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# Standard Test Method for Determining Biodegradability of Materials Exposed to Source-Separated Organic Municipal Solid Waste Mesophilic Composting Conditions by Compost Respirometry<sup>1</sup>

This standard is issued under the fixed designation D5929; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the biodegradation properties of a material by reproducibly exposing materials to conditions typical of source-separated organic municipal solid waste (MSW) composting. A material is composted under controlled conditions using a synthetic compost matrix and determining the acclimation time, cumulative oxygen uptake, cumulative carbon dioxide production, and percent of theoretical biodegradation over the period of the test. This test method does not establish the suitability of the composted product for any use.

1.2 This test is performed at mesophilic temperatures. Some municipal compost operations reach thermophilic temperatures during operation. Thermophilic temperatures can affect the biodegradation of some materials. This test is not intended to replicate conditions within municipal compost operations that reach thermophilic temperatures.

1.3 The values stated in both inch-pound and SI units are to be regarded separately as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and ~~health~~ environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

[D513 Test Methods for Total and Dissolved Carbon Dioxide in Water](#)

[D1129 Terminology Relating to Water](#)

[D1293 Test Methods for pH of Water](#)

[D2908 Practice for Measuring Volatile Organic Matter in Water by Aqueous-Injection Gas Chromatography](#)

[D6247 Test Method for Determination of Elemental Content of Polyolefins by Wavelength Dispersive X-ray Fluorescence Spectrometry](#)

[E1621 Guide for Elemental Analysis by Wavelength Dispersive X-Ray Fluorescence Spectrometry](#)

### 2.2 APHA-AWWA-WEF Standard ~~Methods~~ Method:<sup>3</sup>

[2540G Total, Fixed, and Volatile Solids in Solid and Semisolid Samples](#)

## 3. Terminology

3.1 *Definitions*—Definitions of terms applying to this test method appear in Terminology [D1129](#).

3.2 *Definitions of Terms Specific to This Standard:*

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee [D34](#) on Waste Management and is the direct responsibility of Subcommittee [D34.03](#) on Treatment, Recovery and Reuse.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from American Public Health Assoc., 1015 15th Street, NW, Washington, DC 20005, Standard Methods for the Examination of Water and Waste Water, 18th ed., 1992.

3.2.1 *acclimation time, n*—the time required for the oxygen uptake to reach 10 % of the total measured cumulative oxygen uptake.<sup>4</sup>

3.2.2 *inoculum, n*—a mixture of organic substances in varying degrees of biodegradation to provide microbial-rich substrate in which to perform biodegradation testing.

3.2.3 *oxygen uptake, n*—the cumulative oxygen consumed by the organisms during the test.

3.2.4 *theoretical carbon dioxide production (ThCDP),(ThCO<sub>2</sub>P), n*—the maximum carbon dioxide that can be produced by a material as calculated by the carbon content of the material.

3.2.5 *theoretical oxygen uptake (ThOU), n*—the maximum oxygen consumption required to fully oxidize a material based on the elemental content of the material.

3.2.6 *virgin newsprint*—nonprinted newspaper roll stock.

#### 4. Summary of Test Method

4.1 This test method consists of the following:

4.1.1 The test samples are prepared by cutting or forming the material into the form it would most likely be seen in the waste stream. A theoretical maximum carbon dioxide production and oxygen uptake are determined from an elemental analysis.

4.1.2 An inoculum is obtained from a municipal source-separated organic MSW or yard waste compost facility. It is procured from a static pile compost that has been composting for at least two months.

4.1.3 The synthetic organic MSW is prepared from virgin newsprint, pine bark or wood chips, corn starch, corn oil, bovine casein, and urea. A buffer/dilution water is prepared from magnesium, calcium, iron, and a phosphate buffer.

4.1.4 The test material, synthetic compost, inoculum, and dilution water are combined and placed in a highly insulated temperature-controlled reactor which monitors oxygen consumption and temperature and captures all evolved carbon dioxide.

