Designation: D 5509 – 96

An American National Standard

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
Reprinted from the Annual Book of ASTM Standards. Copyright ASTM

Standard Practice for Exposing Plastics to a Simulated Compost Environment[1]

This standard is issued under the fixed designation D 5509; 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 (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the exposure of plastics to a specific test environment. The test environment is a laboratory-scale reactor that simulates a self-heating composting system and that uses aeration to control maximum temperature. Plastic exposure occurs in the presence of a media undergoing aerobic composting. The standard media simulates a municipal solid waste from which inert materials have been removed. This practice allows for the use of other media to represent particular waste streams. This practice provides exposed specimens for further testing and for comparison with controls. This test environment does not necessarily reproduce conditions that could occur in a particular full-scale composting process.

1.2 Changes in the material properties of the plastic and controls should be determined using appropriate ASTM test procedures. Changes could encompass physical and chemical changes such as disintegration and degradation.

1.3 This practice may be used for different purposes. Therefore, the interested parties must select the following: exposure conditions from those allowed by this practice; criteria for a valid exposure, that is, minimum or maximum change requirements for the compost and controls; and the magnitudes of material properties changes required for the plastic specimens.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *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 and health practices and determine the applicability of regulatory limitations prior to use.* Specific hazard statements are given in Section 8.

NOTE 1—There is no similar or equivalent ISO standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 638 Test Method for Tensile Properties of Plastics[2]

D 882 Test Methods for Tensile Properties of Thin Plastic Sheeting[2]

D 883 Terminology Relating to Plastics[2]

D 1898 Practice for Sampling of Plastics[2]

D 1922 Test Method for Propagation Tear Resistance of Plastic Film and Thin Sheeting by Pendulum Method[2]

D 3593 Test Method for Molecular Weight Averages and Molecular Weight Distribution of Certain Polymers by Liquid Size-Exclusion Chromatography (Gel Permeation Chromatography GPC) Using Universal Calibration[3]

D 3826 Practice for Determining Degradation End Point in Degradable Polyolefins Using a Tensile Test[4]

2.2 *American Public Health Association Standard:*

5210 B. 5-Day BOD Test, Standard Methods for the Examination of Water and Wastewater[5]

3. Terminology

3.1 *Definitions:* Definitions of terms applying to this practice appear in Terminology D 883. Definitions in Terminology D 883 supersede definitions in this section.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aerobic*—a life process that occurs in the presence of oxygen **(1)**.[6]

3.2.2 *biological reactor*—a vessel in which living organisms, usually microorganisms, catalyze a reaction.

3.2.3 *compost*—a relatively stabilized and sanitized product of composting.

3.2.4 *compost environment*—a biological reactor containing a solid-organic-waste matrix in which aerobic degradation occurs due to the action of microorganisms and other mechanisms.

3.2.5 *degradation*—the process by which a chemical is reduced to a less complex form **(1)**.

3.2.6 *disintegration*—physical breakup of a solid material.

3.2.7 *inoculum*—microorganisms placed in compost to start or accelerate biological action **(1)**.

3.2.8 *simulated solid waste*—a media representing a typical waste stream. Although every item found in an actual stream is not included, it includes representative items which establish a

---

[1] This practice is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.96 on Environmentally Degradable Plastics.

Current edition approved June 10, 1996. Published August 1996. Originally published as D 5509 – 94. Last previous edition D 5509 – 94.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Discontinued*—See 1992 *Annual Book of ASTM Standards*, Vol 08.02.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] *Standard Methods for the Examination of Water and Wastewater*, 18th ed, 1992, published by the American Public Health Assn., 1015 Fifteenth St., NW, Washington, DC 20005.

[6] The boldface numbers in parentheses refer to the list of references at the end of this standard.

consistent and easily reproduced waste matrix.

