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Standard Guide for Chemical Fate in Site-Specific Sediment/Water Microcosms[1]

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1. Scope

1.1 This guide provides procedures and criteria for the development and use of sediment/water microcosms for laboratory evaluations of the fate of chemical substances in the environment. It does not specify specific microcosms but it establishes minimum criteria for distinguishing acceptable microcosms from those that may be incomplete or inappropriate for site-specific extrapolation (see 5.1 and 10.1).

1.2 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E729 Guide for Conducting Acute Toxicity Tests on Test Materials with Fishes, Macroinvertebrates, and Amphibians

E1279 Test Method for Biodegradation By a Shake-Flask Die-Away Method

2.2 *U.S. EPA Standard:*

Toxic Substances Control Act Test Guidelines; Proposed Rule, Site-Specific Aquatic Microcosm Test[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *microcosm*—an intact, minimally disturbed portion of an ecosystem brought into a laboratory for study under controlled experimental conditions.

4. Summary of Guide

4.1 This guide provides guidance on the development, use, and evaluation of microcosm studies used to evaluate the fate of chemical substances in specific aquatic ecosystems. It establishes minimum criteria for distinguishing acceptable site-specific fate microcosms.

5. Significance and Use

5.1 The fate of chemicals released to the environment may be evaluated in the field or in laboratory studies. This guide provides direction on the development, use, and evaluation of microcosm studies that simulate a specific aquatic ecosystem and include sediment and relevant biota. A key objective in the use of site-specific microcosms is the ability to extrapolate information obtained in the laboratory system to field situations with a reasonable degree of confidence.

5.2 Field studies can obtain important information about the fate of chemicals in a particular ecosystem but have many disadvantages. In field studies, environmental variables, in general, cannot be controlled and the study may be subject to wide fluctuations in variables such as temperature, rainfall or sunlight. Introduction of a chemical into an ecosystem may produce an unacceptable environmental risk. Furthermore, field studies often are prohibitively expensive.

5.3 Some environmental fate studies use structural or synthetic communities (not site-specific microcosms) created by placing water, soil or sediment, plants, animals and microbiota in a container according to an established protocol. Some synthetic communities have been specifically designed to examine the fate of chemical substances in aquatic environments (that is, Metcalf et al. (**1**)[4] and Isensee and Tayaputch (**2**). These synthetic communities provide reproducible environments in which to evaluate and rank chemicals according to their fate but extrapolation to specific ecosystems is difficult. This is because they lack complex population structures and processes analogous to specific natural ecosystems. In addition, they frequently contain a biomass of organisms that is not scaled to the volume of water or sediment, thereby giving exaggerated rates of chemical metabolism.

5.4 A microcosm replicates many of the processes affecting the fate of a chemical in a complex ecosystem. A microcosm can be examined under controlled laboratory conditions in the absence of certain variables that might interfere with an

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

[3] Federal Register, Vol 52, No. 187, 1987, pp. 36352–36360.

[4] The boldface numbers given in parentheses refer to a list of references at the end of the text.

understanding of a particular process. Microcosms provide an opportunity to manipulate variables and to study their effects and interactions. Microcosms also offer replication possibilities for assessing environmental variability, an advantage that is not available from field studies.

5.5 Microcosms can be used to examine the significance of various fate processes. By examining test compounds in microcosms it is possible to determine the relative effects of various fate processes (for example, biotic versus abiotic). This makes it possible to focus on critical processes and consider site-specific environmental situations where these processes predominate or are absent. Although some fate processes such as hydrolysis or partitioning to sediments may be quantified adequately in simpler studies (for example, shake-flask or aquaria tests) others such as bioturbation may require the complexity of a microcosm for adequate assessment. An important aspect of microcosm testing is determining the significance of biological processes in environmental fate. By studying test compound fate in sterilized microcosms, the role of bioturbation (that can distribute a chemical deep in sediment beds) can be assessed along with biodegradation.

