Particle Size Distribution of Manure and By-product Slurries

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Slurries are a special class of liquids that contain suspended solids. Very rarely are all the suspended particles in slurry the same size. Usually, particles are an assortment, or a distribution, of different sizes. This Fact Sheet defines how **Particle Size Distribution** is measured, and demonstrates how this property can be used to estimate the mass of total solids removed by gravity screens.

Definitions

In OSU Fact Sheet BAE1759, *Solids Content of Wastewater and Manure*, s**olids** are defined as the portion of a liquid or slurry that is left when the water is removed. The **Total Solids (TS)** content of a sample is the mass of solids remaining after the sample has been dried in a 103 C oven for 24 hours, divided by the original mass of the sample. Total solids are further divided into dissolved and suspended solids. The distinction being suspended solids can be removed by settling. Settling is largely a function of particle size. **Total Suspended Solids (TSS)** is the mass of solid particles that cannot pass through a filter with 1.5 micron (1/17,000 inch) openings.

Measuring Particle Size Distribution

To determine particle size distribution, a wet slurry sample is passed through a series of sieves with progressively smaller openings. The sieves are arranged so the first sieve has the largest holes; the second sieve has slightly smaller holes, the third sieve's holes smaller still, etc. A common arrangement is to stack five or six sieves with openings ranging from 5,000 to 100 microns. Particles with these **characteristic dimensions** are considered sand. Particle size distribution is determined by calculating the mass percentage of TS passing through each opening size and plotting as a graph such as the one shown in Figure 1.

Five sieves were used in the experiment plotted in Figure 1. Results are recorded as a percentage of the total solids content. Openings were 3,360; 2,000; 1,190; 595; and 250 microns. Manure produced by pigs fed two different diets was passed through the sieves. All of the particles from the fine ground corn manure passed through the 3,360 micron sieve, and this was recorded as 100 percent passing. Fifteen percent of total solids from the cracked corn diet were retained by the 3,360 micron sieve; therefore, 85 percent were recorded as passing. Another 8 percent of the cracked corn manure total solids were trapped by the 2,000 micron sieve. This means 23 percent of total solids were retained by both the 3,360 and 2,000 micron sieves (15 percent + 8 percent); and the result is plotted as 77 percent passing the 2,000 micron sieve. Fifty-five percent of cracked corn manure solids and 57 percent fine ground corn manure solids passed through all the sieves. If 57 percent of fine ground total solids passed through the 250 micron sieve, then 43 percent of TS are either dissolved solids, or suspended solids with characteristic dimension between 1.5 and 250 microns.

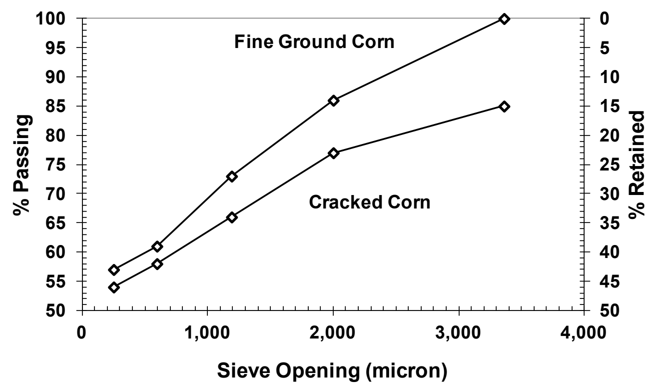

Figure 1. Particle size distribution of swine manure slurries resulting from diets made with cracked and fine ground corn (From Jett et al., 1974).

Particle Shape and Characteristic Dimension

The shape, as well as the size, of a particle determines if it passes through a sieve opening. If manure solids were balls, we would expect each ball to pass through an opening that was slightly larger than its diameter. Manure particles are irregular in shape. The characteristic dimension of the particle is defined as the size of the screen opening that will retain the particle. This works pretty well for describing spheres and cubes, but what about hair? A hair will be trapped by a sieve with large openings, because the hair will likely be trapped lengthwise, lying flat on the screen. But, the hair is not a ball with a diameter slightly larger than the characteristic dimension of the screen opening. It is best to think of characteristic dimension as the screen opening that will trap a certain mass percentage of solids – not the size of a particle.

