HORIBA Scientific

Technical Note

Number vs. Volume Distribution

TN154

PARTICLE SIZE RESULT INTERPRETATION: NUMBER VS. VOLUME DISTRIBUTIONS

Interpreting the results from a particle size measurement requires understanding which technique was used and the basis of the calculations. Each technique will generate a different result since each measures different physical properties of the sample. Once the physical property is measured, a calculation of some type generates a representation of a particle size distribution. Some techniques report only a central point and spread of the distribution, others provide greater detail across the upper and lower particle size detected. The particle size distribution can be calculated based on several models: most often as a number or volume/mass distribution.

Number vs. Volume Distribution

The easiest way to understand a number distribution is to consider measuring particles using a microscope. The observer assigns a size value to each particle inspected. This approach builds a number distribution – each particle has equal weighting once the final distribution is calculated. As an example, consider the nine particles shown in Figure 1. Three particles are 1 µm, three are 2 µm, and three are 3 µm in size (diameter). Building a number distribution for these particles will generate the results shown in Figure 2, where each particle size accounts for one third of the total. If this same result were converted to a volume distribution, the result would appear as shown in Figure 3 where 75% of the total volume comes from the 3 µm particles, and less than 3% comes from the 1 µm particles.

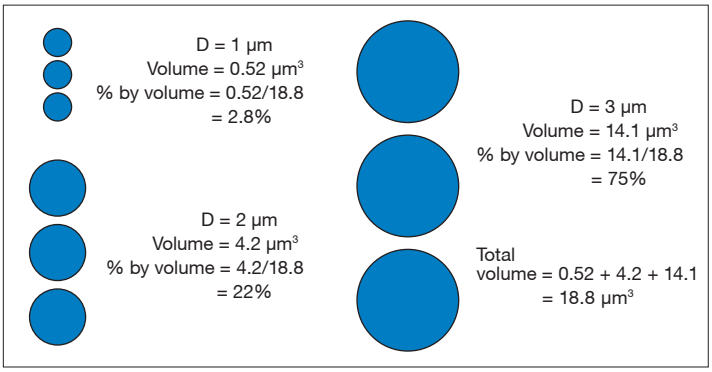

Figure 1: Particles 1, 2, and 3 µm in size

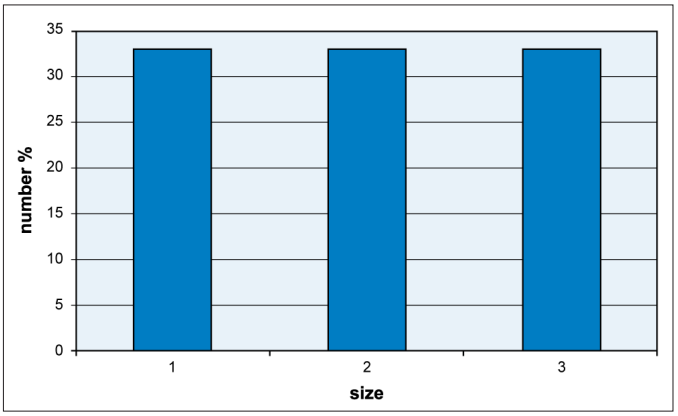

Figure 2: Number Distribution

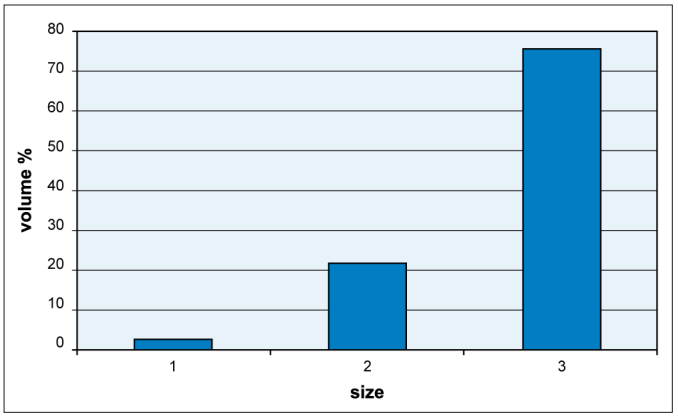

Figure 3: Volume Distribution

When presented as a volume distribution it becomes more obvious that the majority of the total particle mass or volume comes from the 3 µm particles. Nothing changes between the left and right graph except for the basis of the distribution calculation.

