Ecological Soil Screening Levels
for
Cobalt
Interim Final
OSWER Directive 9285.7-67

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

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# TABLE OF CONTENTS

1.0 INTRODUCTION ................................................................. 1

2.0 SUMMARY OF ECO-SSLs FOR COBALT .................................. 2

3.0 ECO-SSL FOR TERRESTRIAL PLANTS ..................................... 3

4.0 ECO-SSL FOR SOIL INVERTEBRATES ................................... 3

5.0 ECO-SSL FOR AVIAN WILDLIFE ........................................... 5

5.1 Avian TRV ........................................................................ 5

5.2 Estimation of Dose and Calculation of the Eco-SSL .................. 5

6.0 ECO-SSL FOR MAMMALIAN WILDLIFE .................................. 8

6.1 Mammalian TRV ............................................................. 8

6.2 Estimation of Dose and Calculation of the Eco-SSL ................. 11

7.0 REFERENCES ................................................................. 12

7.1 General Cobalt References .................................................. 12

7.2 References Used for Derivation of Plant and Soil Invertebrate Eco-SSLs .................. 12

7.3 References Rejected for Use in Derivation of Plant and Soil Invertebrate Eco-SSLs ............................................................... 13

7.4 References Used for Derivation of Wildlife TRVs ..................... 23

7.5 References Rejected for Use in Derivation of Wildlife TRVs ........... 25
LIST OF TABLES

Table 2.1  Cobalt Eco-SSLs (mg/kg dry weight in soil) ............................. 2
Table 3.1  Plant Toxicity Data - Cobalt ......................................... 4
Table 5.1  Summary of Avian Toxicity Data Used to Derive TRV - Cobalt ............. 6
Table 5.2  Calculation of the Avian Eco-SSLs for Cobalt ........................... 8
Table 6.1  Summary of Mammalian Toxicity Data Used to Derive TRV - Cobalt ....... 9
Table 6.2  Calculation of the Mammalian Eco-SSLs for Cobalt .................. 11

LIST OF FIGURES

Figure 2.1  Typical Background Concentrations of Cobalt in U.S. Soils ............... 2
Figure 5.1  Avian TRV Derivation for Cobalt .................................... 7
Figure 6.1  Mammalian TRV Derivation for Cobalt .................................. 10

LIST OF APPENDICES

Appendix 5-1  Avian Toxicity Data Extracted and Reviewed for Wildlife Toxicity Reference Value (TRV) - Cobalt
Appendix 6-1  Mammalian Toxicity Data Extracted and Reviewed for Wildlife Toxicity Reference Value (TRV) - Cobalt
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 soil or ingest biota that live in or on soil. Eco-SSLs are derived separately for four groups of ecological receptors: plants, soil invertebrates, bird and mammals. As such, these values are presumed to provide adequate protection of terrestrial ecosystems. Eco-SSLs for wildlife are derived to be protective of the representative of the conservative end of the distribution in order to make estimates for local populations. The Eco-SSLs are conservative 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 these Eco-SSLs as cleanup standards.

The detailed procedures used to derive Eco-SSL values are described in separate documentation (U.S. 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 cobalt and the documentation for their derivation. This document provides guidance and is designed to communicate national policy on identifying cobalt 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.
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.

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This document provides the Eco-SSL values for cobalt and the documentation for their derivation. This document provides guidance and is designed to communicate national policy on identifying cobalt 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 COBALT

Cobalt belongs to Group VIII of the periodic classification of elements and shares properties with nickel and iron. Cobalt is a relatively rare element in the earth’s crust (0.0023%) and is usually found in association with other metals such as copper, nickel, manganese, and arsenic. Release of cobalt to the environment occurs via soil and natural dust, seawater spray, volcanic eruptions, forest fires, and other continental and marine biogenic emissions. Anthropogenic sources include fossil fuel burning, processing of cobalt-containing alloys, copper and nickel smelting and refining, sewage sludge, and agricultural use of phosphate fertilizers.

Cobalt is an essential trace metal that functions as a component of vitamin $B_{12}$. Vitamin $B_{12}$ acts as coenzyme in many enzymatic reactions, including some involved in hematopoiesis, and is essential to growth and normal neural function. Non-ruminant animals require dietary intake of cobalt in the physiologically active form of vitamin $B_{12}$. Intake of inorganic cobalt is sufficient to meet the nutritional requirements of ruminant animals, since ruminal microorganisms have the capacity to biosynthesize vitamin $B_{12}$ (Henry, 1995). No other essential functions of cobalt have been identified.

Although cobalt is an essential nutrient, excessive oral doses result in a variety of adverse responses. The best characterized toxic responses are increases in red blood cell counts (polycythemia), cardiomyopathy, and effects on the male reproductive system (Paternain et al., 1988; Haga et al., 1996; Pedigo and Vernon, 1993). In addition, reduced food and water intake and growth inhibition are commonly observed (Diaz et al., 1994a; 1994b). At present, the mechanisms underlying cobalt toxicity are poorly understood.

In the terrestrial environment, the availability of cobalt is primarily regulated by pH and is usually found in soils as divalent cobalt. At low pH it is oxidized to trivalent cobalt and often found associated with iron. Adsorption of divalent cobalt on soil colloids is high between pH 6 and 7, whereas leaching and plant uptake of cobalt are enhanced by a lower pH. Soil pH is very important in cobalt uptake by plants and phytotoxicity. More acidic soils sorb cobalt less strongly (http://toxnet.nlm.nih.gov).

The Eco-SSL values derived to date for cobalt are summarized in Table 2.1.

