Particle Size Analysis

Introduction

Particle size is a fundamental property of sedimentary materials that may tell us much about their origins and history. In particular the conditions of transport and deposition of particles are often inferred from their size. The size distribution is also an essential property for assessing the behaviour of granular material under applied forces (*e.g.* fluid, gravitational or aeolian).

Only a sphere has a single characteristic linear dimension. Irregular sedimentary particles possess many properties from which several characteristic dimensions may be obtained. This include a particles projected area, volume, lengths, perimeter, and the size of a hole through which it may pass. These can be determined by sieving, laser diffraction, settling tubes, image analysis and electro-resistance.

It is rare to encounter materials that are well sorted (low standard deviations) and are unimodal – most are polymodal with a wide range of particle sizes, from tens of millimetres down to colloidal (<1μm) clay.

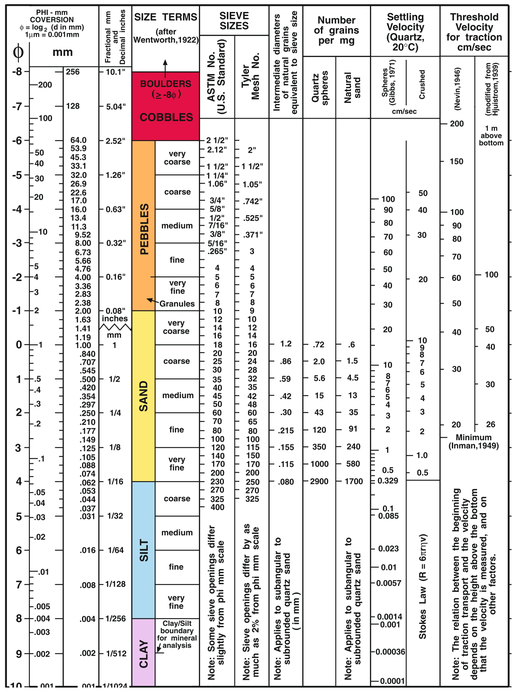


Figure 1 (above): Wentworth grain size chart (reprinted from Williams *et al.* 2006). Courtesy of the U.S.G.S.

Dry & Wet Sieving

Principle: Sieving is commonly used to produce grain size distributions for particles between 64mm-64μm. By passing the sample through a stack of sieves of decreasing aperture, and weighing the contents of each, it is possible to ascertain the proportion each particle size range contributes to the sample.

Method (dry sieving): Stack the sieves for the required size fractions in descending order of size of aperture, placing a receiver on the bottom. Place the (pre-weighed) sample in the top sieve and cover with a lid. Place the stack of sieves on the shaker, set the timer and turn on. When sieving has finished, weigh the contents of each sieve. A large stack of sieves will need to be separated into two smaller stacks for analysis.

Method (wet sieving): Stack the sieves for the required size fractions in descending order of size of aperture, placing a bucket underneath. Empty the sample into the top container and rinse it through the stack, gently agitating with the hose. Empty the contents of the sieves into trays using the hose, and place the trays into an oven to dry the sample. Weigh the contents of the trays individually. A large stack of sieves will need to be separated into smaller stacks for analysis.

Considerations: The larger the sample, the lower the analytical error because weighing errors become proportionately less important as sample size increases. Sieving time will influence results because grains with an size close to the aperture of the sieve must be orientated in a particular way to pass. Care should be taken not to bias samples through unequal sieving time.

Care of test sieves: Sieves should be used with care, cleaned regularly, and stored in a clean, dry place. Particles should not generally be forced through test sieves, although this may be unavoidable for the smaller apertures. Blocked sieves may be inverted and the frame tapped to free particles, or the underside may be gently brushed.

Sieves should be cleaned regularly by soaking in hot water with detergent followed by oven dried at *c.*60˚C and stored. Sieves used for wet sieving should not be allowed to dry before washing and drying.

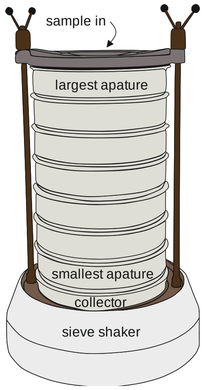


Figure 2 (above): Sieve shaker configuration.

