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THE PRESENT POSITION OF THE MECHANICAL ANALYSIS OF SOILS.

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Introduction. The process of mechanical analysis was developed to give more precision to terms such as sand, loam and clay that are employed by a pratical man in describing soils. Its function is to sort out by appropriate means the particles composing a soil into groups of specified limits of diameter. The methods of mechanical soil analysis in their various forms are, undoubtedly, among the more tedious operations, with which soil scientists are confronted. The importance of a determination of this kind lies in the fact that the behaviour of the soil towards water, its power of retaining and handing over the rainfall to the plant and also its physical texture and amenability to cultivation—factors which are of greater importance in the nutrition of the crop than the amount of plant food present—are all determined by the sizes of the particles of which the soil is composed. This fundamental fact has long been recognised and has led to a tremendous amount of work on the part of various investigators, in an effort to devise methods for making mechanical analyses of soils and determining the proportions of particles of various sizes.

The older methods. The old standard methods for this purpose may be divided into two groups; in one, the separation is effected by a stream of running water, the velocity of which is increased to carry over successively coarser particles, and in the other by leaving the turbid mixture of soil and water to settle for given periods of time, the longer the time interval, the finer being the group of particles remaining suspended. The former, known as the elutriation method was made quantitative by Schone (1867) and as modified by Meyer (1882) was for long in general use in Germany. The apparatus was further improved and the whole method reduced to an accurate form by Hilgard (1873, 1893) to whom we are indebted for a considerable elucidation of the whole subject. The second or the sedimentation method, depending on sedimentation for a given time, was elaborated by Woff, (1875) critically discussed by Osborne (1886, 1887) and introduced into Great Britain by Hall (1904, 1906) after further examination and modification. The principal disadvantage in practice of these two methods is the repeated pouring off, especially necessary in the heavy clay soils, the large volume of water needed and the great number of beakers to be used. Although in the older United States Bureau of Soils method (1904), time is saved by using a centrifuge, the cost of the apparatus and the absence of necessary electrical facilities have precluded its general adoption in routine laboratories.

The Concept of Size Distribution Curves. In addition, the methods of elutriation and sedimentation are "fundamentally defective in that the grouping of particles of various sizes is quite arbitrary, sharp lines being drawn where none exists in nature, and the soil is represented as a mixture of 5 or 6 different substances when in point of fact, the number of components is indefinitely large. In order to avoid an arbitrary grouping of the soil particles and to facilitate the transition from one system to another, Oden (1915) introduced the *Maxwellian* conception of the *distribution* according to size, i. e., to obtain a characteristic curve by plotting as abcissae some quantity related to size against some quantity related to the amount corresponding to every size; based on this idea of expressing the mechanical analysis as a continuous function of particle size, Oden (1916, 1922, 1925) developed a method in which a pan attached to one arm of a self-recording balance (Coutts, Crowther, Keen and Oden, 1924) is placed near the bottom of a vessel containing the soil suspension and by mathematical analysis of the curve showing the increase of weight with time, a curve—known as the summation or size distribution curve (Robinson, 1924) is constructed showing the distribution of the particles as a function of size. Wiegner (1918) has used the same principle employing a different experimental method in which the change in hydrostatic pressure in a given plane in the sedimenting column is recorded by the motion of the meniscus in a balancing column of water. Crowther (1927) has described a sedimentation apparatus in which a sensitive differential liquid manometer is used to show the amount of material remaining in suspension at a definite depth in the sedimenting column. These methods are not, however, suited for routine use in laboratories where large numbers of soils have to be examined and the technique at present contains a source of error that seriously impairs their use for fundamental research work. This error was first brought to light by Coutts and Crowther (1925), who, during their experiments, with the Oden-Keen balance found that owing to the sediment collecting in the scale pan, the liquid below the scale pan becomes less dense, setting up currents in the neighbourhood which seriously perturb the indications of the instrument. Shaw and Winterer (1927) have independently investigated the inherent error using a wide range of particles, both in texture and chemical composition. Their results confirmed those of Coutts and Crowther. Other sources of experimental error in continuous sedimentation methods of mechanical analysis have been pointed out by Fisher and Oden (1923–24). Optical methods using transmission of a beam of light through a glass cell, as a measure of the sedimentation process taking place within it, the transmitted light being received on a photo-electric cell (Richardson, 1934) would appear to obviate the above sources of error. Such methods however are tedious and not suitable for routine adoption.

