Ecological Soil Screening Levels for Beryllium
Interim Final
OSWER Directive 9285.7-64

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
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Washington, DC 20460

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1.0 INTRODUCTION

Ecological Soil Screening Levels (Eco-SSLs) are concentrations of contaminants in soil that are protective of ecological receptors that commonly come into contact with and/or consume biota that live in or on soil. Eco-SSLs are derived separately for four groups of ecological receptors: plants, soil invertebrates, birds, and mammals. As such, these values are presumed to provide adequate protection of terrestrial ecosystems. Eco-SSLs are derived to be protective of the conservative end of the exposure and effects species distribution, and are intended to be applied at the screening stage of an ecological risk assessment. These screening levels should be used to identify the contaminants of potential concern (COPCs) that require further evaluation in the site-specific baseline ecological risk assessment that is completed according to specific guidance (U.S. EPA, 1997, 1998, and 1999). The Eco-SSLs are not designed to be used as cleanup levels and the United States (U.S.) Environmental Protection Agency (EPA) emphasizes that it would be inappropriate to adopt or modify the intended use of these Eco-SSLs as national cleanup standards.

The detailed procedures used to derive Eco-SSL values are described in separate documentation (US EPA, 2003). The derivation procedures represent the collaborative effort of a multi-stakeholder group consisting of federal, state, consulting, industry, and academic participants led by the U.S. EPA, Office of Solid Waste and Emergency Response.

This document provides the Eco-SSL values for beryllium and the documentation for their derivation. This document provides guidance and is designed to communicate national policy on identifying beryllium concentrations in soil that may present an unacceptable ecological risk to terrestrial receptors. The document does not, however, substitute for EPA’s statutes or regulations, nor is it a regulation itself. Thus, it does not impose legally-binding requirements on EPA, states, or the regulated community, and may not apply to a particular situation based upon the circumstances of the site. EPA may change this guidance in the future, as appropriate. EPA and state personnel may use and accept other technically sound approaches, either on their own initiative, or at the suggestion of potentially responsible parties, or other interested parties. Therefore, interested parties are free to raise questions and objections about the substance of this document and the appropriateness of the application of this document to a particular situation. EPA welcomes public comments on this document at any time and may consider such comments in future revisions of this document.

2.0 SUMMARY OF ECO-SSLs FOR BERYLLIUM

Beryllium occurs naturally in the earth's crust, in coal, and in minerals, such as beryl, bertrandite, bromellite, chrysoberyl, and beryllonite. Plagioclase feldspar contains most of the world's beryllium. The greatest known concentrations of beryllium are found in certain pegmatite bodies, where crystals of beryl account for a few percent of the total pegmatite volume, and may be found in several of the strata of zoned dykes. The element is sometimes concentrated in hydrothermal veins, and some granitic rocks contain sufficient amounts to permit the crystallization of small

Data concerning the fate of beryllium in the environment are limited. Since the major source of atmospheric beryllium is coal combustion, the most prevalent chemical form is probably beryllium oxide, mainly bound to particles smaller than 1 µm. The residence time of these particles in the atmosphere is about 10 days (US EPA, 1987). Beryllium returns to earth by wet and dry deposition in a similar manner to other metals and on particles of comparable size distribution (Kwapulinski & Pastuszka, 1983 as cited in IPCS, 1990).

Reactions of beryllium in solution and soil depend on the pH. At environmental pH ranges of 4 to 8, beryllium oxide is highly insoluble, thus preventing mobilization in soil. Beryllium is strongly adsorbed by finely dispersed sedimentary materials including clays, iron hydroxides, and organic substances (Izmerov, 1985). Thus, very little is released into ground water during weathering. If beryllium oxide is converted to the ionized salts (chloride, sulfate, nitrate) during atmospheric transport, solubility upon deposition and, hence, mobility in soils would be greatly enhanced, but this has not been reported in the literature as cited in IPCS, 1990.

If beryllium is bioavailable in the soil matrices, it can be assimilated by plants. Beryllium is classified as a fast-exchange metal, and can potentially interfere with the transport of nutritive metals, such as calcium, into eukaryotic cells (Wood & Wang, 1983). Although there is a lack of data on beryllium levels in environmental organisms representing high trophic levels and on the fate of beryllium in ecosystems, it is not believed to biomagnify within food chains. Some plant species, however, including hickory trees (Carya spp.), act as accumulators of beryllium (Griffitts, 1977; Nikonova, 1967, Sainsbury et al., 1968), and plant ash may contain greater amounts of beryllium in comparison to soil as cited in IPCS, 1990.

Eco-SSL values for beryllium were derived for soil invertebrates and mammalian wildlife (Table 2.1). Eco-SSL values for beryllium could not be derived for plants or avian wildlife. For these receptor groups, data were insufficient to derive soil screening values. The Eco-SSLs for beryllium are 21 mg/kg dry weight (dw) for mammalian wildlife and 40 mg/kg dw for soil invertebrates. The Eco-SSLs are higher than the reported range of background soil concentrations in eastern and western U.S. soils (Figure 2.1). The reported background concentrations of many metals in U.S. soils are described in Attachment 1-4 of the Eco-SSL guidance (U.S. EPA, 2003).