4.1.5 The system is monitored, and oxygen uptake rates, temperature profiles, and total carbon dioxide produced are recorded.

4.1.6 The total oxygen uptake and carbon dioxide produced are compared with the theoretical values obtained from the elemental analysis, and a percent of biodegradation is generated-calculated. Possible negative effects of the material are evaluated by observing the acclimation time of the synthetic MSW and evaluating the oxygen uptake rate.

#### 5. Significance and Use

5.1 ~~As the crisis in solid waste continues to grow, MSW composting is increasingly being considered as one~~ considered an important component in the overall solid waste management strategy. The volume reduction achieved by composting, combined with the production of a usable end product, is resulting in increasing numbers of product (for example, compost as a soil amendment), has resulted in municipalities analyzing and selecting source-separated organic MSW composting as an alternative to incineration or to reduce reliance on landfill disposal. This test method will help landfill disposal of biodegradable organic materials. This standard provides a method to analyze and determine the effect of materials on the compost process and establish if the material can be properly disposed through solid waste composting facilities; the performance, utility, and feasibility of the composting process as a method for managing organic solid waste material.<sup>5</sup> Using this method, key parameters of process performance, including theoretical oxygen uptake (ThOU) and theoretical carbon dioxide production (ThCO<sub>2</sub>P) are determined.

5.2 This test method ~~attempts to provide~~ provides a simulation of the overall compost process while maintaining reproducibility. Exposing the test material with several other types of organic materials that are typically in MSW provides an environment which provides the key characteristics of composting: material not in a sole carbon source environment which allows co-metabolism; compost system is self heating, and provides a the composting process, including direct measurement of organism respiration.

#### 6. Apparatus

6.1 *Compost Respirometry Apparatus (see Fig. 1):*

6.1.1 A minimum of six reactors, 2 to 6-L volume, with the test material in triplicate and the controls in triplicate. The reactors should be surrounded with efficient insulation to minimize heat loss and be gastight. Insulation should be 8 cm of urethane foam or equivalent. A temperature-controlled water bath may be used as an alternative to insulating the vessels.

6.1.2 *Tubing*, with high resistance to gas permeation.

6.1.3 *Peristaltic Pump*, to control and maintain gas flow through each reactor.

6.1.4 *4-L Scrubber Vessel*, for each reactor fitted with a scrubber solution sampling port.

6.1.5 *Differential Pressure Switch*, for each reactor that actuates between 2 and 5 in. (51 and 127 mm) of water.

6.1.6 *Solenoid and Mass Flowmeter*, to control and measure the addition of pure (99.997+)(99.997+) oxygen to system.

<sup>4</sup> Tabak, Henry H. and Lewis, Ronald F., *CEC/OECD Ring Test of Respiration Method for Determination of Biodegradability*, U. S. Environmental Protection Agency, pp. 1-3. Tabak, H. H. and Lewis, R. F., "CEC/OECD Ring Test of Respiration Method for Determination of Biodegradability," U.S. Environmental Protection Agency, pp. 1-3.

<sup>5</sup> Biocycle: Journal of Waste Recycling Staff, eds., *The Biocycle Guide to Composting Municipal Wastes*, JG Press, Inc., 1989. *The Biocycle Guide to Composting Municipal Wastes*, JG Press, Inc., 1989.

6.1.7 *Temperature Probe*, situated in the middle of the compost.

6.1.8 *Data Acquisition and Control System*, for the measurement of temperature and the control and measurement of the oxygen addition.