The Pipette Method. The development of a greatly improved method of mechnical analysis, depending on the depth—concentration relationship in settling suspensions, and known as the Pipette-sampling method was worked out independently by Robinson (1922) in England, by Jennings, Thomas and Gardner (1922) in America, and by Krauss (1922, 1923) in Germany. The principle of the method is to take at a predetermined depth x, and time t a sample of the suspension by means of a pipette. This sample contains no particle whose velocity of fall exceeds x/t; all particles with less velocity are present in the sample in the same concentration as in the original suspension. The pipette sample is evaporated and weighed. Knowing the capacity of the pipette this weight can be expressed as a concentration whose percentage ratio to the concentration of the original suspension gives at once the percentage weight of particles with velocity less than x/t. The bulk suspension is then thoroughly shaken to obtain a uniform suspension again and another pipette sample is taken corresponding to a different critical velocity. By suitably choosing the depths and times of sampling a number of values are obtained from which the particle-size distribution of the soil could be ascertained.

In the pipette method, there is the implicit assumption that the sample withdrawn by the pipette comes from the infinitely thin horizontal layer of suspension in which the pipette tip stands. This assumption is not of course true and several workers (Puri and Amin, 1928; Kottgen and Heuser, 1929) have suspected errors due to a disturbance of the sedimenting column and have devised (Jennings *et. al*: *loc. cit.*) pipettes with bent tips of several orifices etc. intended to define more closely the region from which the liquid is removed. Kohn (1928) has demonstrated in an important theoretical contribution to the hydrodynamics of sedimentation analysis that such precautions are quite unnecessary. According to him quite insignificant errors are introduced by the fact that a pipette removes liquid from a sphere round its tip and not from the thin horizontal layer postulated in the simple theory of the pipette method. Kottgen and Heuser (1931) dispute Kohn's view (1931) that disturbances due to stream line processes during decantation and pipette sampling have insignificant effects on the composition of the sample withdrawn.

Bouyoucos (1927, 1928) has introduced a method which, like the pipette method, depends on measuring the density of the suspension after a given time. A hydrometer calibrated to read in grams of soil per litre is placed in the suspension and readings are taken after 1 minute and 15 mins. The results show fair agreement with those obtained by the pipette method (1934). Keen (1928) draws attention to a fundamental defect in Bouyoucos' method. The density variation at different depths of the suspension progressively changes with time while the particles are slowly settling and the actual manner in which it changes with time depends on the size distribution of the soil and therefore varies from soil to soil.

Marshall (1930) has developed a new centrifuge method of sedimentation analysis capable of extending the range of size distribution for soil particles from 2 μ, the upper limit conventionally ascribed to clay particles, down to 0·02 μ and has later (Marshall, 1931) extended the method to the mechanical analysis of clays down to 0·05 μ equivalent diameter, and used it to study the dispersion of clays combined with different bases.

British Official and International Methods. In the year 1923, the Agricultural Education Association of England appointed a Sub-Committee to make a systematic examination of the function and significance of mechanical analysis and to ascertain how far quantitative and accurate measurements could be substituted for those earlier determinations which were necessarily evolved on a conventional and empirical basis. The pipette method propounded by Robinson (*loc. cit.*) proved so successful that it was adopted as the Official Method of the A. E. A. (1926). A beginning of international effort towards reviewing the methods of mechanical analyses was made by the International Society of Soil Science in connection with the Soil Congress at Rome in 1924. Their investigations were considered at a special meeting of the First Commission at Rothamsted in October 1926 and the recommendations finally adopted at the International Soil Congress at Washington in 1927. This Official International Method is based on preliminary dispersion by hydrogen peroxide, hydrochloric acid and ammonia with pipette-sampling similar to those adopted by the A. E. A. in 1925, as the Official British Method. Some minor differences remained and the A. E. A. (Keen, 1928; A. E. A., 1928) has subsequently revised its method so as to bring it into line with the International Method. The revised British Method differs from the International Method only in the one unimportant detail that the analyses are to be expressed as percentages of the air-dry soil. They will however include the air-dry moisture content so that recalculations to the International Method can be readily made.

