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Standard Guide for Selecting and Using Ecological Endpoints for Contaminated Sites[1]

This standard is issued under the fixed designation E1848; 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 guide covers an approach to identification, selection, and use of ecological endpoints (both assessment and measurement endpoints) (**1-8**)[2] that are susceptible to the direct and indirect effects of both chemical and non-chemical stressors or agents associated with wastes and contaminated media at specific sites under current and future land uses. It does not address assessment and measurement endpoints for non-site specific studies (for example, chemical-specific or regional risk assessments) or measurements in abiotic media (soil, water, or air).

1.2 This guide addresses only the identification, selection, and use of assessment and measurement endpoints, not the full range of activities that occur in an ecological assessment or ecological risk assessment at a contaminated site (**1, 3-8**). These activities are addressed in other ASTM guides and references provided at the end of this guide.

1.3 This guide is intended to identify assessment and measurement endpoints to be used for screening, preliminary, focused, detailed, and quantitative ecological risk assessments conducted in a linear or iterative fashion (**3, 8**). This is a partial, incomplete listing of possible levels of assessment. In a tiered ecological risk assessment, it may be necessary to redefine ecological endpoints when planning to collect more data or when additional site data are obtained and evaluated.

1.4 This guide is intended to be used by trained biologists, ecologists, and ecotoxicologists familiar with risk assessment, and ecological and ecotoxicological concepts.

1.5 This guide (including Appendix X1) consists of a series of options or instructions and does not recommend a specific course of action or provide detailed guidelines to be followed at all sites. See 2.2.2 of *Regulations Governing ASTM Technical Committees*.[3]

1.6 *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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.*

[1] This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.05 on Environmental Risk Management.

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

[3] Available from ASTM International Headquarters and the ASTM website, www.astm.org.

2. Referenced Documents

2.1 *ASTM Standards:*[4,5]

E943 Terminology Relating to Biological Effects and Environmental Fate

E1689 Guide for Developing Conceptual Site Models for Contaminated Sites

2.2 *Other Documents:*

EPA/100/F15/005 Generic Ecological Assessment Endpoints (GEAEs)For Ecological Risk Assessment: Second Edition With Generic Ecosystem Services Endpoints Added, July 2016

Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance, Government of Canada, March 2012

3. Terminology

3.1 *Definitions*—Definitions are provided specifically for use with this guide. Many of the terms listed in this section have been modified from those defined in other publications (**1-8**).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *assessment endpoint*—an explicit expression of an environmental value (ecological, not monetary) to be protected (**3**).

3.2.1.1 *Discussion*—

An assessment endpoint is an ecological condition of potential concern or effect experienced by an ecological receptor with ecological and societal value that drives risk-based decision-making at a contaminated site (for example, a specific reduction in the abundance of a fish population or the disruption of the structure of benthic community). It is a qualitative, quantitative, or quantifiable expression, measure, metric, or index involving an ecological receptor at risk. Under some circumstances, assessment endpoints may be measured and used directly for assessment purposes. Assessment endpoints are the ultimate focus in risk characterization and link measurement endpoints (see below) to policy goals and the risk management process (**1-3, 5, 6, 8**).

3.2.2 *chemical stressor*—a chemical, chemical mixture or radionuclide present in an environmental medium that is known or suspected to induce an adverse biological, toxicological or ecological response in an exposed ecological receptor (**3-8**).

3.2.2.1 *Discussion*—

A chemical stressor is often referred to as an "ecological contaminant of concern."

3.2.3 *exposure area*—a geographic location in which one or more site-related stressors are present and ecological receptors are potentially exposed.

3.2.4 *direct effect*—an adverse impact on an exposed ecological receptor (for example, increased mortality or reduced growth) as a result of the action of a site-related stressor.

3.2.5 *ecological endpoint*—a general term to refer to an assessment or measurement endpoint in an ecological risk assessment (**2, 3**).

3.2.5.1 *Discussion*—

Measurement of chemical concentrations in soil, water, or air are not ecological endpoints; these measurements indicate exposure levels that may be used to evaluate the potential for an ecological response.

3.2.6 *ecological receptor*—ecosystems, habitats, communities, populations, and individual organisms (except humans) that can be exposed directly or indirectly to site stressors (**3, 4, 7, 8**).

3.2.7 *endpoint*—an ecological characteristic (measure, metric, or index) that may be adversely affected by a site-related stressor (**4**).

3.2.8 *indirect effect*—an adverse impact on an ecological receptor (for example, predator) resulting from the direct effect of a stressor on another ecological receptor (for example, reduction in food supply or habitat).

[4] 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.

[5] A bibliography of related references and documents is provided in Appendix X2.

3.2.9 *indicator species*—an organism that is typically common and represents a broad class of species present at the site or in surrounding areas, or both.

