**Sand Grain Size Analysis
(Sieve Analysis)**

# Purpose

The biosand filter requires a certain range of sand grain sizes to effectively treat drinking water. Conducting a grain size analysis (also called a "sieve analysis") provides a good assessment of a sand source. After shaking a sample of sand through a mini sieve set, you can record and analyze the results. Then you can calculate the relevant sand parameters to help you determine if a sand source is suitable for use in a biosand filter. This document explains how to do the analysis and calculations. An electronic (spreadsheet) version of the analysis is also available on the CAWST website (www.cawst.org/en/resources/pubs).

Using a grain size analysis, you can determine if a sample of prepared sand meets the criteria for good quality filtration sand for use inside a biosand filter. If a sample of prepared filtration sand (sieved, washed and dried) is within the recommended ranges for Effective Size (ES), Uniformity Coefficient (UC) and amount of silt, then filters installed using this sand would be expected to have the correct flow rate and effectively treat drinking water.

# Method – Paper Analysis

A sand grain size analysis is performed by shaking a sample of sand through a series of five sieves with different screen sizes. The sieve sizes used in these instructions were specifically selected for analyzing sand for the biosand filter. The top sieve in the series has the largest holes in the screen, and the bottom sieve has the smallest holes in the screen. After 5 minutes of shaking the sieve set, sand grains of different sizes will remain on top of each of the sieves.

Measure the amount of sand that remains on top of each of the sieves. Put each number in the table on the worksheet at the end of this document. Then, you can calculate how much sand went through each sieve. By graphing the data on a semi-log graph (provided on the worksheet), you can determine many important parameters of the sand.

One important parameter is the size of hole that allows 10% of the sand to pass through (or 90% of the sand is bigger than this hole size). This value is called the d10 or the Effective Size (ES) of the sand. Another important parameter is the hole size that 60% of the sand would pass through (or 40% of the sand is bigger than this hole size). This value is called the d60. Dividing the d60 value by the d10 value gives the Uniformity Coefficient (UC = d60/d10). Compare the Effective Size and Uniformity Coefficient from your analysis with CAWST’s recommended values to see if the sand would make good quality filtration sand. The instructions describe this procedure in more detail.

This analysis uses volume measurements rather than weight to measure how much sand remains on top of each sieve. This minimizes the equipment required, and also provides adequate results for the purpose of analyzing sand for biosand filters. Please note: This is a field method for rapid assessment and not an approved engineering standard operating procedure.

NOTE:

It is very important that the sand sample is totally dry before sieving. Wet or damp sand will plug the screens. This will make it difficult to sieve and the results will be incorrect.

# Materials Required

* Sand sample: at least 100 ml of very dry sand for analysis. The sand sample must be taken from the actual sand that will be used for filtration. -Try to get a good mix from the sand you will use.
* Graduated cylinder: 100 mL size with 1 mL markings. Plastic is recommended, so it does not break in the field.
* Mini Sieve Set:

*Please note: The following screen numbers are given according to the Tyler Standard Sieves Sizes. Please refer to the opening size in mm to ensure you are using the same size screens.*

* #24 screen (opening size = 0.71 mm)
* #40 screen (opening size = 0.38 mm)
* #60 screen (opening size = 0.25 mm)
* #80 screen (opening size = 0.18 mm)
* #150 screen (opening size = 0.10 mm)
* Catch pan (to catch all sand that passes #150 screen)
* Sieve set lid (placed on the top sieve to contain the sand while shaking)

\*Note: Instructions on how to make a sieve set for this analysis are available from CAWST. Please contact cawst@cawst.org

* Semi-log graph paper (provided in the Appendix)
* Pencil (If the graph paper is laminated, then you can use an erasable marker so that the markings can be erased and the graph can be reused many times.)
* Ruler
* Calculator

# Types of Analyses

There are 3 different ways you can use this analysis. Decide which way you will be doing the analysis and follow the instructions in the appropriate section below.

**A: Analyze prepared filtration sand** (sieved through a 0.7 mm screen and washed) to see if it matches the recommended values.

**B: Analyze unprepared sand** (not sieved though a 0.7 mm screen) to see if it will match recommended values for filtration sand once it is prepared.

**C: Analyze mixed material at a source** to see how much of it you will be able to use as filtration sand and how much will be waste.

If you are assessing a new sand source, such as a quarry, it is advisable to do both **B** and **C** (above). The results will help you determine the best material to use, so it is both economical and effective for water treatment.