<table>
<thead>
<tr>
<th>Plants</th>
<th>Soil Invertebrates</th>
<th>Avian Wildlife</th>
<th>Mammalian Wildlife</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>40</td>
<td>NA</td>
<td>21</td>
</tr>
</tbody>
</table>

NA = Not Available. Data were insufficient to derive an Eco-SSL.
3.0 ECO-SSL FOR TERRESTRIAL PLANTS

Of the papers identified from the literature search process, 32 were selected for acquisition for further review. Of those papers acquired, three met all 11 Study Acceptance Criteria. Each of these papers was reviewed and the studies were scored according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 3-2). Five studies received an Evaluation Score greater than ten. These studies are listed in Table 3.1. There was only one study result with an acceptable endpoint; the other four results are unbounded lowest observed adverse effect concentrations (LOAECs) which cannot be used to derive an Eco-SSL. Therefore, an Eco-SSL could not be derived for beryllium for plants according to the Eco-SSL guidance (US EPA, 2003; Attachment 3-2).

4.0 ECO-SSL FOR SOIL INVERTEBRATES

Of the papers identified from the literature search process, six were selected for acquisition for further review. Of those papers acquired, three met all 11 Study Acceptance Criteria. Each of these papers was reviewed and the studies were scored according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 3-2). Three studies received an Evaluation Score greater than ten. These studies are listed in Table 4.1. The studies in Table 4.1 are sorted by bioavailability score and all three studies are used to derive the soil invertebrate Eco-SSL according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 3-2). The Eco-SSL is the geometric mean of the EC20 values reported for each of three test species and is equal to 40 mg/kg dw.

5.0 ECO-SSL FOR AVIAN WILDLIFE

The literature search completed according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-2) identified 167 studies with possible toxicity data for beryllium for mammalian species. There were no studies identified for the toxicity of beryllium to avian species; therefore an Eco-SSL could not be derived for beryllium.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Study ID</th>
<th>Test Organism</th>
<th>Soil pH</th>
<th>OM%</th>
<th>Bio-availability Score</th>
<th>ERE</th>
<th>Tox Parameter</th>
<th>Tox Value Soil Conc. (mg/kg dw)</th>
<th>Total Evaluation Score</th>
<th>Eligible for Eco-SSL Derivation?</th>
<th>Used for Eco-SSL?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaplan, D.I., 1990</td>
<td>a</td>
<td>Kale, <em>Brassica oleracea v.acephalia L.</em></td>
<td>6.5</td>
<td>1.9</td>
<td>2</td>
<td>GRO</td>
<td>MATC</td>
<td>56.8</td>
<td>16</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Sajwan, K.S., 1996</td>
<td>a</td>
<td>Soybean, <em>Glycine max</em></td>
<td>4.9</td>
<td>1.9</td>
<td>2</td>
<td>GRO</td>
<td>LOAEC</td>
<td>25</td>
<td>12</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Sajwan, K.S., 1996</td>
<td>b</td>
<td>Soybean, <em>Glycine max</em></td>
<td>6.5</td>
<td>1.9</td>
<td>2</td>
<td>GRO</td>
<td>LOAEC</td>
<td>25</td>
<td>12</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Sajwan, K.S., 1996</td>
<td>c</td>
<td>Soybean, <em>Glycine max</em></td>
<td>5.5</td>
<td>3.2</td>
<td>2</td>
<td>GRO</td>
<td>LOAEC</td>
<td>25</td>
<td>12</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Sajwan, K.S., 1996</td>
<td>d</td>
<td>Soybean, <em>Glycine max</em></td>
<td>6.0</td>
<td>3.2</td>
<td>1</td>
<td>GRO</td>
<td>LOAEC</td>
<td>25</td>
<td>12</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

ERE = Ecologically relevant endpoint
GRO = growth
LOAEC = Lowest observed adverse effect concentration
MATC = Maximum acceptable toxicant concentration. Geometric mean of NOAEC and LOAEC.
N = No
NOAEC = No observed adverse effect concentration
OM = Organic matter content
Y = yes
### Table 4.1 Invertebrate Toxicity Data - Beryllium

<table>
<thead>
<tr>
<th>Reference</th>
<th>IP Number</th>
<th>Test Organism</th>
<th>Soil pH</th>
<th>OM%</th>
<th>Bio-availability Score</th>
<th>ERE</th>
<th>Tox Parameter</th>
<th>Soil Conc. (mg/kg dw)</th>
<th>Total Evaluation Score</th>
<th>Eligible for Eco-SSL Derivation?</th>
<th>Used for Eco-SSL?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuperman et al., 2002</td>
<td>62344</td>
<td>Pot worm <em>Enchytraeus crypticus</em></td>
<td>4.29 - 5.29</td>
<td>1.2</td>
<td>2</td>
<td>REP</td>
<td>EC20</td>
<td>45</td>
<td>17</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Phillips et al., 2002</td>
<td>62345</td>
<td>Springtail <em>Folsomia candida</em></td>
<td>4.29 - 5.29</td>
<td>1.2</td>
<td>2</td>
<td>REP</td>
<td>EC20</td>
<td>28</td>
<td>18</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Simini et al., 2002</td>
<td>62343</td>
<td>Earthworm <em>Eisenia fetida</em></td>
<td>3.83 - 5.29</td>
<td>1.2</td>
<td>2</td>
<td>REP</td>
<td>EC20</td>
<td>52</td>
<td>16</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

