1.7	0.14	0.15	0.6	0.2	0.6	0.1	12.4	0.6
3	7.81	2.23	7	16.6	36	2.6	0.29	0.13	1.5	0.2	1.5	0.1	8	0.08
4	7.74	2.73	15.5	9.4	47.5	7.2	0.41	0.98	3	0.2	3	1	8.8	0.31
5	7.35	0.17	13	44.2	19	15	0.14	1.17	16.4	5	16.4	1.3	32.4	0.16
6	8.08	1.03	7	87.1	37	7.5	0.49	0.33	0.7	0.2	0.7	0.3	18.8	0.08
7	8.21	0.34	7	55.9	38.5	10	0.2	0.28	10.4	0.4	10.4	0.4	14.8	0.16
8	7.39	1.21	7.3	3.2	26.5	24.1	0.25	0.83	2.6	0.3	2.6	0.6	2.2	0.16
Minimum	7.35	0.17	7	3.2	18.4	1.7	0.14	0.13	0.6	0.2	0.6	0.1	2.2	0.08
Maximum	8.21	2.73	320.5	87.1	47.5	24.1	0.49	1.17	40.4	5	40.4	1.6	48	0.6
mean	7.78	1.05	48.21	33.50	33.68	9.36	0.27	0.51	9.45	1.04	9.45	0.68	18.18	0.21
Deviation	0.34	0.97	110.07	29.48	11.31	7.26	0.13	0.41	13.70	1.69	13.70	0.57	15.04	0.17

These conditions are due to alkalinity of these soils where insolubilization occurs as a result of insoluble compounds formation.

As can be seen in Figure 1a, at 60 rpm, the "apparent" sand content decreased as mechanical stirring time was increased. For this fraction, using Calgon as dispersant, the average apparent sand contents for the eight soils were 56.65, 29.86 and 24.09 for stirring times of 0, 6 and 16 hours, respectively.

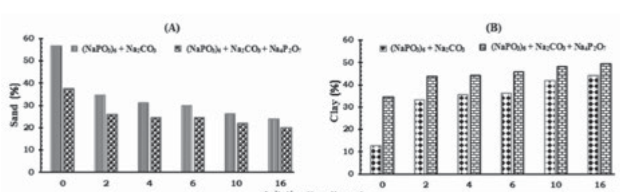

Figure 1. Comparison of sand and clay contents in function of stirring time at 60 rpm and two dispersant solutions.

Apparent clay contents obtained with different stirring times are shown in Figure 1b, it can be seen a progressive increasing in clay percentages, at the same time that stirring times increased. It is important to emphasize that using the proposed dispersant, a higher clay content was found at the zero stirring time with 34.66% whereas, for Calgon, clay content was 12.88%.

In addition, after stirring process, clay contents at 10 and 16 hours were quite similar for both dispersants, 41.87 and 44.13% for Calgon and 48.05 and 49.38% for proposed mixture, respectively; this corresponds to an increasing in 2.26 and 1.33% after 6 h. When sand and clay contents are compared with an increasing in stirring times, it was observed that the greatest difference between the percentages of these fractions occurs after 2 hours (Figure 1b).

Results evidence the importance of mechanical dispersion in analysis of particle size distribution; since treatment of 0 hours showed highest sand contents and lowest clay content when two chemical dispersion methods were used. On the other hand, in relation with dispersants solutions, Figures 1a and 1b show that, independently of stirring time, dispersant solution with $Na_4P_2O_7$ had achieved a higher dispersion capacity in comparison with Calgon dispersing solution.

By application of Tukey test, is evidenced a significant difference of 5% among stirring times during sand, clay and silt fractions quantification with the use of dispersant solutions. However, no significant difference between 10 and 16 h of stirring was not evidenced. The above mentioned, indicates the contents of soil textural fractions are the same for these times (Table 2).

Table 2. Tests of means for sand, silt and clay contents at different stirring times.