5.6 The following are examples of chemical fate information that might be obtained in microcosm studies.

5.6.1 How long a chemical substance will persist in its parent form in a particular environment,

5.6.2 Whether the fate of a chemical is primarily dependent on biotic or abiotic processes,

5.6.3 The effect on the fate of a chemical by the presence of plants that may take up the chemical and store or metabolize it and that provide additional surfaces for microbial colonization,

5.6.4 The effect on the fate of a chemical by the activity of benthic organisms that move water and sediment, and

5.6.5 The effect of nutrient flux at the water sediment interface on the biodegradation of chemicals in the water column and in the sediment.

6. Preliminary Studies

6.1 A shake-flask test with site water and sediment (for example, using Test Method E1279) is recommended to provide preliminary information about the fate of a test compound. Biotic and abiotic degradation rate constants, in the presence and absence of sediment, can be determined with this test along with an indication of potential sorption to sediments. An example of data for the pesticide fenthion generated from both shake flask and microcosm tests has been reported (**3, 4**). The preliminary study may identify those fate processes that should receive close attention during a microcosm study and provide guidance on sampling frequency. Some test compounds, such as those that persist for a very short time period in shake flask tests, may not require further testing in a microcosm. An appropriate reference chemical such as methyl parathion (**5**) or Linear Alkylbenzene Sulfonate (LAS) may be used with the shake flask and microcosm tests.

7. Design Features for Sediment/Water Microcosms

7.1 *Size:*

7.1.1 Because of their size, microcosms can model only a small part of any aquatic ecosystem. They may vary in size from a fraction of a litre to several hundred litres. Smaller sizes maximize the advantages of microcosm use, including operation within a controlled laboratory environment, replicability, containment of toxic chemicals and simplification of dosing and mixing.

7.1.2 A microcosm should be sufficiently large to permit the removal of water and sediment samples during the course of the study without significantly affecting surface to volume ratios over the course of an experiment and without significantly depleting either the water or sediment volumes. Microcosms also must be large enough to readily accommodate monitoring probes, mixing apparatus, etc.

7.1.3 The inclusion of relatively large biotic species (for example, clams and large plants) may not be appropriate in microcosms of only a few litres size. Small microcosms, however, may be the most appropriate for studies of chemical fate processes such as biodegradation and sorption, which generally are not affected significantly by this size constraint.

7.1.4 Since the size and design of a microcosm depends primarily on the issue that is being addressed (**6, 7**), no "ideal" microcosm design can be recommended. For example, studies focusing on the interaction of a test compound with sediment, benthic macrophytes, bioturbating-macrofauna, or small fish each require specific modifications to accommodate the necessary compartments/organisms. A variety of water/sediment, site-specific microcosms have been described for studying the fate of xenobiotic compounds in the aquatic environments. These test systems vary in size from Ecocores, used by Spain, et al., containing approximately 175 mL of water (**8**), to the 140 L test systems used by Perez et al. (**9**), with many intermediate sizes (**3, 10, 11, 12**).

7.2 *Water:*

7.2.1 Collect water for the microcosm from the field site above or nearly above the site of sediment core collection. Collect water by hand bucketing or non-destructive pumping. If the water column in the natural system is stratified, the microcosm water should contain samples taken from representative depths.

7.2.2 If the site water is to be the source of the test compound, sampling containers should be composed of materials such as glass or fluorocarbon plastics to minimize sorption. Take care to avoid the use of plastics (for example, plasticized polyvinyl chloride) that may leach plasticizers into the water. Transport water samples to the test facility with minimum delay and maintain field temperatures as close as possible. Effects of containerization ("wall effect") may occur soon after collection, and thus shipment over long distances may be detrimental. If, for some reason water must be held in the laboratory overnight, gently stir it using a magnetic stirrer and loosely cover the water container to prevent dissolved oxygen depletion.

7.3 *Sediment:*

7.3.1 Because of the well-documented significance of sediment in the biodegradation of many chemical substances (**13, 14, 15, 16**), the microcosm designs covered by this guide include intact sediment cores.

7.3.2 Site-specific extrapolation of sediment-enhanced biodegradation information must take into consideration the water