3.2.9.1 *Discussion*—

There is sufficient information on its life history and response to contaminants to construct a model to predict (with uncertainty) the potential for effects.

3.2.10 *measurement endpoint*—a measurable response to a stressor (measure, metric, or index) that is quantifiably related to the valued characteristic chosen as the assessment endpoint (**3**).

3.2.10.1 *Discussion*—

Examples of a measurement endpoint are the reduction in the growth, survival, or reproduction of minnows in a standard laboratory toxicity test. These examples of measurement endpoints would be appropriate for assessment endpoints defined as specific predefined reductions in the growth, survival, or reduction in a forage fish population in a stream, river, or lake at the site (**2-4, 8**).

3.2.10.2 *Discussion*—

A measurement endpoint may serve as an assessment endpoint if the measurement endpoint (measured value) is the ecological value to be protected. See related term *measure of effect*(**9**).

3.2.11 *non-chemical stressor*—a biological agent, physical disturbance, condition, or non-chemical characteristic of a waste material, substrate, or source associated with a contaminated site and corrective actions that is known or suspected to interfere with the normal functioning of an ecological receptor (**3**).

3.2.11.1 *Discussion*—

Non-native species, biologically engineered organisms, and pathogens are examples of non-chemical biological stressors. Radiation other than that associated with specific radionuclides, erosion, dredging, impounding, grading, vegetation removal and similar alterations/disruptions, altered particle size distribution, substrate instability, temperature and pH extremes, dissolved oxygen content, water-holding capacity, organic content, physical effects of oil, and similar site characteristics unrelated to specific chemicals are non-chemical stressors. No specific term is proposed for non-chemical stressors that corresponds to "ecological contaminant of concern" for chemical stressors.

4. Significance and Use

4.1 This guide assumes that a decision has been made that an ecological risk assessment is required for a contaminated site. In some cases, this decision could be made before any site data are collected. See Fig. 1.

4.2 The selection of assessment endpoints (defined as ecological values to be protected) and measurement endpoints (ecological characteristics related to the assessment endpoints) is a critical step in conducting an ecological risk assessment. Endpoint selection identifies those effects which are ecologically significant and not merely those that are adverse, thus providing a more rational and defensible basis for making risk and remedial decisions.

4.3 This guide provides an approach for identifying, selecting and using assessment and measurement endpoints in an ecological risk assessment for a contaminated site. This guide has been developed because there is no universal, simple measure of ecological health analogous to measures used in human health risk assessment. Assessment and measurement endpoints have to be identified and selected from a variety of individual circumstances on a stressor-, ecosystem- and scale-specific basis. It is important to recognize that a diverse set of ecological endpoints could be required for a specific site. EPA/100/F15/005 Generic Ecological Assessment Endpoints (GEAEs) For Ecological Risk Assessment: Second Edition With Generic Ecosystem Services Endpoints Added. July 2016)

4.4 This guide is intended to be used primarily by a biologist, ecologist, ecotoxicologist, or a team of environmental scientists during problem formulation and work plan development prior to initiating data collection activities at a contaminated site (**3-8, 10**).

4.5 Ecological risk assessment is usually an iterative process. In many circumstances it proceeds as a series of tiers, that is, desktop/screening, preliminary, and detailed/focused phases. This guide can be used to refine or modify assessment and measurement endpoints developed in earlier phases of the process.

4.6 This guide can be used whenever assessment and measurement endpoints must be identified and selected following an initial or preliminary problem formulation/planning phase:

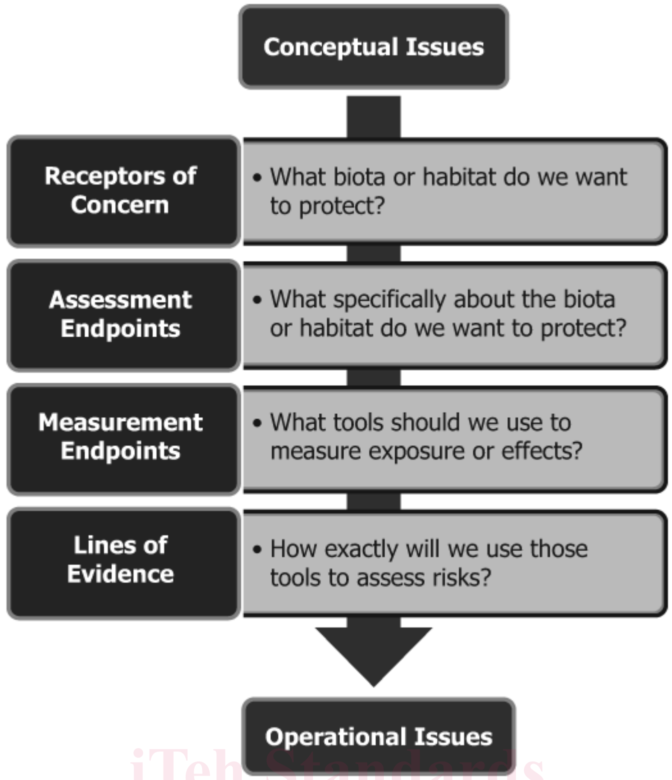

FIG. 1 Conceptual Relationships between Assessment Endpoints, Measurement Endpoints and Lines of Evidence (Source: Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance, Government of Canada, March 2012)