	$(NaPO_3)_6 + Na_2CO_3 + Na_4P_2O_7$			$(NaPO_3)_6 + Na_2CO_3$		
Time	Sand	Clay	Silt	Sand	Clay	Silt
Hours	%					
0	37.58 a	34.66 c	27.74 b	56.65 a	12.88 d	30.46 b
2	25.81 b	43.95 b	30.22 ba	34.57 b	33.12 c	32.30 ba
4	24.50 cb	44.16 b	29.66 ba	31.23 c	35.48 b	33.27 ba
6	24.58 cb	45.83 b	31.25 a	29.86 c	36.25 b	33.88 a
10	21.93 d	48.05 a	30.01 a	26.37 d	41.87 a	31.75 ba
16	20.00 d	49.38 a	30.61 a	24.09 d	44.13 a	31.76 ba

Similar letters in vertical form mean that data no vary statistically by means test (p = 0.05).

According to data analysis by means of adjusted equations, the regression model satisfactorily describes the tendency in decreasing of sand fraction, when mechanical stirring time increased for two dispersant solutions. Results obtained from model have allowed obtaining a decreasing in sand percentage from 0 to 16 h (i.e., 56.65% without agitation to 24.09% at 16 hours of agitation, for Calgon and 37.58 and 20% for proposed mixture, respectively).

The best model obtained for clay content increasing was . These results were a consequence of stirring time and dispersants used since these were the analyzed parameters in this study. An increasing in clay percentage varied between 12.88% for treatment without stirring and 44.13% in 16 h of stirring with Calgon dispersant, whereas in the proposed mixture these results ranged between 34.66 and 49.38% for the same times (Figure 2).

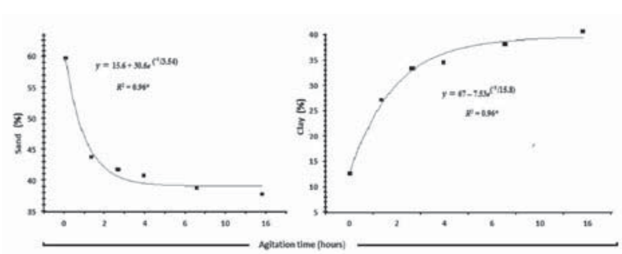

Figure 3. Curves and mathematical models that describe the trends of sand and clay fractions as a function of increasing in stirring time.

Mathematical models obtained in sand fraction for each soil are shown in Table 3. Significant determination coefficients were calculated (P <0.05 and 0.01) and ranged from 0.94 to 0.99 for the Calgon and from 0.90 to 0.97 for the proposed dispersant solution.

Table 3. Mathematical models for sand and clay fractions quantification by increasing in stirring time.