EC\textsubscript{20} = Effect concentration for 20% of test population  
ERE = Ecologically relevant endpoint  
OM = Organic matter content  
REP = Reproduction  
Y = yes  

6.0 ECO-SSL FOR MAMMALIAN WILDLIFE

The derivation of the Eco-SSL for mammalian wildlife was completed as two parts. First, the toxicity reference value (TRV) was derived according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-5). Second, the Eco-SSL (soil concentration) was back-calculated for each of three surrogate species based on the wildlife exposure model and the TRV (U.S. EPA, 2003).

6.1 Mammalian TRV

The literature search completed according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-2) identified 167 studies with possible toxicity data for mammalian species. Of these studies, 163 were rejected for use as described in Section 7.5. The remaining papers four papers were reviewed and the studies were scored according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-3). The results of the data extraction and review are summarized in Table 6.1. The complete results are included as Appendix 6-1.

There are six results for biochemical (BIO), pathology (PTH), growth (GRO), and survival (MOR) endpoints with a total Data Evaluation Score of > 65 that are used to derive the TRV (U.S. EPA, 2003; Attachment 4-4). These data are plotted in Figure 6.1 and correspond directly with the data presented in Table 6.1. The no-observed adverse effect level (NOAEL) results for growth and reproduction are used to calculate a geometric mean NOAEL. This mean NOAEL is examined in relationship to the lowest bounded lowest-observed adverse effect level (LOAEL) for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-5).

A geometric mean of the NOAEL values for growth and reproduction could not be calculated as only one NOAEL is available for growth or reproductive effects. There are no bounded LOAELs for comparison. Therefore, the TRV is equal to the lowest NOAEL for effects on growth, reproduction, or survival which is equal to 0.532 mg beryllium/kg bw/day.

6.2 Estimation of Dose and Calculation of the Eco-SSL

Three separate Eco-SSL values were calculated for mammalian wildlife, one for each of three surrogate receptor species representing different trophic groups. The mammalian Eco-SSLs derived for beryllium were calculated according to Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-5) and are summarized in Table 6.2.
Table 6.1  Mammalian Toxicity Data Extracted for Wildlife Toxicity Reference Value (TRV)
Beryllium

<table>
<thead>
<tr>
<th>Result #</th>
<th>Reference</th>
<th>Test Organism</th>
<th>Method of Analyses</th>
<th>Route of Exposure</th>
<th>Exposure Duration</th>
<th>Exposure Duration Units</th>
<th>Age</th>
<th>Age Units</th>
<th>Lifestage</th>
<th>Sex</th>
<th>Effect Type</th>
<th>Effect Measure</th>
<th>Response Site</th>
<th>NOAEL Dose (mg/kg bw/day)</th>
<th>LOAEL Dose (mg/kg bw/day)</th>
<th>Data Evaluation Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Goel et al, 1980</td>
<td>Rat (Rattus norvegicus)</td>
<td>U OR</td>
<td>75 d</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
<td>M</td>
<td>ENZ</td>
<td>ALPH</td>
<td>LU</td>
<td>0.478</td>
<td>74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Goel et al, 1980</td>
<td>Rat (Rattus norvegicus)</td>
<td>U OR</td>
<td>75 d</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
<td>M</td>
<td>HIS</td>
<td>GHIS</td>
<td>LU</td>
<td>0.478</td>
<td>77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Freundt and Ibrahim, 1990</td>
<td>Rat (Rattus norvegicus)</td>
<td>U DR</td>
<td>91 d</td>
<td>NR</td>
<td>NR</td>
<td>SM</td>
<td>F</td>
<td>GRO</td>
<td>BDWT</td>
<td>WO</td>
<td>0.953</td>
<td>72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Schroeder and Mitchener, 1975</td>
<td>Rat (Rattus norvegicus)</td>
<td>U DR</td>
<td>39 d</td>
<td>21 d</td>
<td>JV</td>
<td>M</td>
<td>GRO</td>
<td>BDWT</td>
<td>WO</td>
<td>0.630</td>
<td>72</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Schroeder and Mitchener, 1975</td>
<td>Mouse (Mus musculus)</td>
<td>U DR</td>
<td>70 d</td>
<td>19-20 d</td>
<td>JV</td>
<td>F</td>
<td>GRO</td>
<td>BDWT</td>
<td>WO</td>
<td>0.718</td>
<td>72</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Schroeder and Mitchener, 1975</td>
<td>Rat (Rattus norvegicus)</td>
<td>U DR</td>
<td>1464 d</td>
<td>21 d</td>
<td>JV</td>
<td>B</td>
<td>MOR</td>
<td>LFSP</td>
<td>WO</td>
<td>0.532</td>
<td>73</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ALPH = alkaline phosphatase;  B = both; BDWT = body weight changes; bw = body weight; d = days; DR = drinking water; ENZ = enzyme; F = female; GHIS = general histological changes; GRO = Growth; HIS = histology; JV = juvenile; kg = kilogram; LFSP = lifespan; LOAEL = lowest observed adverse effect level; LU = lung; M = male; mg = milligram; mo = months; MOR = effects on survival; NOAEL = no observed adverse effect level; NR = not reported; OR = other oral (e.g. capsule); Score = Total Data Evaluation Score as described in US EPA (2003; Attachment 4-3); SM = sexually mature; U = unmeasured; WO = whole organism.
1) There are at least three results available for two test species within the growth, reproduction, and mortality effect groups. There are enough data to derive a TRV.