4.6.1 Analysis phase (exposure assessment, hazard/effects assessment, stress/dose-response assessment;

4.6.2 Risk characterization phase; or

4.6.3 Remediation phase and possible subsequent ecological monitoring.

4.7 This guide is intended to be used in the evaluation of baseline conditions (current and future) and in the evaluation of conditions resulting from remedial actions or corrective measures.

5. General Considerations

5.1 Ecological risk assessment is a process of evaluating risks to individuals (in the case of threatened or endangered species or those afforded special protection), populations, communities and ecosystems exposed to chemical and non-chemical stressors. Stressors can act individually or together over multiple ecosystem types and diverse spatial scales. Conditions of the site and risk assessment that should be considered in identifying and selecting assessment and measurement endpoints include (2,3):

5.1.1 *Stressor Characteristics*—Types, properties, intensity, interactions, and spatial and temporal patterns;

5.1.2 *Ecosystem Types*—Aquatic, terrestrial, and wetlands and their subcategories (for example, marine);

5.1.3 *Spatial Scale*—The exposure area over which the exposure to the stressor occurs and direct and indirect ecological effects are potentially produced;

5.1.4 *Temporal Scale*—The expected duration of exposure (acute to chronic) to the stressor, direct and indirect ecological effects, and recovery time following removal of the stressor;

5.1.5 *Ecological Organization*—The level of biological organization (individual, population, community, or ecosystem) at which risk to an ecological receptor is to be assessed; and

5.1.6 *Functionality/Values*—Site-specific factors contributing to the importance of local ecological receptors.

5.2 Assessment and measurement endpoints are selected for specific ecosystem and stressor combinations associated with a site. Assessment and measurement endpoints may address multiple ecosystem and habitat types, spatial and temporal scales, and levels of ecological organization.

5.3 The conceptual site model describes sources, releases and transport pathways for contaminants present at a site. This information is used to define exposure pathways and exposure areas and is usually developed before identifying and selecting endpoints. Assessment and measurement endpoints should be identified for all exposure pathways considered at a site. Ecological endpoints become part of the conceptual site model. Exposure pathway/exposure area and combinations of assessment and measurement endpoints can be selected from this large set for subsequent analysis. Guide E1689 should be consulted on procedures for developing the conceptual site model.

5.4 The following characterize some of the uses or roles of assessment and measurement endpoints in an ecological risk assessment:

5.4.1 Incorporate resources potentially at risk or that require protection into the risk assessment process;

5.4.2 Complete development of a conceptual site model and problem formulation;

5.4.3 Design field and laboratory studies, toxicity tests, and other data collection requirements;

5.4.4 Focus site remediation/corrective actions;

5.4.5 Evaluate potential efficacy of remedial alternatives/technologies; and

5.4.6 Evaluate recovery of impacted populations, communities, and ecosystems.

6. Desirable Characteristics of Assessment and Measurement Endpoints

6.1 Desirable characteristics of assessment endpoints include, but are not limited to, the following (**2**,**3**):

6.1.1 Relevant to decision-making, local public concerns, and ecological considerations (societal or ecological relevance, or both);

6.1.2 Relevant to the site or surrounding area, or both, under current or future land uses, or both (current and future endpoints may be different);

6.1.3 Potentially susceptible to adverse effects from exposure to one or more site contaminants or stressors;

6.1.4 Consistent with the spatial and temporal scale of the action of stressors present at the site;

6.1.5 Address ecological receptors that are expected to receive higher exposure to site contaminants or stressors relative to other ecological receptors;

6.1.6 Amenable to hypothesis formulation, evaluation, and prediction; and

6.1.7 Value to be protected is clearly defined.

6.2 Desirable characteristics of measurement endpoints include, but are not limited to (**2**,**3**):

6.2.1 Correlated with or can be used to predict or infer changes in an assessment endpoint;

6.2.2 Relevant to the site and/or surrounding area under current or future land uses, or both;

6.2.3 Consistent with the spatial and temporal scale of the action of stressors present at the site;

6.2.4 Capable of detecting an adverse effect of concern in the presence of one or more site stressors;

6.2.5 Amenable to hypothesis formulation, measurement and prediction;

6.2.6 Clearly defined; and

6.2.7 Known range of expected variability.

7. Candidate Site-Related Ecological Receptors

7.1 In general terms, ecological receptors that are subjects of assessment and measurement endpoints include, but are not limited to, individuals and populations of a particular species, assemblages of species and communities, and habitats and ecosystems potentially exposed at or in the area surrounding the site. All organisms within the exposure area are potential receptors. Information should be available to indicate that organisms selected are potentially affected in an adverse way by site stressors (**4**). This may require the use of data on related or surrogate species if data on indigenous species cannot be located (**4**).