6.2 *Miscellaneous:*

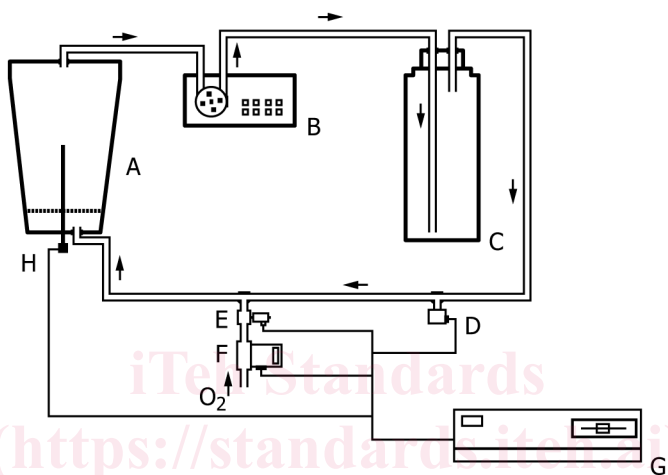
6.2.1 *Temperature Control Room*, water bath, or hood to maintain the external temperature of the apparatus at  $40^{\circ}\text{C} \pm 2^{\circ}\text{C}$ .

6.2.2 *Flow Meter*, to measure recirculation flow in each reactor (optional).

6.2.3 *Computer Control of Peristaltic Pump*, for automatic recirculation flow control (optional).

6.3 Suitable devices for the measurement of pH, dry solids ( $40^{\circ}\text{C}$ ), ( $105^{\circ}\text{C}$ ), elemental analysis of material, carbon dioxide content of scrubbers, weight, and volume of the final compost material.

NOTE 1—All apparatus components should be made of nonreactive and nonabsorbing material.



NOTE 1—The compost respirometer features a 4-L reactor vessel (A) insulated with 8 cm of urethane foam. (A water bath may be used to control temperature as an alternative to insulation.) The atmosphere is drawn through the reactor by a peristaltic pump (B) to maintain aeration. The effluent gases are passed through a 4-L scrubber vessel (C) containing 1.5 L of 5 M NaOH to remove any carbon dioxide from the effluent gas stream. Samples are drawn from this scrubber solution during the evaluation to determine the carbon dioxide released by the compost. As the microorganisms consume the oxygen in the system, a pressure drop occurs and is detected by a highly sensitive pressure switch (D). This signals the data acquisition and control system (G) and the oxygen is replaced with pure bottled oxygen by a solenoid (E) and the amount added is measured by a mass flowmeter (F). The gases are then returned to the reactor. A thermocouple (H) is centered in the test reactor to monitor the temperature of the compost. The system is sealed to prevent interference from barometric fluctuations.

FIG. 1 Compost Respirometer Functional Diagram

## 7. Test Materials

7.1 The test materials can be in any form as long as their dimensions do not exceed 3 by 3 by 12 cm. The test materials should be in the form that they would be seen present in the waste stream. A representative sample must be obtained by using appropriate ASTM methods or other documented method.

7.2 Analyze the test materials for carbon, hydrogen, nitrogen, oxygen, phosphorus, sulfur, and any other elements that are suspected to be present at a level to affect microbial metabolism and oxygen uptake. The ThOU must be calculated for each material.

7.2.1 Guide E1621, Test Method D6247, or other reliable methods may be used for elemental analysis.

7.3 Calculate the  $\text{ThCO}_2$  from the carbon content of the test material. See 12.2 for this calculation.

7.4 The nitrogen content of the synthetic MSW should be adjusted if the C/N ratio of the parent mixture is greater than 40:1. This is accomplished by adjusting the urea content of the synthetic MSW. The synthetic MSW has adequate nitrogen to support the addition of up to 35 g of carbon before the ratio exceeds 40:1. If the urea content is adjusted, all reactors including controls must contain the same concentration of urea.

## 8. Reagents and Materials

8.1 *Scrubber Solution*, containing 3.25 N NaOH in distilled water. Store in a gas-tight plastic container. Add 30 mg of phenolphthalein to the solution to indicate scrubber exhaustion.

