

# Use of a microwave oven for moisture determination in a soil science laboratory<sup>1</sup>

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## ABSTRACT

A microwave oven has been found to be satisfactory for determining soil moisture content gravimetrically. Five, 10, and 20 fifty-gram samples of a loamy sand and a clay soil at air dry, 15-bar percentage, field capacity, and saturation moisture contents were oven dried in a microwave oven and compared to the standard soil drying method. The minimum amount of time for drying was 5 min and the maximum was 35 min. The higher the moisture content and the greater the oven loading rate, the longer the drying time that was necessary to reach constant weight.

**Additional index words:** Soil drying, Laboratory instruction.

TYPICALLY, gravimetric soil moisture determinations in the laboratory have to be spread over more than one laboratory period, requiring students to return at times other than the designated laboratory time. The possible use of a microwave oven for soil moisture determination (2) seemed ideal in an introductory soil science laboratory. It was desirable to allow the drying and weighing of the laboratory samples for gravimetric moisture content during only one period and to eliminate the 24-hour drying period required with forced-air drying ovens.

In the soil moisture laboratory taught at Colorado State University, a class project is designed to develop part of a soil moisture desorption curve for a sandy soil and a clayey soil so that students can gain an understanding of the effect of soil texture on soil moisture retention. Samples of soils are saturated, then placed on tension tables at 10, 20, 30, and 40 cm of water tension. Upon equilibration after 48 hours or more, the students weigh, oven dry, and reweigh the soil samples to determine the moisture percentages. If the students had placed the saturated soil samples on the tension table, in a previous laboratory, use of the microwave oven could allow them to complete the gravimetric de-

terminations of soil moisture during the one period designated for that exercise. This would be a decided advantage.

Miller et al. (2) showed that the drying time in a microwave oven increased with increasing water content and increasing sample size. Since the moisture content, as well as the number of samples to be dried at one time, varies considerably, it was of interest to investigate these variables to determine how they affect drying time of a coarse and a fine textured soil. This would give guidelines to insure soil samples were dried equivalent to a 24-hour drying period in a forced-air drying oven with different sample numbers and moisture contents.

## MATERIALS AND METHODS

A preliminary comparison of drying effectiveness was made between a forced air drying oven (105 C for 24 hours) and a microwave oven (20 min) on two soils (one a sandy soil and one a clayey soil) at field capacity and air dry conditions. Ten subsamples containing 50 g of a sandy soil, 5 of which were at field capacity and 5 were air-dried, were placed in both ovens for the times indicated then weighed. This was repeated using a clayey soil.

Subsequently in a more detailed study, five replications of two other soils, loamy sand (84% sand, 7% silt, and 9% clay) and a clay (29% sand, 26% silt, and 45% clay) were brought to various moisture levels as follows:

*A. Air Dry.* These samples were simply spread out on the laboratory bench and allowed to dry in the air for 1 week.

*B. 15-Bar Percentage.* The soils were placed on a ceramic pressure plate to a depth of 0.63 cm (1/4 in) in rubber rings. The soils and plates were submerged in water and allowed to stand for 48 hours, after which they were placed in a pressure chamber of 15 bars pressure for a period of 3 days.

*C. Field Capacity.* Soil samples were placed in a 1,000 ml cylinder and enough water was added to penetrate about two-thirds the depth of the column in 3 days leaving air dry soil at the bottom of the cylinder. Samples from the center of the moist soil were used for oven drying.

*D. Saturation.* Soil samples were placed in a container and water added until a thin film remained above the surface. The samples were covered and left for 48 hours in this condition before oven drying.

The other variable in the study was three oven loading rates (5, 10, and 20 samples dried at one time). Moist soil samples of 50 g each were placed in tared paper weighing cups and placed in a 110-V Montgomery Ward Signature Portable Microwave Oven<sup>3</sup> with a frequency of 2,450 MHz. Samples were removed at various time intervals and weighed.

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**Table 1—Comparison of effectiveness of a microwave oven and a forced air oven (typical soil drying oven) for drying 50 g soil samples at field capacity and air dry condition**

Drying method†	Field capacity		Air dry	
	Sandy	Clayey	Sandy	Clayey
1	40.36	38.66	49.34	48.48
2	40.43	38.66	49.35	48.56
3	40.95	39.46	49.38	48.64

† 1) Soils dried for 20 min in a microwave oven; 2) Same soil samples as in No. 1 were then placed in a forced air drying oven for 24 hours; 3) Soils were dried 24 hours in a forced air drying oven.