2) There are not three NOAEL results available for calculation of a geometric mean.

4) There is one NOAEL value for reproduction or growth effects.

5) There are no bounded LOAELs for comparison. The TRV is equal to the lowest NOAEL for effects on growth, reproduction, or survival.

6) The mammalian wildlife TRV for beryllium is equal to 0.532 mg beryllium/kg bw/day which is the lowest NOAEL for effects on growth, reproduction, and survival.
Table 6.2 Calculation of the Mammalian Eco-SSL for Beryllium

<table>
<thead>
<tr>
<th>Surrogate Receptor Group</th>
<th>TRV for Beryllium (mg dw/kg bw/d)</th>
<th>Food Ingestion Rate (FIR)² (kg dw/kg bw/d)</th>
<th>Soil Ingestion as Proportion of Diet (Pₛ)²</th>
<th>Concentration of Beryllium in Biota Type (i)²,³ (Bᵢ) (mg/kg dw)</th>
<th>Beryllium in Diet of Prey⁴ (Cᵢₚₑᵢ)</th>
<th>Eco-SSL (mg/kg dw)⁵</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammalian herbivore (vole)</td>
<td>0.532</td>
<td>0.0875</td>
<td>0.032</td>
<td>ln(Bᵢ) = 0.7345 * ln(Soilᵢ) - 0.5361 where i = plants</td>
<td>NA</td>
<td>21</td>
</tr>
<tr>
<td>Mammalian ground insectivore (shrew)</td>
<td>0.532</td>
<td>0.209</td>
<td>0.030</td>
<td>Bᵢ = 0.045 * Soilᵢ where i = earthworms</td>
<td>NA</td>
<td>34</td>
</tr>
<tr>
<td>Mammalian carnivore (weasel)</td>
<td>0.532</td>
<td>0.130</td>
<td>0.043</td>
<td>Bᵢ = Cᵢₚₑᵢ * 0.05 where i = mammals</td>
<td>Cᵢₚₑᵢ = 0.045 * Soilᵢ</td>
<td>90</td>
</tr>
</tbody>
</table>

¹ The process for derivation of wildlife TRVs is described in Attachment 4-5 of U.S. EPA (2003).
² Parameters (FIR, Pₛ, Bᵢ values, regressions) are provided in U.S. EPA (2003) Attachment 4-1 (revised February 2005).
³ Bᵢ = Concentration in biota type (i) which represents 100% of the diet for the respective receptor.
⁴ Cᵢₚₑᵢ = Concentration in the diet of small mammals consumed by predatory species (weasel).
⁵ HQ = FIR * (Soilᵢ + Bᵢ) / TRV solved for HQ=1 where Soilᵢ = Eco-SSL (Equation 4-2; U.S. EPA, 2003).
NA = Not Applicable
This Page Intentionally Left Blank
7.0 REFERENCES

7.1 General Beryllium References


7.2 References for Plants and Soil Invertebrates


### 7.3 References Rejected for Use in Deriving Plant and Soil Invertebrate Eco-SSLs

These references were reviewed and rejected for use in derivation of the Eco-SSL. The definition of the codes describing the basis for rejection is provided at the end of the reference sections.

**Not Avail**


**OM**


**OM**


**Media**


**Species**


**Mix**


**Media**


**No Dur**


**No Dur**


**FL**


Romney, E. M. and Childress, J. D. 1965. Effects of Beryllium in Plants and Soil. Soil Sci. 100[3], 210-217


7.4 References Used to Derive the Wildlife TRV


7.5 References Rejected for Use in Derivation of Wildlife TRV

These references were reviewed and rejected for use in derivation of the Eco-SSL. The definition of the codes describing the basis for rejection is provided at the end of the reference sections.

Diss Some changes produced in growth reproduction, blood and urine of rats by salts of zinc with certain observations on the effects of cadmium and beryllium salts

Diss A study of the chemistry and mutagenicity of welding fume 910380.


