Ecological Soil Screening Levels for Cobalt

Interim Final

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U.S. Environmental Protection Agency
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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 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.

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.

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 2.1 Cobalt Eco-SSLs (mg/kg dry weight in soil)

Plants	Soil Invertebrates	Wildlife	
		Avian	Mammalian
13	NA	120	230

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).

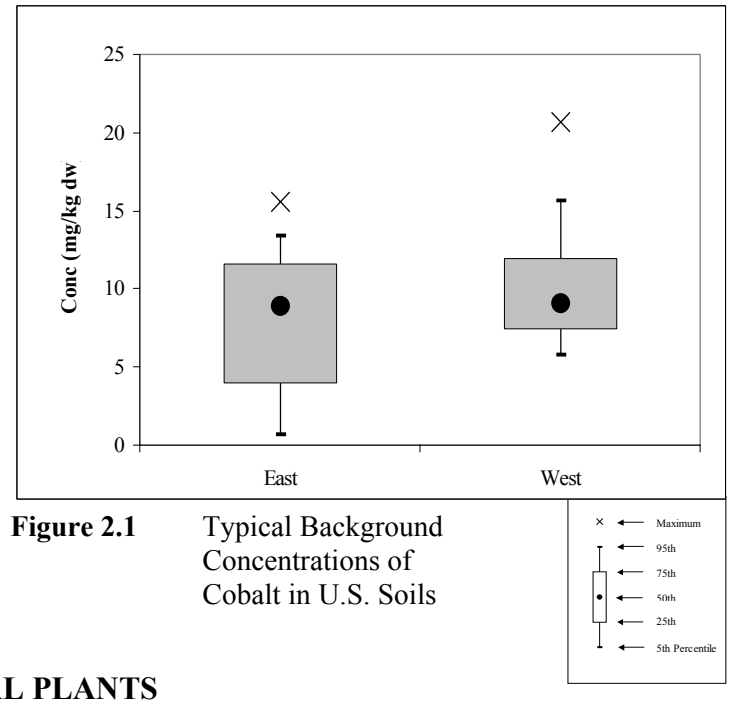


Figure 2.1 Typical Background Concentrations of Cobalt in U.S. Soils

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 EC_{20} 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 3.1 Plant Toxicity Data - Cobalt

Reference	Study ID	Test Organism		Soil pH	OM %	Bio-availability Score	ERE	Tox Parameter	Tox Value Soil Conc. (mg/kg dw)	Total Eval. Score	Eligible for Eco-SSL Derivation?	Used for Eco-SSL?
TN & Associates, Inc., 2000	a	Alfalfa	*Medicago Sative*	5.0	5.0	2	GRO	EC_{20}	0.60	18	Y	Y
TN & Associates, Inc., 2000	b	Barley	*Hordeum vilgare*	5.0	5.0	2	GRO	EC_{20}	29.8	18	Y	Y
TN & Associates, Inc., 2000	c	Radish	*Raphanus sative*	5.0	5.0	2	GRO	EC_{20}	14.5	18	Y	Y
TN & Associates, Inc., 2000	d	Alfalfa	*Medicago Sative*	6.3	0.1	2	GRO	EC_{20}	13.4	18	Y	Y
TN & Associates, Inc., 2000	e	Barley	*Hordeum vilgare*	6.3	0.1	2	GRO	EC_{20}	36.4	18	Y	Y
TN & Associates, Inc., 2000	f	Radish	*Raphanus sative*	6.3	0.1	2	GRO	EC_{20}	45.2	18	Y	Y
								Geometric Mean	13.4			
Data not Used to Derive Eco-SSL												
Rehab, F.I., 1978		Cotton	*Gossypium spp.*	6.6	2.4	1	GRO	LOAEC	100	12	Y	N