# Instructions

# TrainernotesbwA: Analyze Prepared Filtration Sand

1. Prepare the sand as you would before installing it in the biosand filter. Sieve it through a #24 screen, wash it according to the instructions in the Biosand Filter Construction Manual, and dry it.
2. Stack the mini sieve set with the coarsest screen (#24) on top followed by the #40, #60, #80, #150 and finally, the catch pan on the bottom.
3. Fill the graduated cylinder to the 90 mL mark with the dry, prepared sand sample. Use a piece of paper, such as these instructions, rolled or folded as a ‘funnel’ to make it easier to fill the graduated cylinder. The exact volume of sand you start with is not very important, as the results will be expressed as a percentage. We suggest only using 90 mL instead of to 100 mL because once the sand is shaken through the sieve set and you pour it back into the cylinder to read the results, it will show more volume than what you started with. This is due to unpacking as the grains are not packed as tightly anymore. If you start with 100 mL and the gradations or mL marks on your graduated cylinder only go up to 100 mL, you will not be able to accurately read all of the results.
4. Pour the entire 90 mL sample from the graduated cylinder onto the top screen (#24) and place the lid on top.
5. Shake the entire sieve set, including the bottom catch pan and top lid, for at least 5 minutes. Shake it with energy! Shake both sideways and up and down to make sure the sand passes all the way down through the various screens.
6. After 5 minutes, remove the top lid and pour the sand from the #24 screen into the graduated cylinder. Use a piece of paper as a funnel to help pour the sand into the cylinder. Read the amount of sand in the graduated cylinder. In the table on the worksheet, record the value in the column for the #24 screen under the heading **Cumulative Sand Remaining On the Screen**. Do not pour out the sand from the cylinder afterwards. Note: There should be very little or no sand on the #24 screen since your sample should have already been sieved through the #24 screen size to remove the coarse sand.
7. Remove the #40 screen and pour the sand from it into the cylinder (on top of the sand already in the cylinder from the #24 screen). Read the total amount of sand in the cylinder. Record the value in the column “**Cumulative Sand Remaining On the Screen”** for the #40 screen.
8. Repeat Step 6 for the #60 screen, then the #80 screen, the #150 screen, and finally the catch pan. The final volume will probably not be exactly 90 mL. The volume may be less if some sand was lost while shaking. Try to avoid any sand loss by emptying the sieves thoroughly into the cylinder and using a paper funnel to pour the sand into the cylinder. The final volume may be more than 90 mL because as you pour the sand back into the cylinder it forms separate layers, so the fine sand is not mixed into the coarse sand. This makes the sand less compact. You can lightly tap the cylinder after pouring in the material from each sieve to help uniform settling.
9. Calculate the **Percent Sand Remaining On the Screen** and the **Percent Smaller Than the Screen** for each screen size and record your results.

**Example Sand Sieve Analysis**

|  |  |  |  |
| --- | --- | --- | --- |
| **Screen Size** | **Cumulative Sand Remaining On the Screen** **(Measure)****mL** **(A)** | **Percent Sand Remaining On the Screen** **(Calculate)****%** **(C=A/B\*100)** | **Percent Smaller Than the Screen (Calculate and Graph)****%** **(100-C)** |
| #24 | 0 ml | 0 % | 100 % |
| #40 | 17.1 ml | 18.0 % | 82.0 % |
| #60 | 72.9 ml | 76.7 % | 23.3 % |
| #80 | 87.8 ml | 92.4 % | 7.6 % |
| #150 | 94.6 ml | 99.6 % | 0.4 % |
| Catch pan | **95 ml (B)** | 100 % | 0 % |

1. Plot the **Percent Smaller Than the Screen** value for each sieve size on the graph paper and then draw a line joining the 5 points as shown in the Example Worksheet. (Line starts at #24 screen size and ends at #150 screen size, and should slope down to the right.)
2. Determine the **Effective Size** (**d10** value). This is defined as the size of hole that allows 10% of the sand to pass through (or 90% of the sand is bigger than this hole size) . Read this value from the graph where the line crosses the **Percent Smaller Than the Screen** line at 10%.

**Recommended ES = 0.15 mm to 0.20 mm**

* *Important parameter to achieve 0.4 L/minute flow rate.*
* *If the effective size is less than 0.15 mm, the filter may flow too slowly and may be too slow for the users.*
* *If the effective size is more than 0.20 mm, the filter may flow too fast and not be fully effective.*
* *The recommended values are within the range recommended for community slow sand filters.*
1. Determine the **Uniformity Coefficient**. The Uniformity Coefficient (**UC**) indicates whether there is a large or small range of grain sizes within the sand sample. To calculate the **UC**, you need the **d10** (**ES** from above), and the **d60**. The **d60** is defined as the size of hole that allows 60% of the sand to pass through (or 40% of the sand is bigger than this hole size) . Read this value from the graph where the line you drew crosses the **Percent Smaller Than the Screen** line at 60%. The **UC** is **d60** divided by **d10**.



**Recommended UC = 1.5 to 2.5**

* *Important parameter to achieve 0.4 L/minute flow rate.*
* *A UC close to 1 means a small range of grain sizes within the sand sample. There will be few smaller grains to fit between the larger grains, so the sand will be less tightly packed. This will lead to a (slightly) higher flow rate.*
* *A higher UC means a larger range of grain sizes within the sand sample. The smaller grains will fill in the gaps between the bigger grains, resulting in more tightly packed sand. This will lead to a (slightly) lower flow rate.*
* *The recommended values are within the range recommended for community slow sand filters.*
1. Determine the amount of silt, or the **Percent Smaller Than the #150 Screen.** This is the measure of the very fine sand (also called rock flour) that can plug the filtration sand and cause turbid water to come out of the biosand filter. CAWST recommends that the sand is washed sufficiently so that not more than 4% goes through the #150 screen. Having more than 4% silt will result in a filter flow rate that is too slow. If there is more than 4% silt in your sand, you can try washing it more and repeating the analysis.