<table>
<thead>
<tr>
<th>Plants</th>
<th>Soil Invertebrates</th>
<th>Wildlife</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Avian</td>
</tr>
<tr>
<td>13</td>
<td>NA</td>
<td>120</td>
</tr>
</tbody>
</table>

NA = Not Available. Data were insufficient to derive an Eco-SSL.
Eco-SSL values for cobalt were derived for plants and avian and mammalian wildlife. Eco-SSL values for cobalt could not be derived for soil invertebrates as data were insufficient. The Eco-SSLs range from 13 mg/kg dry weight (dw) for plants to 230 mg/kg dw for mammalian wildlife. These concentrations are higher than the reported range of background soil concentrations in eastern and western U.S. soils (Figure 2.1). Background concentrations of many metals in U.S. soils are described in Attachment 1-4 of the Eco-SSL guidance (U.S. EPA, 2003).

3.0 ECO-SSL FOR TERRESTRIAL PLANTS

Of the papers identified from the literature search process, 152 were selected for acquisition for further review. Of those papers acquired, four met all 11 Study Acceptance Criteria (U.S. EPA 2003; Attachment 3-1). Each of these papers were reviewed and the studies were scored according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 3-2). Seven studies received an Evaluation Score greater than ten. These studies are summarized in Table 3.1.

The data in Table 3.1 are sorted by bioavailability score and all study results with a bioavailability score of two are used to derive the plant Eco-SSL for cobalt. Six separate studies are used to derive the plant 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 under two separate test conditions (pH and % organic matter (OM)) and is equal to 13 mg/kg dw.

4.0 ECO-SSL FOR SOIL INVERTEBRATES

A soil invertebrate Eco-SSL could not be derived for cobalt. Of the papers identified from the literature search process, 11 were acquired for further review. Of those acquired, none met all 11 Study Acceptance Criteria (U.S. EPA, 2003; Attachment 3-1).
<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 Eval. Score</th>
<th>Eligible for Eco-SSL Derivation?</th>
<th>Used for Eco-SSL?</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN &amp; Associates, Inc., 2000</td>
<td>a</td>
<td>Alfalfa</td>
<td>5.0</td>
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<td>GRO</td>
<td>EC$_{20}$</td>
<td>0.60</td>
<td>18</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>TN &amp; Associates, Inc., 2000</td>
<td>b</td>
<td>Barley</td>
<td>5.0</td>
<td>5.0</td>
<td>2</td>
<td>GRO</td>
<td>EC$_{20}$</td>
<td>29.8</td>
<td>18</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>TN &amp; Associates, Inc., 2000</td>
<td>c</td>
<td>Radish</td>
<td>5.0</td>
<td>5.0</td>
<td>2</td>
<td>GRO</td>
<td>EC$_{20}$</td>
<td>14.5</td>
<td>18</td>
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<td>Y</td>
</tr>
<tr>
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<td>Alfalfa</td>
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<td>0.1</td>
<td>2</td>
<td>GRO</td>
<td>EC$_{20}$</td>
<td>13.4</td>
<td>18</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>TN &amp; Associates, Inc., 2000</td>
<td>e</td>
<td>Barley</td>
<td>6.3</td>
<td>0.1</td>
<td>2</td>
<td>GRO</td>
<td>EC$_{20}$</td>
<td>36.4</td>
<td>18</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>TN &amp; Associates, Inc., 2000</td>
<td>f</td>
<td>Radish</td>
<td>6.3</td>
<td>0.1</td>
<td>2</td>
<td>GRO</td>
<td>EC$_{20}$</td>
<td>45.2</td>
<td>18</td>
<td>Y</td>
<td>Y</td>
</tr>
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<td>Data not Used to Derive Eco-SSL</td>
<td></td>
<td>Cotton</td>
<td>6.6</td>
<td>2.4</td>
<td>1</td>
<td>GRO</td>
<td>LOAEC</td>
<td>100</td>
<td>12</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

EC$_{20}$ = Effect concentration for 20% of test population  
ERE = Ecologically relevant endpoint  
GRO = growth  
NOAEC = No-observed adverse effect concentration  
LOAEC = Lowest-observed adverse effect concentration  
MATC = Maximum acceptable toxicant concentration. Geometric mean of NOAEC and LOAEC.  
N = No  
OM = Organic matter content  
Y = yes  
Bioavailability Score described in *Guidance for Developing Eco-SSLs* (USEPA, 2003)  
Total Evaluation Score described in *Guidance for Developing Eco-SSLs* (USEPA, 2003)
5.0 ECO-SSL FOR AVIAN WILDLIFE

The derivation of the Eco-SSL for avian 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).

5.1 Avian TRV

The literature search completed according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-2) identified 530 papers with possible toxicity data for either avian or mammalian species. Of these papers, 498 were rejected for use as described in Section 7.5. Of the remaining papers, 11 contained data for avian test species. These papers were reviewed and data were extracted and scored according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-3 and 4-4). The results of the data extraction and review are summarized in Table 5.1. The complete results are included as Appendix 5-1.

Within the 11 reviewed papers, there are 24 results for biochemical (BIO), behavioral (BEH), pathology (PTH), growth (GRO), and survival (MOR) effects that meet the Data Evaluation Score of >65 for use to derive the TRV (U.S. EPA 2003; Attachment 4-5). These data are plotted in Figure 5.1 and correspond directly with the data presented in Table 5.1. The no-observed adverse effect (NOAEL) values for growth and reproduction are used to calculate a geometric mean NOAEL. This result 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 was calculated at 7.61 mg cobalt/kg bw/day. This value is lower than the lowest bounded LOAEL for either growth or mortality results. Therefore, the TRV is equal to the geometric mean NOAEL at 7.61 mg cobalt/kg bw/day.