4. Summary of Practice

4.1 This practice consists of: preparing a representative simulated-solid-waste mixture; loading the biological reactor with controls, test specimens, simulated solid waste, and inoculum; operating and monitoring the biological reactor to ensure active biological degradation; and removing the specimens for cleaning (if desired), conditioning, testing, and reporting.

5. Significance and Use

5.1 Changes to the material properties of a plastic within a compost unit by various mechanisms, such as biodegradation or hydrolysis, are important. Such changes can affect the degradation of other materials enclosed by the plastic and the resulting composition and appearance of the composted material. This practice allows screening of the stability of plastics exposed to a self-heating compost process. ASTM test methods run on plastic products or specimens before and after exposure in accordance with this practice can determine the degree to which material properties of the plastic have changed.

5.2 This practice also allows the determination of the effect of the plastic on the composting process. This is done by comparing rates and lengths of temperature rise, and extents of compost dry-weight or carbon loss.

5.3 This practice does not preclude the pre-exposure of the test specimens to other environments.

5.4 *Limitations*:

5.4.1 Due to the wide variation in the construction, operation, and content of composting systems and due to variations in regulatory requirements for composting systems, this practice does not simulate the environment of all composting systems. However, it is expected to simulate the environment of a self-heating compost process operated under near-optimum conditions.

5.4.2 Appropriate post-exposure testing is not included in this practice, but it is addressed by other ASTM test methods.

5.4.3 Predicting the long-term fate or effects of a plastic from the results of short-term exposure in accordance with this practice could be difficult. Use caution when considering such extrapolations.

5.4.4 A specimen that becomes indistinguishable from other materials within the system could be not fully mineralized. Determination of degradation products and their toxicity requires further testing.

5.4.5 This practice does not address effects occurring after the compost process, such as effects of the compost on soil.

6. Apparatus

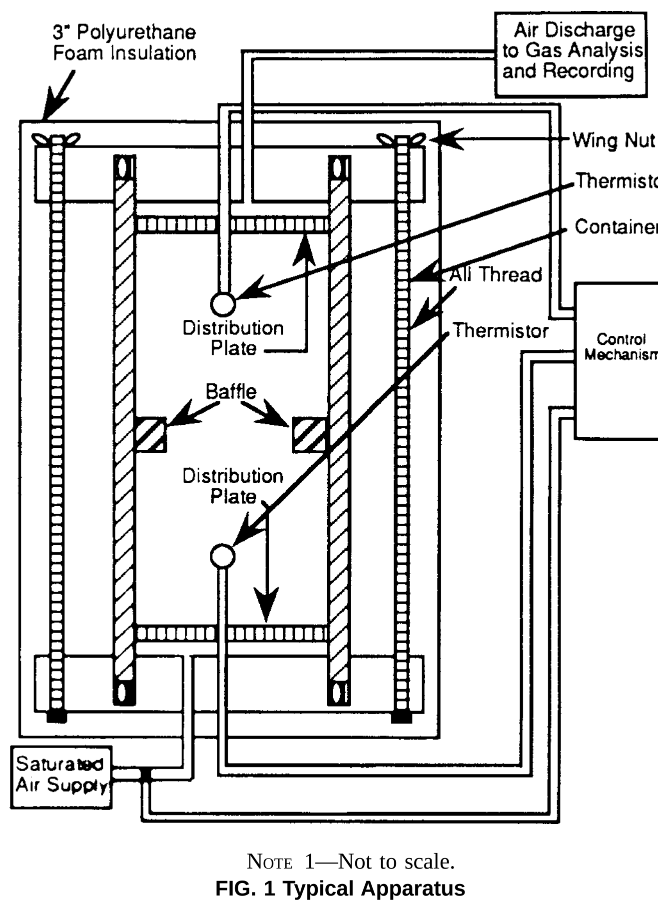
6.1 *Biological Reactor*, for containing the simulated solid waste and plastic specimens in a suitable environment. This may consist of a 30-cm (1-ft) diameter by 90-cm (3-ft) long column. Reactor sizes may be increased or decreased as long as sufficient volume is available to allow the reactor to be self-heating, and the diameter-to-length ratio is in the range from 1:1 to 1:3. The reactor size should not be so small that it prevents an even distribution of waste components throughout the column. Fit the reactor with temperature-measuring devices. Extend these devices into the compost to between one fourth and three fourths the depth and width of the compost. There shall be entrance and exit ports for air feed and discharge, and there shall be a distribution plate-baffle or other device to ensure that the airflow through, or air contact with, the compost is distributed as evenly as possible. For example, in the cylindrical reactor shown in Fig. 1, the identical top and bottom distribution plates have 50 uniformly spaced 3.2-mm (⅛-in.) diameter holes and 2.5 cm (1-in.) perimeters, without holes. The perimeter acts as a baffle. The pictured reactor also has a second baffle extending 2.5 cm (1 in.) inward from the chamber walls positioned at the midpoint. These baffles help prevent air from leaking around instead of passing through the compost matrix. The reactor openings shall be attached by a method that provides a hermetic seal. The container and appurtenances shall be constructed of a noncorrosive chemically inert material. The tubing attached to the vessel should be flexible so that the chamber can be inverted.