Soils	Model	R^2	Model	R^2
	$(NaPO_3)_6 + Na_2CO_3$		$(NaPO_3)_6 + Na_2CO_3 + Na_4P_2O_7$	
	Sand			
1	$y = 5.0+12.9e^{(-x/0,32)}$	0.98**	$y = 4.0+6.14e^{(-x/6,14)}$	0.97**
2	$y = 32.2+24.3e^{(-x/3,91)}$	0.99**	$y = 26+17.7e^{(-x/4,41)}$	0.92*
3	$y = 21.7+49.0e^{(-x/1,91)}$	0.99**	$y = 17+11.4e^{(-x/4,0)}$	0.97**
4	$y = 17.8+31.7e^{(-x/4,17)}$	0.97**	$y = 13+20.4e^{(-x/3,45)}$	0.98**
5	$y = 44.2+17.5e^{(-x/4,6)}$	0.97**	$y = 39+16.8e^{(-x/5,76)}$	0.95*
6	$y = 37.2+27.2e^{(-x/3,69)}$	0.94*	$y = 32+12.8e^{(-x/5,71)}$	0.90*
7	$y = 25+23.2e^{(-x/3,42)}$	0.98**	$y = 19+7.21e^{(-x/4,74)}$	0.93*
8	$y = 15.6+30.6e^{(-x/3,54)}$	0.96**	$y = 10+16.2e^{(-x/4,54)}$	0.92*
	Clay			
1	$y = 48-14.5e^{(-x/14,8)}$	0.75*	$y = 54-4.54e^{(-x/19,1)}$	0.61*
2	$y = 28-13.1e^{(-x/46,6)}$	0.87*	$y = 34-6.01e^{(-x/14,8)}$	0.82*
3	$y = 57-24.9e^{(-x/23,1)}$	0.98**	$y = 62-7.75e^{(-x/16,4)}$	0.96**
4	$y = 61-29e^{(-x/26,7)}$	0.98**	$y = 67-7.53e^{(-x/15,8)}$	0.97**
5	$y = 18-7.31e^{(-x/22,6)}$	0.97**	$y = 21-3.32e^{(-x/17,7)}$	0.78*
6	$y = 34-13e^{(-x/18,2)}$	0.97**	$y = 39-9.94e^{(-x/21,7)}$	0.97**
7	$y = 48-13.9e^{(-x/18,7)}$	0.96**	$y = 55-7.56e^{(-x/23,9)}$	0.88*
8	$y = 60-22.7e^{(-x/23,7)}$	0.96**	$y = 64-9.20e^{(-x/20,3)}$	0.93*

On the other hand, for clay fraction, the best model obtained was described by a first-order exponential increase (P <0.05 and 0.01). When Calgon was used as dispersant, determination coefficients between 0.93 and 0.98 (P <0.05 and 0.01) were determined for most soils. Only model for soil 1 did not present a good fit, with quadratic correlation coefficient of 0.75 and 0.61 for two dispersant solutions.

In Table 4, can be seen that when clay, sand and silt contents measured in function of stirring time are used for determination of textural classification by Bouyoucos. For a stirring time of 10 h, dispersant based on $(NaPO_3)_6 + Na_2CO_3 + Na_4P_2O_7$ was similar in 75% to that determined by Pipette method whereas when $(NaPO_3)_6 + Na_2CO_3$ was used as dispersant, similarity obtained was only 62.5%.

Table 4. Textural classifications obtained at different stirring times by Bouyoucos and Pipette method.

	- $((NaPO_3)_6 + Na_2CO_3)+Na_4P_2O_7$ --				--------- $((NaPO_3)_6 + Na_2CO_3)$ -------				-------------- Pipette --------------			
Soils	**Sand**	**Clay**	**Silt**	**Texture**	**Sand**	**Clay**	**Silt**	**Texture**	**Sand**	**Clay**	**Silt**	**Texture**
					stirring for 6 hours							
1	8	47	45	Silty clay	9	24	67	Silt loam	2	46	51	Silty Clay
2	32	26	42	Loam	37	23	40	Loam	18	35	47	Silty clay loam
3	20	57	24	Clay	25	51	24	Clay	7	72	21	Clay
4	18	62	20	Clay	24	56	20	Clay	18	57	25	Clay
5	45	17	38	Loam	48	16	36	Loam	24	17	59	Silty loam
6	36	35	29	Clay loam	44	27	30	Clay loam	21	42	37	Clay
7	22	50	28	Clay	29	41	30	Clay	18	50	33	Clay
8	20	59	20	Clay	23	53	24	Clay	15	61	24	Clay
					stirring for 10 hours							
1	7	53	41	Silty clay	7	39	54	Silty clay loam	2	46	51	Silty clay
2	28	33	39	Clay loam	35	27	38	Clay loam	18	47	35	Clay loam
3	18	61	21	Clay	21	55	24	Clay	7	72	21	Clay
4	14	66	21	Clay	24	56	20	Clay	18	57	25	Clay
5	43	19	38	Loam	47	17	37	Loam	24	17	59	Silty loam
6	35	38	28	Clay loam	39	33	28	Clay loam	21	42	37	Clay
7	26	53	21	Clay	26	46	28	Clay	18	50	33	Clay
8	12	62	27	Clay	16	58	26	Clay	15	61	24	Clay
					stirring for 16 hours							
1	4	54	42	Silty clay	6	48	47	Silty clay	2	46	51	Silty clay
2	26	34	40	Clay loam	32	28	40	Clay loam	18	47	35	Clay loam
3	17	62	21	Clay	21	57	22	Clay	7	72	21	Clay
4	13	67	20	Clay	18	61	21	Clay	18	57	25	Clay
5	39	21	40	Loam	39	18	43	Loam	24	17	59	Silty loam
6	32	39	30	Clay loam	37	34	29	Clay loam	21	42	37	Clay
7	19	55	26	Clay	25	48	27	Clay	18	50	33	Clay
8	10	64	26	Clay	16	60	24	Clay	15	61	24	Clay