5.2 Estimation of Dose and Calculation of the Eco-SSL

Three separate Eco-SSL values were calculated for avian wildlife, one each for three surrogate species representing different trophic groups. The avian Eco-SSLs for cobalt were calculated according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-5) and are summarized in Table 5.2.
<table>
<thead>
<tr>
<th>Result #</th>
<th>Reference</th>
<th>Conc/Dose Units</th>
<th>Method of Analysis</th>
<th>Route of Exposure</th>
<th>Exposure Duration</th>
<th>Age Units</th>
<th>Age</th>
<th>LifeStage</th>
<th>Sex</th>
<th>Effect Group</th>
<th>Effect Measure</th>
<th>Response Site</th>
<th>NOAEL Dose (mg/kg/day)</th>
<th>LOAEL Dose (mg/kg/day)</th>
<th>Data Evaluation Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diaz et al., 1994</td>
<td>100</td>
<td>Chicken (Gallus domesticus)</td>
<td>U FD 42 d 1 d</td>
<td>JV B</td>
<td>BIO</td>
<td>RBCE</td>
<td>BL</td>
<td>0.920</td>
<td>4.59</td>
<td>74</td>
<td>13.0</td>
<td>29.0</td>
<td>85</td>
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</tr>
<tr>
<td>2</td>
<td>Ling et al., 1979</td>
<td>6666</td>
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<td>U FD 3 w 1 d</td>
<td>JV M</td>
<td>BIO</td>
<td>HMCT</td>
<td>BL</td>
<td>9.30</td>
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<td>M FD 14 d 1 d</td>
<td>JV M</td>
<td>BEH</td>
<td>FCNS</td>
<td>WO</td>
<td>13.0</td>
<td>29.0</td>
<td>85</td>
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<td>JV B</td>
<td>BEH</td>
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<td>Chicken (Gallus domesticus)</td>
<td>M FD 14 d 1 d</td>
<td>JV M</td>
<td>PTH</td>
<td>GLSN</td>
<td>WO</td>
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<td>29.0</td>
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<tr>
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<td>Chicken (Gallus domesticus)</td>
<td>U FD 42 d 1 d</td>
<td>JV B</td>
<td>PTH</td>
<td>ORWT</td>
<td>HE</td>
<td>4.59</td>
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<td>29.0</td>
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<tr>
<td>7</td>
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<td>JV M</td>
<td>PTH</td>
<td>GLSN</td>
<td>MB</td>
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<tr>
<td>8</td>
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<td>U FD 5 w 1 d</td>
<td>JV F</td>
<td>GRO</td>
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<td>JV M</td>
<td>GRO</td>
<td>BDWT</td>
<td>WO</td>
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<td>8.20</td>
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<td>29.0</td>
<td>85</td>
<td></td>
</tr>
<tr>
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<td>92</td>
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<td>U FD 2 w 1 d</td>
<td>JV B</td>
<td>GRO</td>
<td>BDWT</td>
<td>WO</td>
<td>4.29</td>
<td>8.59</td>
<td>82</td>
<td>13.0</td>
<td>29.0</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Paulov, 1971</td>
<td>91</td>
<td>Duck (Anas sp.)</td>
<td>U FD 8 d 2 d</td>
<td>JV NR</td>
<td>GRO</td>
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<td>WO</td>
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</tr>
<tr>
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<td>JV B</td>
<td>GRO</td>
<td>BDWT</td>
<td>WO</td>
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<tr>
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<td>JV M</td>
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</tbody>
</table>

B = both; BIO = biochemical; BL = blood; BDWT = body weight changes; BEH = behavior; bw = body weight; d = days; F = female; FCNS = food consumption; FD = food; g = grams; GLSN = gross lesions; GRO = growth; HE = heart; HMCT = hematocrit; IM = immature; JV = juvenile; kg = kilograms; LOAEL = lowest-observed adverse effect level; M = male; M = measured; MB = muscle and bone; mg = milligrams; MOR = effects on mortality and survival; MORT = mortality; NOAEL = No-Observed Adverse Effect Level; NR = Not reported; ORWT = organ weight changes; PTH = pathology; SURV = survival; U = unmeasured; w = weeks; WO = whole organism.
Wildlife TRV Derivation Process

1) There are at least three results available for two test species within the growth and survival effect groups. There are enough data to derive TRV. There is no data available on reproductive effects in avian species.

2) There are at least three NOAEL results available for calculation of a geometric mean.

3) The geometric mean of the NOAEL values for growth equals 7.61 mg cobalt/kg bw/day.

4) The geometric mean NOAEL value is lower than the lowest bounded LOAEL for growth or survival results.

5) The avian wildlife TRV for cobalt is equal to 7.61 mg cobalt/kg bw/day which is the geometric mean of the NOAEL values for growth.
Table 5.2 Calculation of the Avian Eco-SSLs for Cobalt

<table>
<thead>
<tr>
<th>Surrogate Receptor Group</th>
<th>TRV for Cobalt (mg dw/kg bw/d)</th>
<th>Food Ingestion Rate (FIR) (kg dw/kg bw/d)</th>
<th>Soil Ingestion as Proportion of Diet (Ps)</th>
<th>Concentration of Cobalt in Biota Type (i) (Bi) (mg/kg dw)</th>
<th>Eco-SSL (mg/kg dw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avian herbivore (dove)</td>
<td>7.61</td>
<td>0.190</td>
<td>0.139</td>
<td>B_i = 0.0075 * Soil_i where i = plants</td>
<td>270</td>
</tr>
<tr>
<td>Avian ground insectivore (woodcock)</td>
<td>7.61</td>
<td>0.214</td>
<td>0.164</td>
<td>B_i = 0.122 * Soil_i where i = earthworms</td>
<td>120</td>
</tr>
<tr>
<td>Avian carnivore (hawk)</td>
<td>7.61</td>
<td>0.0353</td>
<td>0.057</td>
<td>ln(B_i) = 1.307 * ln(Soil) - 4.4669 where i = mammals</td>
<td>1300</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, B_i values, regressions) are provided in U.S. EPA (2003) Attachment 4-1 (revised February 2005).
3 B_i = Concentration in biota type (i) which represents 100% of the diet for the respective receptor.
4 HQ = FIR * (Soil_i * Ps + Bi) / TRV) solved for HQ=1 where Soil_i = Eco-SSL (Equation 4-2; U.S. EPA, 2003).
NA = Not Applicable

6.0 ECO-SSL FOR MAMMALIAN WILDLIFE

The derivation of the Eco-SSL for mammalian wildlife was completed as two parts. First the 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 was completed according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-2) and identified 530 papers with possible toxicity data for cobalt for either avian or mammalian test species. Of these studies, 498 were rejected for use as described in Section 7.5. Of the remaining papers, 20 contained data for mammalian test species. These papers were reviewed and the data were extracted and scored according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-3 and 4-4). The results of the data extraction and review are summarized in Table 6.1. The complete results are provided in Appendix 6.1.