FL Abd El-Fadil Ibrahim Hassan, H. 1988. Influence of the heavy metals lead, cadmium, zinc, manganese, copper, mercury and beryllium on the glutathione S-transferases in the rat liver. *<Original> Einfluss der Schwermetalle Pb, Cd, Zn, Mn, Cu, Hg und Be Blei, Cadmium, Zink, Mangan, Kupfer, Quecksilber und Beryllium auf die Glutathion-S-Transferasen der Rattenleber*


Berencsi, G. and Nagymajtenyi, L. 1977. [Pulmonary injury of mice produced by chronically peroral treatment with different substances (author's transl)] Zentralblatt fur Bakteriologie, Parasitenkunde, Infektionskrankheiten


Species

Species
Final rept.

FL

No Oral

No Oral

No Oral

Mix

FL

Unrel

In Vit

Unrel

Unrel

FL
Gueulette, J., Breteau, N., Sabattier, R., and Wambersie, A. 1982. [Relative biological effectiveness (RBE) of d(50)-Be neutrons (Louvain-la-Neuve) and p(34)-Be neutrons (Orleans) for early intestinal tolerance in mice]. <Original> Efficacite biologique relative (EBR) des neutrons d(50)-Be (Louvain-la-Neuve) et des neutrons p(34)-Be (Orleans) pour la tolerance intestinale precoce chez la souris. Comptes rendus des seances de la Societe de biologie et de ses filiales

FL


FL Hulliger, L., Pohler, O., and Straumann, F. 1967. [Influence of some pure metals and alloys on the growth of rabbit fibrocytes in tissue culture]. <Original> Einfluss einiger reiner Metalle und Legierungen auf das Wachstum von Kaninchenfibrocyten in Gewebekulturen. Zeitschrift fur die gesamte experimentelle Medizin einschliesslich


Surv    LaDelfe, C. M.  1981.  Detailed Geochemical Survey Data Release for the San Andres-Oscura Mountains Special Study Area, New Mexico.  GJBX-215-81; LA-8016-MS