7.1.1 Candidate species that can serve as ecological receptors at the individual organism and population level include, but are not limited to:

7.1.1.1 Endangered, threatened, or rare species known or suspected to be present in the vicinity of the site;

7.1.1.2 Federal or state protected species;

7.1.1.3 Species in which populations have recreational, commercial, or other aesthetic or spiritual value to humans;

7.1.1.4 Species that contribute to the creation of important habitat for other species;

7.1.1.5 Species that show mutualistic behavior that enhances the reproduction or dispersal of other species;

7.1.1.6 Consumers (for example, parasites and predators) that are known or suspected to strongly regulate populations of other species associated with the site and surrounding area to the extent that their absence would lead to a decrease in species diversity, changes in community composition, or relative abundance of species; and

7.1.1.7 Other indicator species.

7.2 Candidate assemblages of organisms, communities, and habitats that can serve as ecological receptors include, but are not limited to (**3**, **4**, **8**, **10**,**11**):

7.2.1 Fish communities,

7.2.2 Benthic communities,

7.2.3 Avian communities,

7.2.4 Feeding guilds,

7.2.5 Wetland plant communities,

7.2.6 Terrestrial relict or protected communities and habitats,

7.2.7 Soil invertebrate and microbial communities, and

7.2.8 Other guilds, communities, and habitats of unique importance to the site.

7.3 If used, indicator species should be selected on the basis of potential effects, contaminant exposure, local abundance, habitat requirements, and trophic position (for example, herbivore, piscivorous bird) in the community, habitat or ecosystem being studied

(3, 4, 8, 11). Indicator species can be selected on the basis of site characteristic for all potentially complete exposure pathways, exposure areas, and a variety of trophic positions, as appropriate.

7.4 Mobility, seasonal migration and extent of exposure to the site and exposure areas associated with site releases should be considered, as appropriate, in selecting each receptor for the assessment.

8. Candidate Assessment Endpoints

8.1 Assessment endpoints may be stated qualitatively or quantitatively. Criteria for quantitative changes in specific candidate assessment endpoints are established during problem formulation through a dialog between the risk assessor and the risk manager. The list of possible ways to express assessment endpoints is potentially quite long (1-6,8, 9, 12, 13). The following subsections provide examples of assessment endpoints and examples of how to state them (in quotes following each list). Documentation of specific assessment endpoint statements is discussed in Section 12. Ecological significance relating to assessment endpoints is discussed in Reference (14).

8.2 Candidate assessment endpoints at the ecosystem level of biological organization may include, but are not limited to:

8.2.1 Significant or a specific level of or percentage reduction in ecosystem productivity;

8.2.2 Significant or specific adverse changes in nutrient regeneration and cycling; and

8.2.3 Significant or specific adverse changes in energy flow.

8.2.4 An ecosystem-level assessment endpoint can be stated as "loss or diminishment of a specific ecological function (for example, nitrogen cycling)" or "degradation or destruction of a specific habitat associated with a site or release." The extent of loss of function or degree of change is established during problem formulation for the specific site characteristics, receptor species, and, if appropriate, reference site conditions.

8.3 Candidate assessment endpoints at the community level of biological organization include, but are not limited to:

8.3.1 A significant (or specific percentage) reduction in species diversity/richness;

8.3.2 Significant (or specific) adverse changes in the structure of a specific food web or plant community;

8.3.3 A significant (or specific) reduction in the market value of a specific sport or recreational fishery; and

8.3.4 A significant (or specific) reduction in aesthetic value of a habitat or community.

8.3.5 Community-level assessment endpoints can be stated as "a significant (or specific) reduction in the species richness of a benthic community" or "a significant (or specific) reduction in the yield and quality of a stream fishery." A specific reduction criterion can be established during problem formulation.

8.4 Candidate assessment endpoints at the population level of biological organization include, but are not limited to:

8.4.1 A significant (or specific) reduction in population abundance;

8.4.2 A significant (or specific) lowering of reproductive success;

8.4.3 Changes in age, sex, and size structure that could lead to significant (or specific) reductions in population abundance; and

8.4.4 Local extinction in a defined area.

8.4.5 Population-level assessment endpoints can be stated as "absence of a species normally expected to occur in the vicinity of the site" or "reduction of a population or subpopulation by pre-defined criteria attributable to contaminants associated with the site." Specific criteria for the changes listed above are developed during problem formulation.