Within the 20 papers there are 38 results for biochemical (BIO), behavioral (BEH), physiology (PHY), pathology (PTH), reproduction (REP), growth (GRO), and survival (MOR) endpoints with a total Data Evaluation Score >65 that were used to derive the TRV (U.S. EPA 2003; Attachment 4-3). These data are plotted in Figure 6.1 and correspond directly with the data presented in Table 6.1. The NOAEL values for growth and reproduction are used to calculate a geometric mean NOAEL. This result is examined in relationship to the lowest bounded LOAEL for reproduction, growth and survival to derive the TRV according to procedures in the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-4).
Table 6.1 Mammalian Toxicity Data Extracted for Wildlife Toxicity Reference Value (TRV)

<table>
<thead>
<tr>
<th>Result #</th>
<th>Reference</th>
<th>Test Organism</th>
<th># of Conc/ Doses</th>
<th>Method of Analyses</th>
<th>Route of Exposure</th>
<th>Exposure Duration</th>
<th>General Effect Group</th>
<th>General Effect Measure</th>
<th>Response Site</th>
<th>Effect Measure</th>
<th>NOAEL Dose (mg/kg/day)</th>
<th>LOAEL Dose (mg/kg/day)</th>
<th>Data Evaluation Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maro et al., 1980</td>
<td>Cow (Bos taurus)</td>
<td>2</td>
<td>M</td>
<td>FD</td>
<td>45 d</td>
<td>7 mo</td>
<td>JV</td>
<td>F</td>
<td>BIO</td>
<td>HMGL</td>
<td>BL</td>
<td>0.300</td>
</tr>
<tr>
<td>2</td>
<td>Chetty et al., 1979</td>
<td>Rat (Rattus norvegicus)</td>
<td>6</td>
<td>U</td>
<td>FD</td>
<td>4 w</td>
<td>NR</td>
<td>NR</td>
<td>B</td>
<td>BIO</td>
<td>HMGL</td>
<td>BL</td>
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</tr>
<tr>
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<td>Kadiiska et al., 1985</td>
<td>Pig (Sus scrofa)</td>
<td>2</td>
<td>U</td>
<td>DR</td>
<td>30 d</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
<td>M</td>
<td>BIO</td>
<td>P450</td>
<td>LI</td>
</tr>
<tr>
<td>4</td>
<td>Derr et al., 1970</td>
<td>Rat (R. norvegicus)</td>
<td>2</td>
<td>U</td>
<td>DR</td>
<td>35 d</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
<td>M</td>
<td>BIO</td>
<td>HMCT</td>
<td>BL</td>
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<tr>
<td>5</td>
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<td>Rat (R. norvegicus)</td>
<td>2</td>
<td>U</td>
<td>FD</td>
<td>80 d</td>
<td>44 d</td>
<td>JV</td>
<td>M</td>
<td>BEH</td>
<td>NMVM</td>
<td>WO</td>
<td>1.47</td>
</tr>
<tr>
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<td>Pig (Sus scrofa)</td>
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<td>U</td>
<td>FD</td>
<td>28 d</td>
<td>NR</td>
<td>NR</td>
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<td>Rat (R. norvegicus)</td>
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<td>M</td>
<td>DR</td>
<td>57 d</td>
<td>80 d</td>
<td>JV</td>
<td>M</td>
<td>BEH</td>
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<td>M</td>
<td>PHY</td>
<td>Other</td>
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<td>44 d</td>
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<td>U</td>
<td>FD</td>
<td>4 w</td>
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<td>NR</td>
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<td>PTH</td>
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<td>PTH</td>
<td>BDWT</td>
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<td>Pig (Sus scrofa)</td>
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<td>10 w</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
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<td>NR</td>
<td>GE</td>
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<td>NR</td>
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<td>REP</td>
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<td>12 w</td>
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<td>M</td>
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<td>100 d</td>
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<td>100 d</td>
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<td>M</td>
<td>REP</td>
<td>TEWT</td>
<td>TE</td>
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<td>DR</td>
<td>13 w</td>
<td>12 w</td>
<td>MA</td>
<td>M</td>
<td>REP</td>
<td>TEWT</td>
<td>TE</td>
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<td>U</td>
<td>DR</td>
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<td>8 to 10 w</td>
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<td>PRFM</td>
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<td>7 mo</td>
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<td>44 d</td>
<td>JV</td>
<td>M</td>
<td>GRO</td>
<td>BDWT</td>
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<td>12 w</td>
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<td>M</td>
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<td>OR</td>
<td>5 w</td>
<td>NR</td>
<td>NR</td>
<td>MA</td>
<td>M</td>
<td>GRO</td>
<td>BDWT</td>
<td>WO</td>
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<td>57 d</td>
<td>80 d</td>
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<td>4 w</td>
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<td>NR</td>
<td>B</td>
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<td>GE</td>
<td>F</td>
<td>GRO</td>
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<td>NR</td>
<td>JR</td>
<td>JV</td>
<td>M</td>
<td>GRO</td>
<td>BDWT</td>
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<td>U</td>
<td>DR</td>
<td>13 w</td>
<td>12 w</td>
<td>MA</td>
<td>M</td>
<td>GRO</td>
<td>BDWT</td>
<td>WO</td>
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<td>U</td>
<td>DR</td>
<td>24 d</td>
<td>NR</td>
<td>JR</td>
<td>JV</td>
<td>M</td>
<td>GRO</td>
<td>BDWT</td>
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<td>NR</td>
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<td>5 d</td>
<td>NR</td>
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<td>GE</td>
<td>F</td>
<td>MOR</td>
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<td>2</td>
<td>U</td>
<td>OR</td>
<td>5 w</td>
<td>NR</td>
<td>MA</td>
<td>M</td>
<td>MOR</td>
<td>SURV</td>
<td>WO</td>
<td>20.0</td>
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</tbody>
</table>