Particle Size Distribution and Removal by Gravity Screening

As you might expect, the ability to remove solids by screening is highly influenced by the particle size distribution of slurry's TSS content. A screen can only trap particles larger than its screen openings. Things get more complicated when moving from theory to practice. Excess water is passed through the sieves to wash out dissolved solids and break up clumps when determining particle size distribution. Particles in slurry tend to clump together and form larger particles, increasing the mass of solids retained by a certain screen size. Also, when determining distribution, the entire sample volume passes through the sieves. In a working situation, slurry flows over the top of a gravity screen. Some openings may be clogged or covered with particles, preventing material from passing through the screen. And, if the flow rate is high, a particle may pass right over the screen without "seeing" a hole. When a screen is covered with solids, we say that it is "blinded."

The separation efficiency of a screen is measured as the mass of solids retained by the screen divided by mass of solids contained in the slurry flowing onto the screen. Measured on a mass basis, separation efficiency is roughly equal to percent retained in the sieving experiments. Figure 2 shows the result of many trials passing swine manure slurry over gravity screens of various opening sizes.

Settling efficiency falls below a line of **maximum probable separation efficiency**. Maximum probable efficiency is a function of screen size. Although the feed composition of the trials given in Figure 2 is unknown, the line of maximum probable separation efficiency is comparable to percent total solids retained in Figure 1 (Table 1). Maximum probable efficiency is higher than percent retained in the sieving experiments at small opening sizes (< 1000 microns) probably due to clumping in the raw manure slurry.

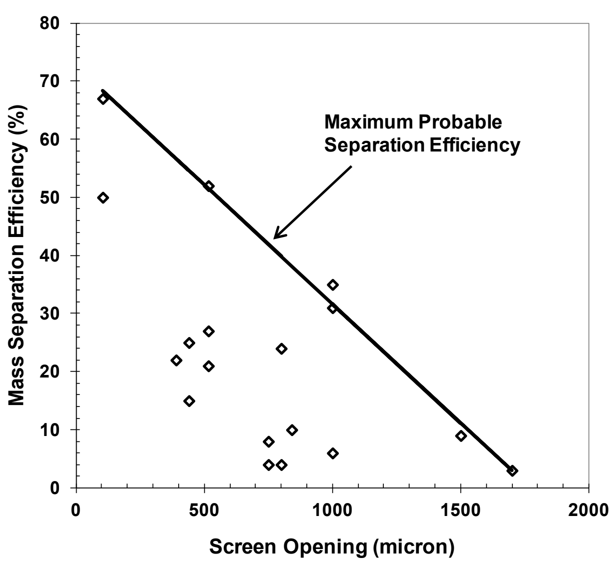

Figure 2. Relationship between screen openings and separation efficiency for gravity screens (data from Zhang and Westerman, 1997).

Why did separation efficiency fall so far below the theoretical maximum in most of the trials shown in Figure 2? Unless the screen is set up correctly, much of the slurry passes over -- not through -- the screen. Those results approaching maximum probable separation efficiency had slurry flow rate, screen angle, screen wash flow rate, etc. tuned just right to achieve best results.

Table 1. Mass of total manure solids from two swine diets retained on sieves (from Figure 1.) compared to maximum probable separation efficiency of screens treating raw swine manure (from Figure 2).

Screen/Sieve Opening Microns	*Retained on Sieve*		*Maximum Probable Separation Efficiency %*
	Fine Corn %	*Cracked Corn %*	
400	42	46	55
600	39	42	50
800	35	39	47
1,000	31	36	35
1,200	27	34	0

Summary

Suspended solids are what separate liquid from slurry. Suspended particles exist in a variety of shapes and sizes, and are usually arranged in a distribution of sizes. The distribution of the sand sized particles of total suspended solids is determined through wet sieving. The particle size distribution of a slurry determines the maximum probable separation efficiency of a gravity screen. Actual separation efficiency will be determined by screen design, set-up, and operation.

References

Jett, S.C., I.J. Ross, H.E. Hamilton, and V.W. Hays. 1974. Size distribution and nutritional value of swine manure separates. Transactions of ASAE 1974:965.

Zhang, R.H., and P.W. Westerman. 1997. Solid-liquid separation of animal manure for odor control and nutrient management. *Applied Engineering in Agriculture*. 13(3):385.

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