Discussion

pH condition determines that soil is slightly alkaline; in addition, composition of parent material and forming processes that gave rise to this type of soil explain the high content of exchangeable bases such as calcium, magnesium and potassium. 2:1 clays, which predominate with high calcium and carbonate contents generating high amounts of hydroxyl ions (OH^-), and in consequence, solution shows an alkaline pH.

Zhang, Li, Li & Harris (2014), indicated that, in soils with these chemical conditions, calcium and $CaCO_3$ contents are high. Kishchuk (2000), indicated that high pH of soil and the presence of $CaCO_3$, affect the availability and balance of several essential nutrients as phosphorus, boron, iron, manganese and zinc. Mauri, Ruiz, Alves, Ker & Martins (2011), showed that in calcareous soils prevails permanent loads that make difficult the stabilization of suspension.

In relation with soil aggregates disaggregation, in soils with high calcium concentration, independently of chemical dispersant used, mechanical stirring was capable to produce separation of granulometry fractions. According to Tormena, Roloff & Sá (1998), an increasing in calcium content can give as a result a greater stability of aggregates, making it difficult to break until the primary particles. In previous studies carried out by Tavares-Filho and Magalhães (2008), a greater efficiency is found with slow stirring when total soil samples dispersion is associated to high content of soil organic matter.

Corá, Fernandes, Beraldo & Marcelo (2009), indicated that results of particle size distributions analysis are apparently conditioned by characteristics of the dispersing medium, which are influenced by physical aspects such as size, velocity and mass derived from rotation.

Data obtained from our experiments evidenced that mechanical stirring at 60 rpm is effective to have achieved a decreasing in sand content and an increasing in clay. This occurs, as consequence of increasing in kinetic energy of system, which is sufficient to overcome the binding forces of soil aggregates, thus, is possible to separate the stuck fine particles from coarse particles. After 2 hours, the results indicate that there is an increasing in fine particle contents; however, Silva, Braga de

Lacerda & Senna de Oliveira (2009), established that 6 hours of mechanical dispersion at low revolutions per minute were sufficient for a complete dispersion of soil samples.

The intrinsic characteristics of proposed mixture at pH 9.1 in the suspension and high Na content were found to be sufficient to have achieve an efficient dispersion. However, Donagemma, Ruiz, Fontes, Ker & Schaefer (2003), concluded that clay particulates are not always completely separated by chemical dispersants and by mechanical dispersion, and therefore, an overestimation of silt content in soil analysis is produced.

In this study, is demonstrated that joint action of chemical and mechanical dispersion methods was necessary to obtain a total dispersion state. In absence of the mechanical dispersion process, soil particulates are not subjected to friction among them and against the walls of container containing them. However, with a continuous collision of soil particles had achieved at 360° rotation at 60 rpm for 10 hours, which is sufficient to obtain a full dispersion of soil samples.