Another way to visualize the difference between number and volume distributions was given to us by a customer who needed to explain the difference to her colleagues. In this case beans are used as the particle system. Figure 4 shows a population where there are 13 beans in each of three size classes, equal on a number basis. Figure 5 shows these beans placed in volumetric cylinders where it becomes apparent that the larger beans represent a much larger total volume than the smaller ones.

Figure 4: 13 beans in each size classes

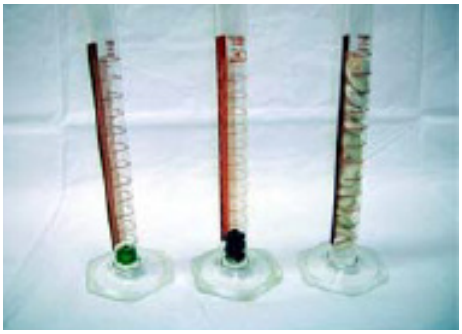

Figure 5: The same 39 beans placed in volumetric cylinders

The next example shown in Figure 6 shows a population of beans where it may not be intuitively obvious but there is an equal volume of each size. It then becomes apparent in Figure 7 when these same beans are placed in volumetric cylinders that each size contains equal volumes.

Figure 6: Equal volume of three bean sizes

Figure 7: Beans in volumetric cylinders

Transforming Results

Results from number based systems, such as microscopes or image analyzers, construct their beginning result as a number distribution. Results from laser diffraction or acoustic attenuation construct their beginning result as a volume distribution. The software for many of these systems includes the ability to transform the results from number to volume or vice versa. It is perfectly acceptable to transform image analysis results from a number to volume basis. In fact, the pharmaceutical industry has concluded that it prefers results be reported on a volume basis for most applications[1].

On the other hand, converting a volume result from laser diffraction to a number basis can lead to undefined errors and is only suggested when comparing to results generated by microscopy. Figure 8 below shows an example where a laser diffraction result is transformed from volume to both a number and a surface area based distribution. Notice the large change in median from 11.58 µm to 0.30 µm when converted from volume to number.

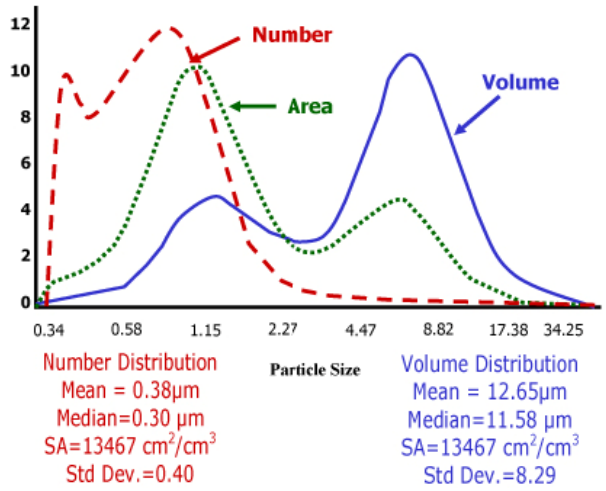

Figure 8: Volume distribution converted to area and number

Reference

Burgess, J., Duffy, E., Etzler, F., Hickey, A., Particle Size Analysis: AAPS Workshop Report, Cosponsored by the Food and Drug Administration and the United States Pharmacopeia, AAPS Journal 2004; 6 (3) Article 20 (https://doi.org/10.1208/aapsj060320)