8.2 *Dilution/Buffer Solution*, containing the following:

Chemical	Purpose	Concentration, g/L
$\text{KH}_2\text{PO}_4$	phosphate buffer	6.8
$\text{Na}_2\text{HPO}_4 \cdot 7\text{H}_2\text{O}$	phosphate buffer	55.6
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	nutrient	0.0225
$\text{CaCl}_2$	nutrient	0.0275
$\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$	nutrient	0.00025

### 8.3 Synthetic Municipal Solid Waste, containing the following:<sup>6,7</sup>

Constituent	Chemical Used	Dry Weight, %
Cellulosics	shredded, virgin newsprint	41
Inerts	pine bark or wood chips	39
Carbohydrates	corn starch	5.2
Lipids	corn oil	5.4
Proteins	bovine casein	2.0
Organic nitrogen	urea	1.4
Buffer/Nutrient	as listed	5.8

8.4 *Polyethylene*, or another ~~nonbiodegradable~~ non-biodegradable material is the negative control material. It should be in the same form as the test materials to provide the same physical conditions in all reactors. The synthetic MSW acts as a positive control to verify the viability of the inoculum, see 13.4 for requirements.

## 9. Hazards

9.1 This test method requires the use of hazardous chemicals. Avoid contact with the chemicals and follow the ~~manufacturer's~~ manufacturer's instructions and ~~Material~~-Safety Data Sheets.

9.2 This test method does not address all of the health and safety issues related to ~~its~~ sits use. It is the responsibility of the user to establish appropriate safety measures.

9.3 ~~High-purity~~ High-purity, high-pressure gases can be dangerous if not handled correctly. Follow all safety precautions and monitor the system often to ensure proper operation.

## 10. Inoculum

10.1 The inoculum should be obtained from MSW or yard waste that has properly composted for two to four months. The compost should be screened with a <3-mm screen.

10.2 The compost can be stored at room temperature for up to 48 h before use. It should not be allowed to dry.

## 11. Procedure

11.1 This procedure is for twelve 4-L reactors with 4-L scrubber vessels. Other configurations will need to adjust weights and volumes to maintain proportional ~~liquid-to-liquid~~ liquid-to-solid ratios of components.

### 11.2 Synthetic Municipal Solid Waste:

11.2.1 *Dilution Water*—Weigh out the ingredients for ~~3600 mL~~ 3600 mL of dilution water. This will make enough dilution water for 13 reactors:

Compound	Quantity per Reactor	Per 3600 mL
$\text{KH}_2\text{PO}_4$	1.87 g	24.5 g
$\text{Na}_2\text{HPO}_4 \cdot 7\text{H}_2\text{O}$	15.29 g	200 g
$\text{MgSO}_4$	0.003 g	0.039 g
$\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$	0.0076 g	0.099 g
$\text{FeCl}_3$	0.0002 g	0.003 g
Urea	4.0 g	52 g

### 11.2.2 Dry Ingredient Preparation:

11.2.2.1 Weigh out 120 g of shredded virgin newsprint and place in a sealed plastic bag. Mark each bag with the actual weight of newsprint.

11.2.2.2 Weigh out 115 g of 2.5 by 2.5 by ~~0.6 cm~~ 0.6 cm (approximately) fresh wood chips or pine bark into a 1-L plastic beaker with 15.1 g of corn starch and 5.95 g of bovine casein. Repeat until twelve sets of dry ingredients are prepared.

### 11.2.3 Inoculum Preparation:

11.2.3.1 Obtain approximately 1 kg of mature compost from a municipal MSW or yard waste compost facility.

11.2.3.2 Screen compost with 3-mm wire mesh screen and retain the <3-mm portion that is used as the inoculum.

<sup>6</sup> Clark, C. S., et al., "Laboratory Scale Composting: Techniques," *Journal of the Environmental Engineering Division-ASCE*, October, 1977. Clark, C. S., et al., "Laboratory Scale Composting: Techniques," *Journal of the Environmental Engineering Division-ASCE*, Vol 103, 1977, pp. 896–906.

<sup>7</sup> U. S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, *Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (update 1988)*, EPA/530-SW-88-033, March 1988. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, "Characterization of Municipal Solid Waste in the United States, 1960 to 2000," (update 1988), EPA/530-SW-88-033, 1988.