ACTP = activity level; B = both; BDWT = body weight changes; BEH = behavior; BIO = biochemical; BL = blood; d = days; DR = Drinking water; F = female; FCNS = food consumption; FD = food; GE = gestation; GHIS = histologic; GLSN = gross lesions; GRO = growth; GV = gavage; HE = heart; HMCT = hematocrit; HMGL = hemoglobin; JV = juvenile; LI = liver; M = male; M = measured; MA = mature; mo = months; MOR = mortality, MORT = Mortality; NMVM = number of movements; NR = Not reported; OR = other oral; P450 = changes in cytochrome P450; PHY = physiology; PTH = pathology; PRFM = sexual performance; PROG = progeny count; PRWT = progeny weight; REP = reproduction; RSUC = reproductive success; SM = sexually mature; SMIX = weight relative to body weight; SURV = survival; TE = testes; TEGD = testes degeneration; TEWT = testes weight; TS = Thymus; U = unmeasured; w = weeks; WO = whole organism
1) There are at least three results available for two test species within the growth, reproduction and survival effect groups. There are enough data to derive TRV.

2) There are at least three NOAEL results available for calculation of a geometric mean.

3) The geometric mean of the NOAEL values for growth and reproduction equals 7.33 mg cobalt/kg BW/day.

4) The geometric mean NOAEL value is less than the lowest bounded LOAEL for reproduction, growth, or survival.

5) The mammalian wildlife TRV for cobalt is equal to 7.33 mg cobalt/kg BW/day.
A geometric mean of the NOAEL values for growth and reproduction was calculated at 7.33 mg cobalt/kg bw/day. This value is lower than the lowest bounded LOAEL for either reproductive, growth, or survival results. Therefore, the TRV is equal to the geometric mean of the NOAEL values for reproduction and growth at 7.33 mg cobalt/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 each for three surrogate species representing different trophic groups. The mammalian Eco-SSLs for cobalt are calculated according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-5) and are summarized in Table 6.2

<table>
<thead>
<tr>
<th>Surrogate Receptor Group</th>
<th>TRV for Cobalt (mg dw/kg bw/d)</th>
<th>Food Ingestion Rate (FIR) (kg dw/kg bw/d)</th>
<th>Soil Ingestion as Proportion of Diet (Ps)</th>
<th>Concentration of Cobalt in Biota Type (i) (Bi) (mg/kg dw)</th>
<th>Eco-SSL (mg/kg dw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammalian herbivore (vole)</td>
<td>7.33</td>
<td>0.0875</td>
<td>0.032</td>
<td>B&lt;sub&gt;i&lt;/sub&gt; = 0.0075 * Soil&lt;sub&gt;j&lt;/sub&gt; where i = plants</td>
<td>2100</td>
</tr>
<tr>
<td>Mammalian ground insectivore (shrew)</td>
<td>7.33</td>
<td>0.209</td>
<td>0.030</td>
<td>B&lt;sub&gt;i&lt;/sub&gt; = 0.122 * Soil&lt;sub&gt;j&lt;/sub&gt; where i = earthworms</td>
<td>230</td>
</tr>
<tr>
<td>Mammalian carnivore (weasel)</td>
<td>7.33</td>
<td>0.130</td>
<td>0.043</td>
<td>ln(B&lt;sub&gt;i&lt;/sub&gt;) = 1.307 * ln(Soil&lt;sub&gt;j&lt;/sub&gt;) - 4.4669 where i = mammals</td>
<td>470</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 B<sub>i</sub> = Concentration in biota type (i) which represents 100% of the diet for the respective receptor.
4 HQ = FIR * (Soil<sub>j</sub> * Ps + Bi) / TRV solved for HQ=1 where Soil<sub>j</sub> = Eco-SSL (Equation 4-2; U.S. EPA, 2003).
NA = Not Applicable
7.0 REFERENCES

7.1 General Cobalt References


7.2 References Used for Derivation of Plant and Soil Invertebrate Eco-SSLs


7.3 References Rejected for Use in Derivation of 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.

**No Dose**


**Mix**


**No Control**


**OM, pH**


**No Dose**


**Media**


**Media**


**Media**


**Mix**


**Mix**


**FL**


**Media**


**Mix**


**Mix**

Andreawe, H. Verteilung Von Schwermetallen In Einem Forstlich Genutzten Wassereinzugsgebiet Unter Dem Einfluss Saurer Deposition Am Beispiel Der Soesemulde (Westharz). (Distribution Of
Heavy Metals In A Wood Culture Water Catchment Area Under The Influence Of Acid De. Govt-Reports-Announcements-&-Index-(GRA&I),-Issue-21,-1995.

OM, pH


FL


FL


Media


Media


Media


Media


Species


Media


Media


Rev


Media


Dup


No Control


Kalashnikova, E. V. Cobalt and cadmium accumulation in the yield of several crops in plant irradiation carried out on soils polluted with heavy metals. Agrokhimiya.Agrokhimiya.0 (9).1991.77-82.


OM, pH

Media

FL

FL

FL

FL

FL

FL

FL

FL

FL

FL

Media

OM

Mix

Media
Media


No Control


Media


Media


Media


No Control


OM, pH


Score


Media


Media


Rev


Media


OM, pH


OM


Score


FL

Media
Von Rosen, G. 1964. Mutations Induced by the Action of Metal Ions in Pisum. II. Further Investigations on the Mutagenic Action of Metal Ions and Comparison with the Activity of Ionizing Radiation. Hereditas 51, 89-134.