FL

No Oral

No Oral

No Oral

No Oral

No COC

FL

FL

No Oral

Chem Meth

Chem Meth

Prim

No Oral

No Oral
dental alloys free of precious metals]. <Original> Experimentelle Untersuchungen zur
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<table>
<thead>
<tr>
<th>Rejection Criteria</th>
<th>Description</th>
<th>Receptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT (Abstract)</td>
<td>Abstracts of journal publications or conference presentations.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>ACUTE STUDIES (Acu)</td>
<td>Single oral dose or exposure duration of three days or less.</td>
<td>Wildlife</td>
</tr>
<tr>
<td>AIR POLLUTION (Air P)</td>
<td>Studies describing the results for air pollution studies.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>ALTERED RECEPTOR (Alt)</td>
<td>Studies that describe the effects of the contaminant on surgically-altered or chemically-modified receptors (e.g., right nephrectomy, left renal artery ligation, hormone implant, etc.).</td>
<td>Wildlife</td>
</tr>
<tr>
<td>AQUATIC STUDIES (Aquatic)</td>
<td>Studies that investigate toxicity in aquatic organisms.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>ANATOMICAL STUDIES (Anat)</td>
<td>Studies of anatomy. Instance where the contaminant is used in physical studies (e.g., silver nitrate staining for histology).</td>
<td>Wildlife</td>
</tr>
<tr>
<td>BACTERIA (Bact)</td>
<td>Studies on bacteria or susceptibility to bacterial infection.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>BIOACCUMULATION SURVEY (Bio Acc)</td>
<td>Studies reporting the measurement of the concentration of the contaminant in tissues.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>BIOLOGICAL PRODUCT (BioP)</td>
<td>Studies of biological toxicants, including venoms, fungal toxins, Bacillus thuringiensis, other plant, animal, or microbial extracts or toxins.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
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<tr>
<td>BIOMARKER (Biom)</td>
<td>Studies reporting results for a biomarker having no reported association with an adverse effect and an exposure dose (or concentration).</td>
<td>Wildlife</td>
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<tr>
<td>CARCINOGENICITY STUDIES (Carcin)</td>
<td>Studies that report data only for carcinogenic endpoints such as tumor induction. Papers that report systemic toxicity data are retained for coding of appropriate endpoints.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>CHEMICAL METHODS (Chem Meth)</td>
<td>Studies reporting methods for determination of contaminants, purification of chemicals, etc. Studies describing the preparation and analysis of the contaminant in the tissues of the receptor.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
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<tr>
<td>CONFERENCE PROCEEDINGS (CP)</td>
<td>Studies reported in conference and symposium proceedings.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>DEAD (Dead)</td>
<td>Studies reporting results for dead organisms. Studies reporting field mortalities with necropsy data where it is not possible to establish the dose to the organism.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>DISSERTATIONS (Diss)</td>
<td>Dissertations are excluded. However, dissertations are flagged for possible future use.</td>
<td>Wildlife</td>
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<tr>
<td>DRUG (Drug)</td>
<td>Studies reporting results for testing of drug and therapeutic effects and side-effects. Therapeutic drugs include vitamins and minerals. Studies of some minerals may be included if there is potential for adverse effects.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>DUPLICATE DATA (Dup)</td>
<td>Studies reporting results that are duplicated in a separate publication. The publication with the earlier year is used.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>Rejection Criteria</td>
<td>Description</td>
<td>Receptor</td>
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<tr>
<td>------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
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<tr>
<td>ECOLOGICAL INTERACTIONS (Ecol)</td>
<td>Studies of ecological processes that do not investigate effects of contaminant exposure (e.g., studies of “silver” fox natural history; studies on ferrets identified in iron search).</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>EFFLUENT (Effl)</td>
<td>Studies reporting effects of effluent, sewage, or polluted runoff.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>ECOLOGICALLY RELEVANT ENDPOINT (ERE)</td>
<td>Studies reporting a result for endpoints considered as ecologically relevant but is not used for deriving Eco-SSLs (e.g., behavior, mortality).</td>
<td>Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>CONTAMINANT FATE/METABOLISM (Fate)</td>
<td>Studies reporting what happens to the contaminant, rather than what happens to the organism. Studies describing the intermediary metabolism of the contaminant (e.g., radioactive tracer studies) without description of adverse effects.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>FOREIGN LANGUAGE (FL)</td>
<td>Studies in languages other than English.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>FOOD STUDIES (Food)</td>
<td>Food science studies conducted to improve production of food for human consumption.</td>
<td>Wildlife</td>
</tr>
<tr>
<td>FUNGUS (Fungus)</td>
<td>Studies on fungus.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>GENE (Gene)</td>
<td>Studies of genotoxicity (chromosomal aberrations and mutagenicity).</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>HUMAN HEALTH (HHE)</td>
<td>Studies with human subjects.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
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<tr>
<td>IMMUNOLOGY (IMM)</td>
<td>Studies on the effects of contaminants on immunological endpoints.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
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<tr>
<td>INVERTEBRATE (Invert)</td>
<td>Studies that investigate the effects of contaminants on terrestrial invertebrates are excluded.</td>
<td>Wildlife</td>
</tr>
<tr>
<td>IN VITRO (In Vit)</td>
<td>In vitro studies, including exposure of cell cultures, excised tissues and/or excised organs.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>LEAD SHOT (Lead shot)</td>
<td>Studies administering lead shot as the exposure form. These studies are labeled separately for possible later retrieval and review.</td>
<td>Wildlife</td>
</tr>
<tr>
<td>MEDIA (Media)</td>
<td>Authors must report that the study was conducted using natural or artificial soil. Studies conducted in pore water or any other aqueous phase (e.g., hydroponic solution), filter paper, petri dishes, manure, organic or histosols (e.g., peat muck, humus), are not considered suitable for use in defining soil screening levels.</td>
<td>Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>METHODS (Meth)</td>
<td>Studies reporting methods or methods development without usable toxicity test results for specific endpoints.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>MINERAL REQUIREMENTS (Mineral)</td>
<td>Studies examining the minerals required for better production of animals for human consumption, unless there is potential for adverse effects.</td>
<td>Wildlife</td>
</tr>
<tr>
<td>MIXTURE (Mix)</td>
<td>Studies that report data for combinations of single toxicants (e.g. cadmium and copper) are excluded. Exposure in a field setting from contaminated natural soils or waste application to soil may be coded as Field Survey.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>Rejection Criteria</td>
<td>Description</td>
<td>Receptor</td>
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<td>-------------------------------------------</td>
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</tr>
<tr>
<td>MODELING (Model)</td>
<td>Studies reporting the use of existing data for modeling, i.e., no new organism toxicity data are reported. Studies which extrapolate effects based on known relationships between parameters and adverse effects.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO CONTAMINANT OF CONCERN (No COC)</td>
<td>Studies that do not examine the toxicity of Eco-SSL contaminants of concern.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO CONTROL (No Control)</td>
<td>Studies which lack a control or which have a control that is classified as invalid for derivation of TRVs.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO DATA (No Data)</td>
<td>Studies for which results are stated in text but no data is provided. Also refers to studies with insufficient data where results are reported for only one organism per exposure concentration or dose (wildlife).</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO DOSE or CONC (No Dose)</td>