The soils were considered dry when they lost no more than 0.1 g between weighings. The actual time of drying may be slightly less than stated in Table 2, since the samples cooled between weighings and when placed back into the oven had to be reheated, thus a slight overestimation in drying time could have resulted.

## RESULTS AND DISCUSSION

The air dry sandy and clayey soils used in the preliminary trial lost all the free moisture in 20 min in a microwave oven and did not lose additional moisture when transferred to a forced-air electric drying oven for an additional 24 hours (Table 1). The same results were obtained for these soils at field capacity.

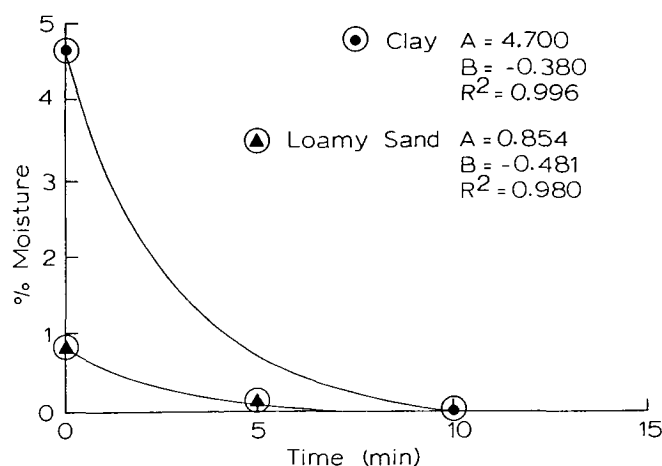
The results of the initial trial indicated that the short drying period in the microwave oven could adequately substitute for drying in a forced air electric oven at 105 C for 24 hours. However, there was a need for determining the drying time for other soil moisture levels and other oven loadings (number of samples).

The mean moisture percentages ( $\bar{x}$ ) of five replications of the loamy sand and the clay used for the second part of the study for the five-sample loading rate for air dry, 15-bar, field capacity, and saturation for the loamy sand was approximately 1, 5, 15, and 30% (oven dry wt basis), respectively. The clay soil moisture percentages were about 4, 17, 33, and 55, respectively, for the same moisture levels.

Figure 1 shows the mean moisture percentages of the air dry clay and loamy sand with time for the five-sample oven loading. The curves in the figure are a function of the form  $y = Ae^{Bt}$  ( $t$  = time,  $y$  = % moisture) fit to the data using the least squares method (1). They are typical of the shape of drying curves with time. The estimated parameters A and B from the equation above are printed on the graph along with the  $R^2$  value which represents the proportion of the total variation accounted for by the fitted model. The point on the time axis after

**Table 2—Time in microwave oven for two soils to reach constant weight ( $\pm 0.1$  g) at three loading rates and four moisture contents. Values are means of five observations**

Soil moisture	Oven drying time (min)					
	5 samples		10 samples		20 samples	
	Loamy sand	Clay	Loamy sand	Clay	Loamy sand	Clay
Air dry	5	10	10	10	10	15
15-Bar percentage	10	10	10	15	15	30
Field capacity	10	15	15	20	20	30
Saturation	15	15	15	20	25	35



**Fig. 1—Moisture percentage changes with microwave oven drying time for air dry loamy sand and clay soil with a loading rate of five samples**

which no more than 0.1 g of moisture was lost, was considered the drying time necessary for the limits of accuracy required in an introductory soil science laboratory. Similar curves were developed for all oven loading rates and all moisture contents used in the study. Drying times were 5, 10, and 10 min for the 5, 10, and 20 samples of air dry loamy sand, respectively, and 10, 10, and 15 min for the 5, 10, and 20 samples of air dry clay, respectively. Minimum times to reach constant weight for the two soils, three oven loading rates, and four moisture contents are shown in Table 2. No more than 35 min were necessary to oven dry 20 (50 g each) samples of saturated soil with the microwave oven. Drying 20 saturated samples at once is likely the most severe test of adequacy of the oven since it will not hold more than about 20 samples and moisture contents of less than saturation are most often used. There is an increase in the time required to dry the soil samples, both with numbers of samples and with increasing moisture contents. These results were quite similar to those of Miller et al. (2) for comparable moisture contents, soil textures, and loading rates.

<sup>3</sup>Name brand indicated for information and does not constitute an endorsement for this product by the authors or institution.

The microwave oven has been found entirely satisfactory for making gravimetric moisture determinations in developing a soil moisture desorption curve in the introductory soil science course at Colorado State University.

#### ACKNOWLEDGMENT

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