FL

OM

No Dose

Media

Media

Meth

No Dose

Media

Mix

Mix

Media

OM, pH

Media

FL


### 7.4 References Used for Derivation of Wildlife TRVs


7.5 References Rejected for Use in Derivation of Wildlife TRVs

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 Content and evolution of cadmium, cobalt, chromium, copper, nickel, lead, and zinc in soils of l'horta and ribera baixa regions (valencia) (spain)


Mix Aleksiev, A. D., Krusteva, E., and Aleksieva-Drbokhlavova, D. 1986. interaction of vitamin a

**CP**


**Surv**


**Unrel**


**CP**


**Rev**


**Mix**


**Surv**


**Surv**

Andreu Perez, Vicente.  1991.  Content and evolution of cadmium, cobalt, chromium, copper, nickel, lead, and zinc in soils of l'horta and ribera baixa regions (valencia) (spain): <original> contenido y evolucion de cadmio, cobalto, cromo, cobre, niquel, plomo, cinc en suelos de las comarcas de l'horta y la ribera baixa (valencia).

**Acute**


**CP**


**FL**


**Mix**


**Phys**


**In Vit**


**FL**


**Phys**

Eco-SSL for Cobalt

March 2005

Mix

Rev
ATSDR. 1990. Toxicological Profile for Cobalt.

FL

Mix

FL

FL

FL

FL

Rev

Drug

FL

HHE

FL
Barkhatov, N. A. 1978. trace elements for restoring normal reproductive function in swine(cobalt, zinc, manganese). Veterinariya, Moscow, USSR.(No.8): 75-78.

Nut def

Mix
Drug

Phys

Nut

Bio Acc

Unrel

Bio Acc

Bio Acc
Bendell-Young, L. I(a) and Bendell, J. F. 1999. grit ingestion as a source of metal exposure in the spruce grouse, dendragapus canadensis. Environmental Pollution. 106(3): 405-412.

Mix

Mix

FL
Berestova, V. I. 1981. cobalt content in the bodies on mink, arctic foxes (alopex lagopus) and silver foxes at various stages of growth: <original> soderzhanije kobal'ta v organizme norok, nestsov i lisits ranogo vozrasta. Scientifur. 5(1): 34-37.

Phys
Berlin, Nathaniel. 1949.Studies on the Mechanism and Development of the Cobalt Polycythemia in the Rat With the Aid of Radioactive Isotopes

Bio Acc

FL
Bessonov, A. I., Grozhevskaya, S. B., Vikharev, V. Ya., and Savkin, V. V. 1986. sperm yield and non-specific reactivity in boars given a diet containing iodine and cobalt.: <document title>puti povysheniya produktivnosti svinei i ovets. 79-85.

Unrel
Bicanin, M. 1975. contribution to the knowledge of quality of grassland herbage on the western sides of mount sara with special reference to essential trace elements in the diet of sheep.

Eco-SSL for Cobalt 28 March 2005

**Phys**


**Nut def**


**Diss**


**CP**


**Bio Acc**


**Phys**


**FL**


**FL**

Bonnet-Masimbert, O., Prenat, M. F., Valentin, J., and Sengel, P. 1971. [Restatement of a method of analysis by activation, using the (p, 2n) reaction followed by spectrometry applied to iron determination in chicken blastoderms]. *mise au point d'une methode d'analyse par acivation, utilisant la reaction (p,2n) suivie de spectrometri , appliquee au dosage du fer dans le blastoderme de poulet.* *Comptes Rendus Hebdomadaires Des Seances De L'Academie Des Sciences.*

**FL**


**FL**


**Mix**


**Nutrition**


Mix

FL

Unrel

CP

Nut def

Model

Nut def

Surv

Surv

Rev

Chem Meth

Rev

No Dose

No Dose


| FL | Fiedler, H. and Hoffmann, H. D. 1970. [the effect of nickel(ii)-l-glutamate and of various cobalt complexes on the behavior of several lipid components in rabbits]: <original> über die wirkung von nickel(ii)-l-glutamat und verschiedenen kobaltkomplexen auf das verhalten einiger |

**Drug**


**FL**


**FL**


**Unrel**


**Nut def**


**Nut def**


**Nut def**


**BioAcc**


**Gene**


**FL**


**Unrel**


**FL**


**FL**


**Acu**


**Drug**


Gilani, S. H. and Alibai, Y.  1985.  the effects of heavy metals on the chick embryo Development.  *American Association of Anatomists 98th Annual Meeting and the Association Canadienne Des Anatomistes (Canadian Association of Anatomists) 29th Annual Meeting*


Abstract

HHE

No Oral

Nut def

Nut def

Bio Acc

CP

Rev

Anat

Mineral

Nut def

Bio Acc

Nut def

Rev

No Oral

Food

CP


Kelley, Timothy R., Pancorbo, Oscar C., Merka, William C., Thompson, Sidney A., Cabrera,


Trace element contents in fattening chicks 18 (6-7) : 527-32.

Klimowicz Zbigniew, Melke Jerzy, and Uziak Stanislaw. 1997. peat soils in the bellsund region,

**Nut def**  

**Drug**  

**Phys**  

**FL**  

**Mix**  

**FL**  

**FL**  

**Imm**  

**FL**  

**FL**  

**Unrel**  

**Mix**  

**Mix**  

**FL**  

**FL**  

**Aquatic**  

---

*Eco-SSL for Cobalt* 40  
March 2005


In Vitro  Anodic oxidation under spark discharge (ANOD) - a new coating procedure in medical technology 41 (3): 219-22.


Unrel  Lemerle, C. and Holmes, J. H. G. 1986. Sodium deficiency of grazing cattle in papua new-

**FL**  

**FL**  

**CP**  

**CP**  

**HHE**  

**Mix**  

**FL**  

**Mix**  

**Drug**  

**Drug**  

**Drug**  

**Nut def**  

**Phys**  


Bio Acc Malzahn, E. 1981. Trace elements and their significance in the post natal development of


**Mix** Medvetetskii, N. S. 1985. Some morphological and biochemical indicators in blood of young cattle given trace elements, vitamin a and ergocalciferol.: biologicheskie aktivnye veshchestva v ratsionakh sel'skokhozyaistvennykh zhivotnykh. 26-29.