<td>Studies with no usable dose or concentration reported, or an insufficient number of doses/concentrations are used based on Eco-SSL SOPs. These are usually identified after examination of full paper. This includes studies which examine effects after exposure to contaminant ceases. This also includes studies where offspring are exposed in utero and/or lactation by doses to parents and then after weaning to similar concentrations as their parents. Dose cannot be determined.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO DURATION (No Dur)</td>
<td>Studies with no exposure duration. These are usually identified after examination of full paper.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO EFFECT (No Efect)</td>
<td>Studies with no relevant effect evaluated in a biological test species or data not reported for effect discussed.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO ORAL (No Oral)</td>
<td>Studies using non-oral routes of contaminant administration including intraperitoneal injection, other injection, inhalation, and dermal exposures.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO ORGANISM (No Org) or NO SPECIES</td>
<td>Studies that do not examine or test a viable organism (also see in vitro rejection category).</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NOT AVAILABLE (Not Avail)</td>
<td>Papers that could not be located. Citation from electronic searches may be incorrect or the source is not readily available.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NOT PRIMARY (Not Prim)</td>
<td>Papers that are not the original compilation and/or publication of the experimental data.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO TOXICANT (No Tox)</td>
<td>No toxicant used. Publications often report responses to changes in water or soil chemistry variables, e.g., pH or temperature. Such publications are not included.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NO TOX DATA (No Tox Data)</td>
<td>Studies where toxicant used but no results reported that had a negative impact (plants and soil invertebrates).</td>
<td>Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NUTRIENT (Nutrient)</td>
<td>Nutrition studies reporting no concentration related negative impact.</td>
<td>Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NUTRIENT DEFICIENCY (Nut def)</td>
<td>Studies of the effects of nutrient deficiencies. Nutritional deficient diet is identified by the author. If reviewer is uncertain then the administrator should be consulted. Effects associated with added nutrients are coded.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>NUTRITION (Nut)</td>
<td>Studies examining the best or minimum level of a chemical in the diet for improvement of health or maintenance of animals in captivity.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>OTHER AMBIENT CONDITIONS (OAC)</td>
<td>Studies which examine other ambient conditions: pH, salinity, DO, UV, radiation, etc.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>Rejection Criteria</td>
<td>Description</td>
<td>Receptor</td>
</tr>
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<td>-------------------</td>
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</tr>
<tr>
<td><strong>OIL (Oil)</strong></td>
<td>Studies which examine the effects of oil and petroleum products.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td><strong>OM, pH (OM, pH)</strong></td>
<td>Organic matter content of the test soil must be reported by the authors, but may be presented in one of the following ways; total organic carbon (TOC), particulate organic carbon (POC), organic carbon (OC), coarse particulate organic matter (CPOM), particulate organic matter (POM), ash free dry weight of soil, ash free dry mass of soil, percent organic matter, percent peat, loss on ignition (LOI), organic matter content (OMC). With the exception of studies on non-ionizing substances, the study must report the pH of the soil, and the soil pH should be within the range of 4 and 8.5. Studies that do not report pH or report pH outside this range are rejected.</td>
<td>Plants and Soil Invertebrates</td>
</tr>
<tr>
<td><strong>ORGANIC METAL (Org Met)</strong></td>
<td>Studies which examine the effects of organic metals. This includes tetraethyl lead, triethyl lead, chromium picolinate, phenylarsonic acid, roxarsone, 3-nitro-4-phenylarsionic acid, zinc phosphide, monomethylarsenic acid (MMA), dimethylarsenic acid (DMA), trimethylarsine oxide (TMAO), or arsenobetaine (AsBe) and other organo metallic fungicides. Metal acetates and methionines are not rejected and are evaluated.</td>
<td>Wildlife</td>
</tr>
<tr>
<td><strong>LEAD BEHAVIOR OR HIGH DOSE MODELS (Pb Behav)</strong></td>
<td>There are a high number of studies in the literature that expose rats or mice to high concentrations of lead in drinking water (0.1, 1 to 2% solutions) and then observe behavior in offspring, and/or pathology changes in the brain of the exposed dam and/or the progeny. Only a representative subset of these studies were coded. Behavior studies examining complex behavior (learned tasks) were also not coded.</td>
<td>Wildlife</td>
</tr>
<tr>
<td><strong>PHYSIOLOGY STUDIES (Phys)</strong></td>
<td>Physiology studies where adverse effects are not associated with exposure to contaminants of concern.</td>
<td>Wildlife</td>
</tr>
<tr>
<td><strong>PLANT (Plant)</strong></td>
<td>Studies of terrestrial plants are excluded.</td>
<td>Wildlife</td>
</tr>
<tr>
<td><strong>PRIMATE (Prim)</strong></td>
<td>Primate studies are excluded.</td>
<td>Wildlife</td>
</tr>
<tr>
<td><strong>PUBL AS (Publ as)</strong></td>
<td>The author states that the information in this report has been published in another source. Data are recorded from only one source. The secondary citation is noted as Publ As.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td><strong>QSAR (QSAR)</strong></td>
<td>Derivation of Quantitative Structure-Activity Relationships (QSAR) is a form of modeling. QSAR publications are rejected if raw toxicity data are not reported or if the toxicity data are published elsewhere as original data.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td><strong>REGULATIONS (Reg)</strong></td>
<td>Regulations and related publications that are not a primary source of data.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td><strong>REVIEW (Rev)</strong></td>
<td>Studies in which the data reported in the article are not primary data from research conducted by the author. The publication is a compilation of data published elsewhere. These publications are reviewed manually to identify other relevant literature.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>Rejection Criteria</td>
<td>Description</td>
<td>Receptor</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>SEDIMENT CONC (Sed)</td>
<td>Studies in which the only exposure concentration/dose reported is for the level of a toxicant in sediment.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>SCORE (Score)</td>
<td>Papers in which all studies had data evaluation scores at or lower then the acceptable cut-off (#10 of 18) for plants and soil invertebrates).</td>
<td>Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>SEDIMENT CONC (Sed)</td>
<td>Studies in which the only exposure concentration/dose reported is for the level of a toxicant in sediment.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>SLUDGE</td>
<td>Studies on the effects of ingestion of soils amended with sewage sludge.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>SOIL CONC (Soil)</td>
<td>Studies in which the only exposure concentration/dose reported is for the level of a toxicant in soil.</td>
<td>Wildlife</td>
</tr>
<tr>
<td>SPECIES</td>
<td>Studies in which the species of concern was not a terrestrial invertebrate or plant or mammal or bird.</td>
<td>Plants and Soil Invertebrates Wildlife</td>
</tr>
<tr>
<td>STRESSOR (QAC)</td>
<td>Studies examining the interaction of a stressor (e.g., radiation, heat, etc.) and the contaminant, where the effect of the contaminant alone cannot be isolated.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>SURVEY (Surv)</td>
<td>Studies reporting the toxicity of a contaminant in the field over a period of time. Often neither a duration nor an exposure concentration is reported.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>REPTILE OR AMPHIBIAN (Herp)</td>
<td>Studies on reptiles and amphibians. These papers flagged for possible later review.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>UNRELATED (Unrel)</td>
<td>Studies that are unrelated to contaminant exposure and response and/or the receptor groups of interest.</td>
<td>Wildlife</td>
</tr>
<tr>
<td>WATER QUALITY STUDY (Wqual)</td>
<td>Studies of water quality.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<tr>
<td>YEAST (Yeast)</td>
<td>Studies of yeast.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
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Appendix 6-1