**Recommended Value for Percent Smaller Than the #150 Screen = < 4%**

* *If there is more than 4% silt in the sand, the flow rate will be very slow.*
* *If filtration sand with more than 4% silt is installed in the filter, the very fine silt may move through the filter and come out the outlet tube, making the filtered water dirty.*
* *If the grain size analysis done on prepared (washed) sand shows that there is more than 4% silt in the sand, the sand should be washed more before it is installed in any filters. The procedure for washing sand is described in the Biosand Filter Construction Manual. If there is a lot of very fine sand, it must be washed several times.*

**TIP:** If you have a choice between sand sources, choose sand with a lower effective size AND a lower uniformity coefficient.

If the ES is *low* (near 0.15 mm), and the UC is *high* (near 2.5), the filter may flow too slowly. This may be inconvenient for users.

If the ES is *high* (near 0.20 mm) and the UC is *low* (near 1.5), the filter may flow too quickly. A filter installed with this sand may not treat water effectively.

**It is important to install one filter with the prepared sand and test the flow rate as a final test to ensure the filtration sand is appropriate.**

# B: Analyze Unprepared Sand

You can estimate if a sand source will produce good filtration sand without sieving, washing and drying the sand sample. Because you do not need to prepare the sand, you can do this analysis right at the sand source (such as a quarry). The result from this analysis will only be approximate, but the result should be similar to the result you would get if you analyze a sample of prepared sand (sieved, washed and dried), according to the procedure described above. The calculations are done using only the range of sand grain sizes that are in the prepared filtration sand (0.1 to 0.7 mm). You do not include in the analysis the portion of the sand that stays on the top (#24) screen. This coarse sand and gravel would be removed during preparation of the filtration sand. You also do not include in the analysis the amount of sand that falls through to the catch pan at the bottom. Most of the very fine sand that is in the catch pan would be removed from the filtration sand when you wash the sand. It should not be included in this analysis.

Instructions to Estimate the Quality of a Sand Source to Use as Filtration Sand

1. Put a 100 mL sample of the unprepared sand into the top of the sieve set.
2. Shake for 5 minutes. Discard (throw out) the sand from on top of the #24 screen *and* the sand in the catch pan.
3. With these portions removed, follow the same procedure as Steps 7-12 of "A: Analyze Prepared Filtration Sand" above. Your values for the #24 screen and catch pan will be "0". Remember: do not pour out the sand in between sieves - you should be recording the total cumulative volume of sand.
4. After calculating the Effective Size and Uniformity Coefficient, check to see if they are within the recommended ranges. If the parameters are within the ranges and you choose to use the sand, you will need to determine how many times to wash the sand so that the prepared filtration sand has less than 4% silt in it. Once you buy and prepare the filtration sand, you can repeat the grain size analysis using prepared sand (sieved, washed and dried) to ensure all of the calculated values are still within the correct ranges.

# C: Analyze Mixed Material at a Source

If you are considering buying some sand, you can estimate how much of the material you will be able to use as filtration sand and how much will be waste. There may be sand or gravel that is too big to use for filtration sand. There may also be a lot of very fine dust in the material that will have to be washed out of the filtration sand.

1. Stack the mini sieve set with the coarsest screen (#24) on top followed by the #40, #60, #80, #150 and finally the catch pan on the bottom.
2. Take a representative sample of dry sand from the source. Fill the graduated cylinder with exactly 100 mL of the dry sand sample.
3. Pour the entire 100 mL sample from the graduated cylinder onto the top screen (#24) and place the lid on top.
4. Shake the sieve set for at least 5 minutes. Shake both sideways and up and down to ensure the sand falls through the various screens.
5. Remove the top lid and pour the sand from the #24 screen into the graduated cylinder. Use a piece of paper as a funnel to help pour the sand into the cylinder. Read the amount of sand in the graduated cylinder. **This value is the % Rejected – Too Coarse.** Empty the graduated cylinder.
* *You may be able to use some of this material that is too big to use as filtration sand as separating gravel inside the filter (grain size range 0.7 - 6 mm).*
* *If there is a large amount of material bigger than the sizes you want, ask if you can sieve the material at the source site before buying it. This way, you only need to transport the portion of sand that you want.*
1. Pour the sand from the catch pan into the *empty* graduated cylinder. Read the amount of sand in the graduated cylinder. **This is the % Rejected – Too Fine.**
* *Most of this very fine sand and dust must be removed from your filtration sand by washing it. The higher the percentage of very fine sand, the more washing will be required. CAWST recommends using material with less than 4% very fine sand or dust.*
1. The Percent Usable as Filtration Sand (amount that can be used as filtration sand) can be calculated by subtracting the **% Rejected - Too Coarse** and the **% Rejected - Too Fine** from 100%.

**% Usable as Filtration Sand =
100 - (% Rejected - Too Coarse) - (% Rejected - Too Fine)**

**Sand Grain Size Analysis - Example**



**Sand Grain Size Analysis - Worksheet**