Pretreatment for Mechanical Analysis. Mechanical analysis consists of two distinct series of operations; the soil must be completely dispersed into its constituent particles and these must then be graded into groups or fractions in accordance with their effective size. While it is true that a mechanical analysis based on complete dispersion does not necessarily give so close a picture of the field structure and any associated physical properties as a gentler dispersion method, it has yet the great advantage that it is far less empirical. Mechanical analysis after complete dispersion does define a fundamental and intrinsic soil property, not directly altered by cultivation and manurial treatment, whereas an arbitrary or conventional dispersion such as boiling with water is liable to variation in its results from soil to soil and worker to worker. The International Method is accordingly based on preliminary dispersion by hydrogen peroxide, hydrochloric acid and ammonia with pipette-sampling for determining particle size. The preliminary treatment with dilute acid was first introduced by Schloesing (1874) and later shown (Hall, 1906; Sreenivasan and Subrahmanyan, 1934) as giving a truer picture of the ultimate physical constitution of the soil by removing calcium carbonate and other materials which bind together a considerable quantity of the finest particles into loose aggregates which otherwise resist disintegration. Besides, such a treatment removes certain soluble salts which otherwise generally induce flocculation of the clay particles. The use of hydrogen peroxide in pretreatment has been advocated by Robinson (1922) who showed that oxidation of the soil organic matter prior to dispersion is necessary to overcome its cementing action on the soil particles.

The Newer Methods of Dispersion. Since the decision at Washington to adopt hydrogen peroxide and hydrochloric acid treatment of soils as an essential preliminary stage in the preparation of soil suspensions for mechanical analysis by the pipette method, the following objections have been raised.—1. Hydrogen peroxide is an expensive and troublesome reagent in many countries. 2. Hydrogen peroxide is decomposed so rapidly by catalysis in certain soils (especially if manganese dioxide is present) that it is extremely tedious, if not impossible to reach a definite end-point in the oxidation. 3. The acid treatment results in considerable loss of soil constituents taking place which cannot be answered except by saying that it is inevitable, and when this loss assumes such alarming proportions as 30—40 per cent. as it actually does in certain calcarious soils, it cannot altogether be ignored. 4. The removal of calcium carbonate reduced the value of mechanical analysis in soils with much of this material. Several cases have also been recorded in which the Official International Method gives poor results in certain types of soils. Thus, Joseph and Snow (1929) found that for Sudan soils, decantation methods (Joseph and Martin, 1921) appear essential, hydrogen peroxide unnecessary, acid pre-treatment not essential and sodium carbonate better than ammonia. They raise the question whether other soils with high silt contents may not really be clay soils difficult to disperse. Bodman (1928) found little difference between the acid-hydrogen peroxide method and the former American method of rubbing up with very dilute ammonia, except that in highly organic and calcareous soils higher results for the finer fractions were given by hydrogen peroxide and in hard pans by the ammonia method. Dennett (1928) in Malay found no necessity for hydrogen peroxide in non-organic soils. Similar observations were made by Charlton (1927) and Puri and Amin (*loc. cit.*) for Indian soils. Groves (1928) observed that certain ferruginous soils do not respond to the usual preliminary treatment with hydrogen peroxide and found a method of pre-treatment with ammcnical hydrogen peroxide followed by repeated gentle rubbing with a rubber pestle to give a satisfactory dispersion with such soils. In a useful compilation of methods for physical and chemical analyses of soils, Prescott (1928) states that the disturbance due to gypsum may be avoided by extracting soil with a large volume of dilute hydrochloric acid. The United States Bureau of Chemistry and Soils (Alexander, 1930; Olmstead and Alexander, 1930: Olmstead *et al*, 1930) has developed a modified hydrogen peroxide method in which hydrochloric acid treatment is omitted. In soils containing manganese dioxide, acetic acid is added with the hydrogen peroxide. Sodium oxalate is used as the dispersing agent. Puri (1929) proposes the omission of both hydrogen peroxide and acid since in the soils without much organic matter, good dispersion is secured with a sodium clay prepared by leaching with sodium chloride and then with water and adding enough sodium hydroxide to make the suspension alkaline. The method was found unsatisfactory (Novak, 1932) for basaltic soils and for soils containing high proportion of organic matter.

Recently, Puri (1935) found in the course of his studies on the use of ammonium carbonate as a reagent for determining bases that boiling the soil with ammonium carbonate solution followed by heating with sodium hydroxide solution gave a sodium clay having a maximum dispersion even with humus and ferruginous soils. Troell (1931) and Crowther and Troell (1932) advocate the use of cold solutions of sodium hypobromite in which also neither hydrogen peroxide nor hydrochloric acid is used for pretreatmet The method has been found unsatisfactory for laterite soils (Chakraborty and Sen, 1935); besides the use of large quantities of obnoxious and injurious chemicals like bromine and ammonia make it unfit for inclusion in routine practice. Chakrabarty and Sen (1932) find that a direct sodium hydroxide method in which the soil is shaken directly with sodium hydroxide and adjusted to a pH of 10·5 ensures optimum dispersion in lateritic soils and works very satisfactorily. Recently, the same authors (1935) have developed a new method for the mechanical analysis of lateritic soils using alkaline permanganate to destroy the organic matter and state that the method might prove equally suitable for all types of soils. Robinson and Richardson (1933) have examined a large number of representative soils and showed that with substitution of sodium hydroxide for ammonia as the dispersing agent, the International Method gives satisfactory dispersion.