Laser Diffraction

Principle: Particle size distributions of between 0.01um and above can be inferred by the angular distribution of the intensity of forward-scattered coherent light. The scattering by spheres at small angles is nearly equivalent to diffraction by apertures of equal diameter. The sample is passed in suspension through a laser light and the scattering of that light detected by a CCD or photodiode.

Method: A sample is prepared by creating a paste of the sample using a spatula and sodium hexametaphosphate 5%w/w. A number (>12) of small subsamples are taken from throughout the paste and smoothed in a plastic dish using a rubber stick. The entire preparation is then ready to be added to the recirculating flow cell, diluted as required, and tested.

Models: Two models are commonly used for the conversion of observed laser-scattering to particle size. The Fraunhofer Approximation needs no information regarding the sample material. It assumes the particles are spherical and opaque. Mie Theory is more satisfactory for small particles (<*c.*1μm), but requires knowledge of the refractive index of the particulate material which may be unobtainable for heterogeneous samples.

Considerations: Samples with particles >2.5mm should be sieved prior to analyses using the Saturn II Digisizer. The concentration of a sample in the analysis cell may have pronounced effects on the result, and sensitivity testing should be performed on samples before analysis. For flocks or samples that are not readily disaggregated, careful consideration should be given to the flow rate through the cell, as well as the duration and intensity of pre-analysis circulation and ultrasonic treatment. Again, sensitivity testing is necessary for difficult samples. High flow rates can cause problems with flow alignment of elongate particles, causing bimodality in unimodal samples; low flows can cause settling.

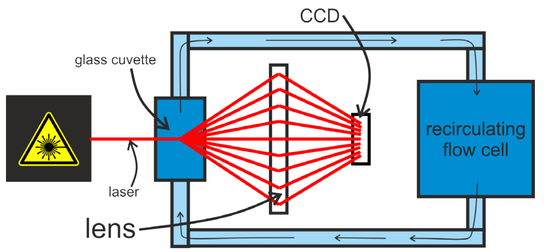
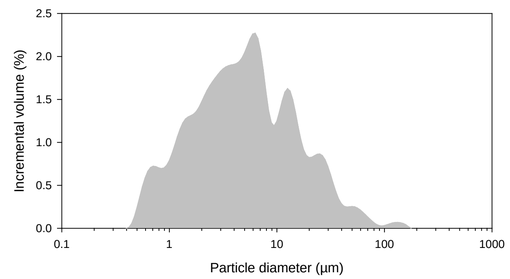


Figure 3 (above): Micromeritics® Saturn II Digisizer analysis apparatus diagram. Showing (L-R): the laser source, flow cell, lens, CCD detector.

Data Presentation

Summary statistics: Grain sizes are often summarised using mean, median and standard deviations. In addition, quartiles or deciles may be presented in the format D_{10}, D_{25}, D_{50} *etc.* The kaolinite for which data is presented in Figures 4 & 5 has a mean of 9.2μm, a median of 4.8μm and one standard deviation is 13.9μm.

Incremental volume & cumulative frequency graphs: These are useful for assessing whether the sample is uni- or polymodal. Sieve data is usually "binned", with the width of the column representing the chosen sieve intervals. Because results obtained by laser diffraction are modelled, the resolution is not shown in this way. Cumulative frequency graphs present the same data but as a cumulative curve – this is useful for quickly extracting summary statistics and comparing samples.



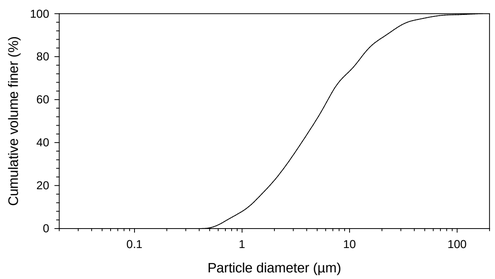


Figure 4 (top). Incremental volume graph of a sample of kaolinite, analysed using laser diffraction.

Figure 5 (bottom): Cumulative frequency graph version of figure 4. Note the log scales on both graphs.

References: **British Standards Institute, 2009.** *BS ISO 13320:2009, Particle size analysis – Laser diffraction methods.* BSI: London. **Syvitski, J. (ed.), 1991.** *Principles, methods and application of particle size analysis.* University Press: Cambridge. **Williams, J. et al., 2006.** *Surficial sediment character of the Louisiana offshore continental shelf region: A GIS Compilation.* USGS report 2006-1195.

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