Phys Murphy, J. and L'estrange, J. L. 1977. The performance and carcass fat characteristics of lambs fattened on concentrate diets part 1 effects of maize and barley as the cereal source and of dietary supplementation with roughage vitamin e cobalt and vitamin B-12. *Ir J Agric Res.* 16(2): 187-204.


Drug Norton, B. W., Cavaye, J. M., and Hales, J. W. a. 1990. Grazing management studies with austalian cashmere goats, 4. cobalt supplementation and intestinal parasite burdens in sheep and...

**Nut def**

**No Dose**

**Mix**

**Mix**

**Not Avail**

**Unrel**

**FL**

**Herp**

**Gene**

**FL**

**FL**

**FL**

**FL**

**Nut Def**

**Mix**
Peron, N., Martinez, G., Iglesias, C., and Morales, J. R. 1976. Effect of mineral, vitamin and

**Not Oral**


**Unrel**


**Alt**


**FL**


**Mix**


**CP**


**CP**


**Bio Acc**


**Surv**


**FL**


**FL**


**Mix**


**FL**

Effect of trace elements on chicken fattening performance in relation to different protein and energy levels in the fodder 10 (2) : 231-40

**Mix**

Nut def


Mix


Surv


FL


Rev


FL


Nut def


Mix


Rev


Unrel


Phys


No Oral


FL


Acu


FL


Bio Acc

Rickard, W. H. and Sweany, H. A. 1975. Radionuclides in Canada Goose Eggs. CONF-750985-
No Oral  

**Nut Def**  

**Nut def**  

No Oral  

**Nut def**  

**Phys**  

**Unrel**  
169-185.

**Nut Def**  
*Canine Pract.*  16(2): 30-35.

**In Vit**  

**Mix**  
*Sbornik Nauchnykh Trudov Leningradskogo Veterinarnogo Institut.*  (71): 102-108.

**FL**  

**FL**  

**Alt**  

**Phys**  

**Nut def**  

**Rev**  
Eco-SSL for Cobalt

51

March 2005


Fate  Snively, W. D. Jr and Becker, B.  1968.  minerals, macro and micro: dynamic nutrients. ii. the

**Mix**

**FL**

**Rev**

**Acute**

**FL**

**FL**

**Nut def**

**Plant**

**Surf**

**FL**

**Nut def**

**Unrel**

**Model**

**FL**

**FL**

**Phys**


**Bio Acc**  

**FL**  

**FL**  

**FL**  

**FL**  

**FL**  

**Unrel**  

**No Oral**  

**In Vitro**  

**Alt**  

**No Dose**  

**FL**  

**FL**  

**Nut def**  

**No Oral**  

**Abstract**  

**Not Oral**  
protoporphyrin-treated rats is a postreceptor defect. *Physiology & Behavior* 56(5): 1009-1014.


**CP** Vallee, B. L. The entatic properties of cobalt carboxypeptidase and cobalt procarboxypeptidase. *IN: Trace Element Metabolism in Animals - 2 : 5.*


**Acute**


**Mix**


**FL**


**Bio Acc**


**Mix**


**FL**


**Mix**

<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>
</tr>
<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>
</tr>
<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>
</tr>
<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>
</tr>
<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>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<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>
</tr>
<tr>
<td>IMMUNOLOGY (IMM)</td>
<td>Studies on the effects of contaminants on immunological endpoints.</td>
<td>Wildlife Plants and Soil Invertebrates</td>
</tr>
<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>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------------------------------------------</td>
</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 Efct)</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</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</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</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>
<tr>
<td>--------------------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>OIL (Oil)</strong></td>
<td>Studies which examine the effects of oil and petroleum products.</td>
<td><strong>Wildlife Plants and Soil Invertebrates</strong></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><strong>Plants and Soil Invertebrates</strong></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, phenylarsionic acid, roxarsone, 3-nitro-4-phenylarsionic acid, zinc phosphate, monomethylarsonic acid (MMA), dimethylarsinic 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><strong>Wildlife</strong></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><strong>Wildlife</strong></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><strong>Wildlife</strong></td>
</tr>
<tr>
<td><strong>PLANT (Plant)</strong></td>
<td>Studies of terrestrial plants are excluded.</td>
<td><strong>Wildlife</strong></td>
</tr>
<tr>
<td><strong>PRIMATE (Prim)</strong></td>
<td>Primate studies are excluded.</td>
<td><strong>Wildlife</strong></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><strong>Wildlife Plants and Soil Invertebrates</strong></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><strong>Wildlife Plants and Soil Invertebrates</strong></td>
</tr>
<tr>
<td><strong>REGULATIONS (Reg)</strong></td>
<td>Regulations and related publications that are not a primary source of data.</td>
<td><strong>Wildlife Plants and Soil Invertebrates</strong></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><strong>Wildlife Plants and Soil Invertebrates</strong></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>
</tbody>
</table>
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Appendix 5-1

Avian Toxicity Data Extracted and Reviewed for Wildlife Toxicity Reference Value (TRV) - Cobalt

March 2005
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Appendix 5.1 Avian Toxicity Data Extracted and Reviewed for Wildlife Toxicity Reference Value (TRV)  

Cobalt  

Page 1 of 1

<table>
<thead>
<tr>
<th>Ref</th>
<th>Exposure</th>
<th>Effects</th>
<th>Conversion to mg/kg bw/day</th>
<th>Result</th>
<th>Data Evaluation Score</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ref #</td>
<td>Chemical Form</td>
<td>%M &amp;%</td>
<td>Common Name</td>
<td>Phase</td>
</tr>
<tr>
<td>-----</td>
<td>----------</td>
<td>-------------</td>
<td>------</td>
<td>---------------------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>Cobalt chloride hexahydrate</td>
<td>24.90%</td>
<td>Chicken (Gallus domesticus)</td>
<td>1-4</td>
</tr>
<tr>
<td>2</td>
<td>6666</td>
<td>Cobalt</td>
<td>100%</td>
<td>Chicken (Gallus domesticus)</td>
<td>1-4</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td>Cobalt chloride hexahydrate</td>
<td>100%</td>
<td>Chicken (Gallus domesticus)</td>
<td>1-4</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>Cobalt chloride hexahydrate</td>
<td>24.9%</td>
<td>Chicken (Gallus domesticus)</td>
<td>2-2</td>
</tr>
</tbody>
</table>