Difficulties due to gypsum may be avoided by removing coarse gypsum after the peroxide treatment by using more concentrated acid and by washing with 10 per cent. ammonium acetate. Oxidation of organic matter by hydrogen peroxide is still considered necessary. Manganese dioxide interferes with this oxidation, but it may be decomposed by preliminary digestion with water and sodium bisulphite. Certain aluminous soils still present a special difficulty as they are not dispersible in alkaline solutions. They may be dispersed in a slightly acid medium, but the loss on dissolution is then relatively high.

The Present Position. The vast amount of literature that has sprung up in recent years dealing with the Methods of mechanical analysis of soils would show that the International method requires modifications in the case of such soils as peats, heavy alkaline soils, laterites, ferruginous soils and *terra rossa* ; it is yet to be recognised however that there cannot possibly be a single method of mechanical analysis of soils of which the details will be the same for all types of soils. The results of cooperative work on mechanical analysis reported at the Lenningrad Congress (Novak, *loc. cit.*) would only serve to emphasise this point. This constitution of the soil is so complex and the details of the various procedures that have been developed so empirical that the discrepancies between results from different laboratories are perhaps inevitable to some extent. This is particularly so in the preliminary treatment of the soil which is designed to disperse aggregates of soil crumbs into their constituent soil particles. There is no doubt that the use of Hydrogen Peroxide, acid and the prolonged boiling are somewhat drastic and may result in the decomposition of the inorganic colloids. Preliminary oxidation of organic matter would not appear to be necessary in soils containing under 1% of organic carbon. The suitability of directly dispersing such soils in a medium denser than water (such as a very dilute solution of agar in water)—of known reproducible viscosity and specific gravity—in which the rate of settling of the soil particles will be naturally slow—should also be investigated. It has the advantage that it yields soil fractions suitable for further examination.

In view of these conflicting results given by the existing methods, it is not surprising that there have been many proposals to introduce instead of mechanical composition some characteristic quality which could be more easily measured and which had some relation to the composition, *e. g.*, hygroscopicity (Mitscherlich, 1903) or cohesion and plasticity (Atterberg, 1912, 1914, 1916). None of these alternatives has been very successful because the qualities were neither precisely defined nor could they be brought into definite relation to the mechanical composition (Enrenberg, 1914, 1915; Oden, 1921 ; Zunker ; 1922). It cannot be denied that the ultimate solution of many of the problems in soil physics and chemistry must depend upon information which will come with a greater knowledge of the mechanical states and processes of the soil in their microscopic details. The ideal method that would succeed for all types of soils and of soil scientists may still await discovery, but the time is ripe for a more detailed study of the existing methods and for establishing an agreed International Method even though with modifications at times. In correlating soils and studying soil genetics, especially over wide areas, the mechanical analysis needs to be supplemented by chemical analysis or other characterisation of the clay fraction and often by mineralogical examination of the coarser ones. For this work, and in research on the interrelationship between different physical and chemical properties of soils, agreed conventions for the mechanical analyses are essential.

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A NOTE ON THE CULTIVATION OF ELEPHANT YAM (*AMORPHOPHALLUS CAMPANULATUS*) IN CHITTOOR TALUK

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The Chittoor variety of Elephant Yam known as சேனை (*Chenai*) in Tamil and (*Theeyakanda*) in Telugu, has a reputation in the markets of the surrounding districts. The normal area in the taluk is 300 acres, but due to low prices, the area has decreased to 240 acres, in the last season.

The average area grown by a ryot is about ten cents and the maximum area grown by a single individual is about thirty cents. The crop is generally grown pure, though other vegetables like radish, onions, brinjals, *bhendai*, etc. may be found to be grown along the sides of irrigation channels, for sometime during the growth of the crop.

Details of cultivation : — *Soil* :- The crop comes up well in all kinds of soils unless they happen to be alkaline. Red loamy soil is considered to give the best yield. High-level irrigable lands are generally chosen, as the crop cannot withstand water-logging.

Season :— The months of *Chithirai* and *Vaikasi* (April to June) are considered to be the best season for planting the corm, but it can be planted upto the month of *Adi* (July--August). If a good crop has