Results of this study do not coincide with those reported by Silva, Tormena, Fidalski & Imhoff (2008), who indicated that six hours of slow stirring are sufficient to produce a complete dispersion of soil samples, but there may be particles of clays added to silt and sand particles. Furthermore, Silva, Braga de Lacerda & Senna de Oliveira (2009), found significant differences between fast and horizontal stirring at 6, 12 and 18 hours for silt and clay. In the same way, dispersants used had achieved a greater dispersion of fine particles by Na action.

A decreasing in sand content produced by an increasing in stirring time and dispersant solutions can be easily understood, as result of combined factors. Among them, an increasing in contact time between soil particles and dispersant molecules enhances the action of dispersant, promoting that equilibrium time for dispersion process can be achieved (at equilibrium time the disintegration of soil aggregates is finished and a significant effect of time is not evidenced).

Note that, mathematical models suggest that an equilibrium state is achieved as stirring time. Thus, mathematical equations constituted by two additive terms are congruent with physical interpretation that soil aggregates are destroyed until a limit values associated with sand fractions.

Vitorino, Ferreira, Curi, Lima & Montezano (2007), suggested that particle size distribution analysis of soils requires sufficient energy to break the binding forces of soil aggregates and humic substances, which must be fragmented through mechanical shock. In addition, mechanical dispersion during prolonged stirring times have allowed to reduce the effect of flocculation produced by cementant substances, which occur in these soils with high carbonate concentration. Alternatively, Imbellone & Mormeneo (2011), studied the texture of hydromorphic vertisols soils with high calcium content and high pH; they found that there is inaccuracy in the quantification of subfractions size by the presence of pseudoparticles in coarse fractions producing an error in relative proportions of sand, silt and clay particles.

An increasing in clay content can be explained by the model , which is achieved by disintegration and dispersion of soil aggregates. This is the result of subjected soil aggregates for 10 and 16 hours of stirring at 60 rpm. In soil aggregates, fractions that are strongly flocculated are subjected to a longer contact time, which causes disintegration; due to an increasing in kinetic energy resulting from collision between sand, silt and clay particles. According to Tavares Filho and Magalhães (2008), total soil dispersion coincides with total destruction of soil aggregates.

It was found that proposed mixture Calgon + $Na_4P_2O_7$, has a greater separation capability of soil aggregates evidencing a greater amount of clay. Dispersant effect of this chemical agent is due to high sodium concentration and pH which have allowed an increasing in diffusive double layer expansion, which have allowed an increasing in soil fraction dispersion. Spera, Denardin, Varella, Pereira dos Santos & Figueroa (2008), found that thickness of diffuse double layer could altered by concentration and type of electrolytes, mainly by ions such as Na+ and K^+. In addition, cations with a low degree of hydration such as Na+ increase interparticle distance; thus short-range attractive forces do not manifest themselves and system is dispersed. In previous studies, Borja, Mercado & Combatt (2015), found that increasing in pH level in solution favored the dispersion of the granulometric fractions, which results in an increasing in clay content. Finally, Do Nascimento, da Silva, da Silva, dos Santos, Santos, de Souza, … & de Jesus (2014), show that addition of chemical dispersant and immediate mechanical stirring present advantages in relation to traditional methods in dispersion of soils for particle size distribution analysis.

Conclusion

Calgon + $Na_4P_2O_7$ is a better chemical dispersant for particle size distribution analysis in slightly alkaline soils in comparison with Calgon $(NaPO_3)_6$. In addition, it was established that mechanical dispersion of soil aggregates takes 10 hours at

60 rpm, from this time, statistically significant differences in percentages of fractions were not found. This provides more accurate and reliable estimates of clay, sand and silt contents at 10 and 16 hours of stirring, using Calgon + $Na_4P_2O_7$ as chemical dispersant and Bouyoucos method, which are similar in 75% to that determined by Pipette method, whereas Calgon only was 62.5%.

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