6.2 *Insulation*, to cover the entire vessel, or an oven or water bath which can be automatically maintained at 1°C below the reactor's core temperature and into which the entire reactor can be placed.

6.3 *Filtered-Air Supply*, that introduces no contaminants and is measured and controllable.

6.4 *Saturating Device*, for saturating the air with water such as a 60-cm (2-ft) column of water with a fritted-glass air-dispersion tube at the bottom.

6.5 *Data Logger*, that can turn the air supply on and off and



NOTE 1—Not to scale.

FIG. 1 Typical Apparatus

record the temperature from the temperature-measuring devices.

6.6 *Control Mechanism*, capable of operating in three distinct phases similar to the system described by Hogan, et al **(2)**. Each phase turns the air supply on once every 10 min. Phase One delivers a constant volume of air each 10 min. In this phase, the volume of air added during each aeration pulse is preselected through experimentation to maximize the rate at which the compost system self-heats. Phase Two requires sensing the temperature of the temperature-measuring devices and regulating the air supply to sustain a maximum temperature of 50 ± 2°C. Regulation at 55 + 2°C, 60 + 2°C, or other temperature may be substituted to simulate regulatory requirements. Phase Three delivers a volume of air every 10 min equal to one fifth that of Phase One.

6.7 *Gas Chromatograph*, flue-gas analyzer, or other analytical device capable of measuring concentrations of CO_2 and O_2, and preferably also CH_4 and N_2, in the exhaust gas.

6.8 *Analytical Balance*, for determining percent moisture gravimetrically in accordance with 9.2.5.

6.9 *Yard-Waste Shredder*, with a 2.5-cm (1-in.) mesh screen and of adequate size for use in shredding and mixing waste components.

7. Reagents and Materials

7.1 *Compost Matrix*—Compost matrixes 7.1.1-7.1.3 are allowed. In all cases do not use materials within the residue lifetime of any previously applied pesticide. Also, do not use materials containing fertilizers or preservatives.

7.1.1 A simulated solid waste prepared by mixing components in the portions shown as follows. This waste mixture is an average of reported municipal solid waste composition values **(3-11)** without inert materials, such as metals, glass, ceramics, ash, dirt, and rocks. The weights given are on a wet-weight (normal moisture content) basis:

Category	Wet Weight, %	Specific Component Weights, %
Food wastes	16.6	tomatoes (3.3) lettuce (3.3) meat (3.3) cottage cheese (3.3) bread (3.4) shredded together
Garden wastes	13.9	leaves (6.9) grass (7.0) both shredded
Paper	58.5	bleached (19.5) brown (19.5) cardboard (19.5) shredded together
Plastics	7.7	plastic being exposed plus shredded plastic milk containers
Textiles	0.8	cotton
Wood	2.5	shredded twigs

7.1.2 A simulated yard-waste mixture composed of one-third dried grass (hay), one-third dried tree leaves, and one-third shredded twigs. If necessary, the ratio of grass, that is typically rich in nitrogen, to leaves, that are typically poor in nitrogen, can be adjusted so that an optimum C/N ratio of 25 to 30 is obtained in the mixture of these two most readily degraded components.