Mammalian Toxicity Data Extracted and Reviewed for Wildlife Toxicity Reference Value (TRV) - Beryllium

February 2005
### Appendix 6.1 Mammalian Toxicity Data Extracted for Wildlife Toxicity Reference Value (TRV)

**Beryllium**

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Ref. No.</th>
<th>Chemical Form</th>
<th>MW%</th>
<th>Test Species</th>
<th>Test Location</th>
<th>Conc/Dose Units for Study</th>
<th>Conc/Dose</th>
<th>Route of Exposure</th>
<th>Exposure Duration</th>
<th>Duration Units</th>
<th>Age</th>
<th>Age Units</th>
<th>Lifestage</th>
<th>Sex</th>
<th>Control Type</th>
<th>Test Conditions</th>
<th>Data Evaluation Score</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>17115</td>
<td>Beryllium nitrate 6.77</td>
<td>Rat (Rattus norvegicus)</td>
<td>2</td>
<td>0/0.6 mg/organ/day</td>
<td>40 U OR 75 d NR NR JV M</td>
<td>2</td>
<td>BIO ENZ ALPH LU</td>
<td>1 3 Y</td>
<td>NOAEL/LOAEL</td>
<td>4 7 10 10 10 10 4 74</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>17115</td>
<td>Beryllium nitrate 6.77</td>
<td>Rat (Rattus norvegicus)</td>
<td>2</td>
<td>0/0.6 mg/organ/day</td>
<td>40 U OR 75 d NR NR JV M</td>
<td>2</td>
<td>PTH HIS GHS LU</td>
<td>1 3 Y</td>
<td>NOAEL/LOAEL</td>
<td>4 7 10 10 7 4 77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>17086</td>
<td>Beryllium sulfate 8.58</td>
<td>Rat (Rattus norvegicus)</td>
<td>2</td>
<td>0/100 mg/L</td>
<td>ADL U BR 91 d NR SMF</td>
<td>2</td>
<td>GRO GRO HDWT WQ 100</td>
<td>N 3.15 N 0.35 0.953</td>
<td>10 5 5 6 10</td>
<td>10 4 72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>17086</td>
<td>Beryllium sulfate 100</td>
<td>Rat (Rattus norvegicus)</td>
<td>2</td>
<td>0/5 mg/L</td>
<td>DLY U BR 39 d 21 d JV M</td>
<td>1</td>
<td>GRO GRO HDWT WQ 5.00</td>
<td>Y 0.090 N 0.11 0.650</td>
<td>10 5 5 6 8 10</td>
<td>10 4 72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1858</td>
<td>Beryllium sulfate 100</td>
<td>Mouse (Mus musculus)</td>
<td>2</td>
<td>0/5 mg/L</td>
<td>NR U OR 30 d 19-20 d JV T</td>
<td>1</td>
<td>GRO GRO HDWT WQ 5.00</td>
<td>Y 0.024 N 0.0035 0.718</td>
<td>10 5 5 6 8 10</td>
<td>10 4 72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>17086</td>
<td>Beryllium sulfate 100</td>
<td>Rat (Rattus norvegicus)</td>
<td>2</td>
<td>0/5 mg/L</td>
<td>DLY U BR 1464 d 21 d JV B</td>
<td>3</td>
<td>MOR MOR LFSP WQ 5.00</td>
<td>Y 0.486 N 0.052 0.532</td>
<td>10 5 5 6 9 10</td>
<td>10 4 73</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0/5 mg/L</td>
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<td>Y 0.497 N 0.053 0.531</td>
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<td>Mouse (Mus musculus)</td>
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<td>NR U OR 320 d 19-20 d JV B</td>
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<td>PTH HIS EDMA WQ 5.00</td>
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All abbreviations and definitions are used in coding studies are available from Attachment 4-3 of the Eco-SSL guidance (U.S. EPA 2003).