The abbreviations and definitions used in coding data are provided in Attachment 4-3 of the Eco-SSL Guidance (U.S.EPA, 2003).
Appendix 6-1

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

March 2005
<table>
<thead>
<tr>
<th>Ref</th>
<th>Chemical Form</th>
<th>MW%</th>
<th>Route of Exposure</th>
<th>Exposure Duration</th>
<th>Duration Units</th>
<th>Age Units</th>
<th>Lifestage</th>
<th>Effect Type</th>
<th>Effect Measure</th>
<th>Response Site</th>
<th>Study NOAEL</th>
<th>Study LOAEL</th>
<th>Body Weight Reported?</th>
<th>Ingestion Rate Reported?</th>
<th>Test Conditions</th>
<th>Total Score</th>
<th>Data Source</th>
<th>Test Substrate</th>
<th>Dose Route</th>
<th>Data Not Used to Derive TRV</th>
<th>Study NOAEL</th>
<th>Study LOAEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cobalt nitrate</td>
<td>171</td>
<td>Cow (Bos taurus)</td>
<td>0.3 mg/kg bw/d</td>
<td>4 w</td>
<td>NR</td>
<td>NR</td>
<td>BEH</td>
<td>NMVR</td>
<td>WO</td>
<td>75</td>
<td>0.47%</td>
<td>0.037</td>
<td>1.47</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>10</td>
<td>6</td>
<td>10</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Cobalt chloride</td>
<td>86</td>
<td>Pig (Sus scrofa)</td>
<td>0.3 mg/kg bw/d</td>
<td>80 d</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
<td>M</td>
<td>ENZ</td>
<td>P450</td>
<td>LI</td>
<td>20</td>
<td>0.175</td>
<td>0.02</td>
<td>20.0</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>10</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>Cobalt sulfate heptahydrate</td>
<td>105</td>
<td>Rat (Rattus norvegicus)</td>
<td>1 mg/ml</td>
<td>35 d</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
<td>M</td>
<td>CHM</td>
<td>HMCT</td>
<td>BL</td>
<td>1</td>
<td>0.1697</td>
<td>0.02</td>
<td>118</td>
<td>10</td>
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<td>4</td>
<td>10</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>Cobalt chloride</td>
<td>124</td>
<td>Rat (Rattus norvegicus)</td>
<td>0/25/50/100 mg/kg bw/d</td>
<td>U</td>
<td>9 d</td>
<td>NR NR</td>
<td>GE</td>
<td>F</td>
<td>REP</td>
<td>PRWT</td>
<td>WO</td>
<td>100</td>
<td>0.28</td>
<td>0.024</td>
<td>24.9</td>
<td>10</td>
<td>8</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>16</td>
<td>Cobalt chloride</td>
<td>124</td>
<td>Mouse (Mus musculus)</td>
<td>0/23/42/72 mg/kg bw/d</td>
<td>U</td>
<td>13 w</td>
<td>12 w</td>
<td>SM</td>
<td>M</td>
<td>REP</td>
<td>RSUC</td>
<td>WO</td>
<td>23</td>
<td>0.0375</td>
<td>0.0078</td>
<td>19.0</td>
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<tr>
<td>24</td>
<td>Cobalt chloride hexahydrate</td>
<td>136</td>
<td>Rat (Rattus norvegicus)</td>
<td>0/400 mg/l</td>
<td>5 w</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
<td>M</td>
<td>CAV</td>
<td>BDWT</td>
<td>WO</td>
<td>400</td>
<td>0.0316</td>
<td>0.005</td>
<td>55.9</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>29</td>
<td>Cobalt sulfate</td>
<td>132</td>
<td>Guinea pig (Cavia porcellus)</td>
<td>0/20 mg/kg bw/d</td>
<td>U</td>
<td>57 d</td>
<td>80 d</td>
<td>JV</td>
<td>F</td>
<td>GRO</td>
<td>BDWT</td>
<td>WO</td>
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<td>0.347</td>
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<td>20.0</td>
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<td>5</td>
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<td>5</td>
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<tr>
<td>41</td>
<td>Cobalt chloride</td>
<td>121</td>
<td>Mouse (Mus musculus)</td>
<td>0/25/50/100 mg/kg bw/d</td>
<td>U</td>
<td>5 w</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
<td>M</td>
<td>CAV</td>
<td>BDWT</td>
<td>WO</td>
<td>25</td>
<td>0.28</td>
<td>0.024</td>
<td>6.23</td>
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<td>8</td>
<td>5</td>
<td>10</td>
<td>10</td>
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<tr>
<td>50</td>
<td>Cobalt chloride</td>
<td>86</td>
<td>Pig (Sus scrofa)</td>
<td>0/500 mg/kg</td>
<td>10 w</td>
<td>NR</td>
<td>NR</td>
<td>JV</td>
<td>M</td>
<td>ENZ</td>
<td>GLPN</td>
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<td>500</td>
<td>18.9</td>
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<td>10</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>Cobalt chloride hexahydrate</td>
<td>86</td>
<td>Pig (Sus scrofa)</td>
<td>0/0.3 mg/kg bw/d</td>
<td>M</td>
<td>45 d</td>
<td>7 mo</td>
<td>JV</td>
<td>F</td>
<td>BDWT</td>
<td>WO</td>
<td>0.3</td>
<td>99</td>
<td>3.00</td>
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<td>5</td>
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</tr>
</tbody>
</table>

The abbreviations and definitions used in coding data are provided in Attachment 4-3 of the Eco-SSL Guidance (U.S.EPA, 2003).