7.1.3 An alternate mixture designed to simulate a particular waste stream may be used.

7.2 An inoculum consisting of an unsterilized, composted potting-soil mixture obtainable from a garden-supply store. Alternate sources of inoculum are material from a commercial composting process, a previous composting exposure, or a commercial compost seed.

7.3 *Inorganic Salts Solution for Initial Moisture Content Adjustment*—Add 1 mL each of phosphate buffer, $MgSO_4$, $CaCl_2$, and $FeCl_3$ solutions per litre of distilled water. These solutions are given in 7.5-7.8, respectively, and are presented in APHA-AWWA-WEF Method 5210 B. These inorganic salts are added to provide some pH buffering and necessary nutrients for microbial growth.

7.4 *Distilled Water*—Use only high-quality water distilled from a block tin or all-glass still. Use deionized water as an alternative. The water must contain less than 0.01 mg/L copper, and be free of chlorine, chloramines, caustic alkalinity, organic material, or acids.

7.5 *Phosphate Buffer Solution*—Dissolve 8.5 g potassium dihydrogen phosphate, KH_2PO_4; 21.75 g dipotassium hydrogen phosphate, K_2HPO_4 ; 33.4 g disodium hydrogen phosphate heptahydrate, $Na_2HPO_4 \cdot 7H_2O$; and 1.7 g ammonium chloride, NH_4Cl, in approximately 500 mL distilled water, and dilute to 1 L. The pH of this buffer should be 7.2 without further adjustment. Discard the reagent (or any of the following reagents) if there is any sign of biological growth in the stock bottle.

7.6 *Magnesium Sulfate Solution*—Dissolve 22.5 g $MgSO_4 \cdot 7H_2O$ in distilled water and dilute to 1 L.

7.7 *Calcium Chloride Solution*—Dissolve 27.5 g anhydrous $CaCl_2$ in distilled water and dilute to 1 L.

7.8 *Ferric Chloride Solution*—Dissolve 0.25 g $FeCl_3 \cdot 6H_2O$ in distilled water and dilute to 1 L.

7.9 *Film*, or other forms of degradable plastics such as uncoated cellophane film, poly(β-hydroxybutyrate-co-β-hydroxyvalerate) (PHBV), or cellulose acetate with an average of 2.0 acetate esters per glucose monomer or other homogeneous and known degree of substitution.

7.10 *High-Density Polyethylene*, that has not been exposed to toxic materials, such as that available from used milk bottles.

8. Hazards

8.1 This practice involves the use of microorganisms and hazardous chemicals that could produce a variety of diseases. Avoid contact with these materials by wearing gloves and other appropriate protective equipment. Use good personal hygiene to minimize exposure, and follow the instructions given in the Material Safety Data Sheets.

8.2 The compost mixture could contain sharp objects. Extreme care should be taken when handling this mixture to avoid injury.

8.3 The biological reactor is not designed to withstand high pressures; operate it at close to ambient pressure. It could be appropriate to shield the reactor in case of relief-valve failure.

9. Procedure

9.1 *Preparation of Plastic Specimens*:

9.1.1 Depending on the test methods applied to the exposed plastics and the use of the data generated, it could be appropriate to use both positive and negative controls, such as, but not limited to, cellophane, PHBV, or cellulose acetate with a known and homogeneous degree of substitution as a positive control and high-density polyethylene as a negative control.

9.1.2 Select plastic samples in accordance with Practice