# Particle Size Distributions

## Abstract

Describes methods of measuring and analyzing the Particle Size Distribution (PSD) in a colloidal suspension or emulsion.

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# 1 Introduction

The particles in a colloidal suspension or emulsion are seldom all of the same size and they often have varying shapes. Describing the size and shape is therefore a significant problem. Emulsion droplets can usually be assumed to be spherical (so long as the distances between the droplets is large enough).

For solid particles we often have to make do with general descriptions of shape like spheroidal, rod- or disk-shaped, even when the system contains individual particles with other shapes.

The particle size may also vary over quite a wide range. It is not unusual for the particles of a suspension produced in a grinding operation, for example, to vary by a factor of 100 from the smallest to the largest size. To describe such situations we normally break the range up into a number of classes and try to find out how many particles are in each size range.

This range is called the particle size distribution (PSD), and it can be represented in the form of a Table or a histogram (see Figure 1).

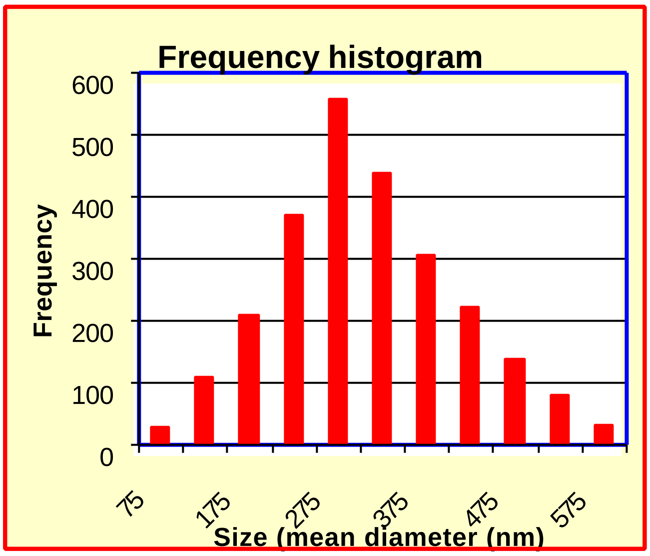


FIGURE 1 A TYPICAL PSD IN THE FORM OF A HISTOGRAM

# 2 Measuring the Particle Size Distribution

A PSD such as shown in Figure 1 could be obtained by counting the particles of different sizes in a microscope (or electron microscope) image. This is, however, a tedious and time consuming procedure and increasingly we seek methods of estimating the PSD by indirect methods.

Such procedures are of two sorts.

- In some cases we separate out the different sizes and then count (or otherwise estimate) how many particles are in each size range.

- In the second procedure, we try to estimate the PSD without first separating out the different size fractions.

The first method is the preferred one when we have plenty of time because it can, in principle, yield the most reliable results. There are, however, many situations in which it is much better to have a reasonable estimate of the PSD, especially if it can be obtained quickly.

The most obvious such situation is in a flowing process stream where the particle size might be a crucial factor in determining the success of a chemical engineering process. Such situations are common in the ceramics industry, in the food processing, cosmetics manufacture and pharmaceutical industries and even in computer chip manufacture.

Scientists and engineers have applied great ingenuity to the development of such particle sizing methods in recent years and there are now a number of ways of obtaining reliable estimates of PSDs in real time. It is important to recognize, however, that such methods will not normally all yield the same results when applied to a particular system.

That does not mean necessarily that one is more accurate than the rest. Indeed, the only time one can expect different methods to yield exactly the same result is when all of the particles are spherical and of the same size. Different methods measure different aspects of the distribution and sometimes, by combining results from two or more methods, one can obtain information that is not otherwise available from the individual methods.

## 3 Plotting the Particle Size Distribution

When the particle size distribution is very broad it is difficult to represent it accurately on the normal scale. It is often advantageous in that case to plot the frequency against the logarithm of the size rather than the size itself. A comparison between the two is shown in Figures 2 and 3.

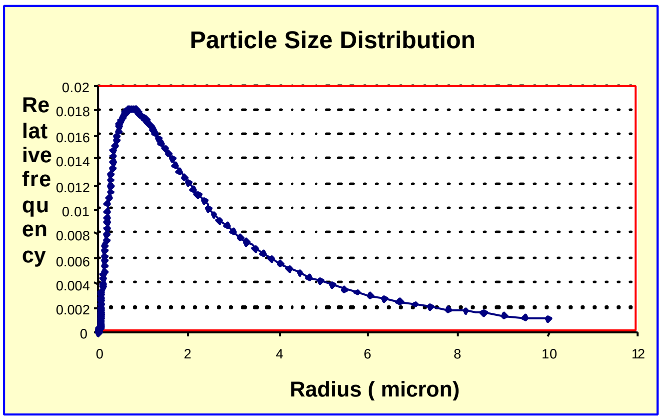


FIGURE 2 A TYPICAL PSD PLOTTED WITH RESPECT TO THE RADIUS (MICRONS)

Notice how asymmetric the plot is in Figure 2 and how the conversion to the log plot (Figure 3) makes for a much more symmetric frequency distribution. The symmetric plot is in this case the normal error curve or the Gaussian distribution function and is the basis of all standard statistical formulae.

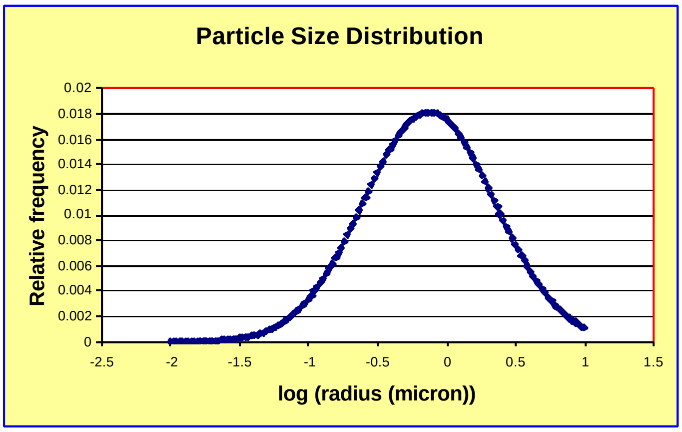


FIGURE 3 THE SAME PSD AS IN FIG 2 PLOTTED WITH RESPECT TO LOG (RADIUS (IN MICRONS))

Figure 3 shows that this particular size distribution is a *log normal distribution*. Since it is so close to the normal distribution curve when plotted in this way, it can be very easily represented. In fact if one specifies the median size (which in this case corresponds to the maximum frequency) and the spread of the distribution, the entire curve is fully specified.

This is the way that most particle size distributions are represented. Almost any real distribution can be approximated in this way, unless it is one that has two or more maxima. Such *multi-modal distributions* are usually thought of as being the sum of two or more normal (or log-normal) distributions.

In some industrial situations it is important to be able to distinguish the presence of a bimodal distribution (where, for example, the presence of a population of larger particles might interfere with the main process). The particle size methods that first separate the different sizes and then measure them are intrinsically better able to detect the presence of a bimodal distribution.

It is, however, sometimes possible to detect such situations, in a rapid real time (on-line) measurement, but only if the peaks in the size distribution are sufficiently separated from one another.