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

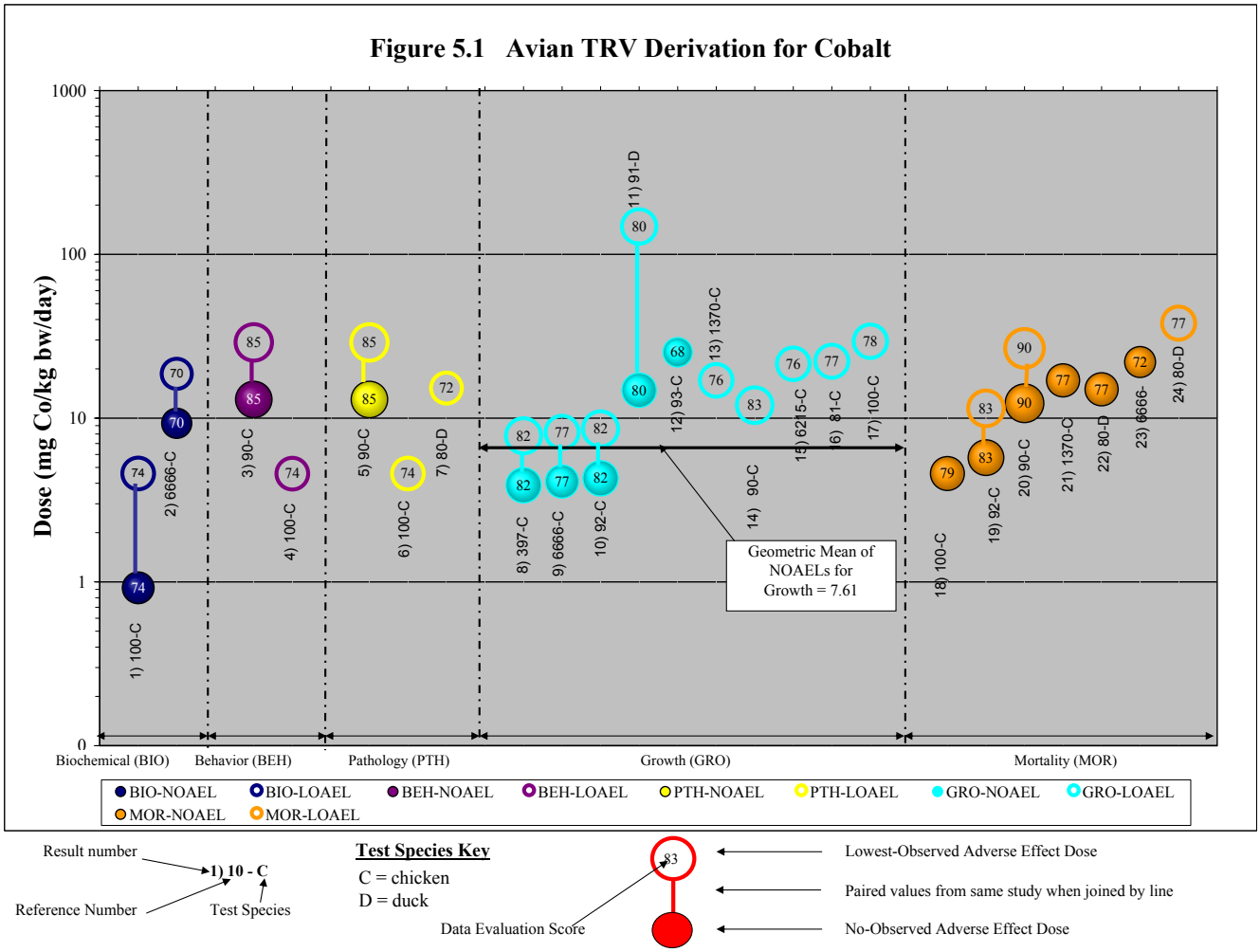
Three separate Eco-SSL values were calculated for avian wildlife, one each for three surrogate species representing different trophic groups. The avian Eco-SSLs for cobalt were calculated according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-5) and are summarized in Table 5.2.

Table 5.1 Avian Toxicity Data Extracted for Wildlife Toxicity Reference Value (TRV)
Cobalt

Result #	Reference	Ref No.	Conc/ Doses	Conc/Dose Units	Method of Analyses	Route of Exposure	Exposure Duration	Duration Units	Age	Age Units	Lifestage	Sex	Effect Group	Effect Measure	Response Site	NOAEL Dose (mg/kg/day)	LOAEL Dose (mg/kg/day)	Data Evaluation Score
Biochemical																		
1	Diaz et al., 1994	100	Chicken *(Gallus domesticus)*	4	U	FD	42	d	1	d	JV	B	BIO	RBCE	BL	0.920	4.59	74
2	Ling et al., 1979	6666	Chicken *(Gallus domesticus)*	4	U	FD	3	w	1	d	JV	M	BIO	HMCT	BL	9.30	18.7	70
Behavior																		
3	Diaz et al., 1994	90	Chicken *(Gallus domesticus)*	4	M	FD	14	d	1	d	JV	M	BEH	FCNS	WO	13.0	29.0	85
4	Diaz et al., 1994	100	Chicken *(Gallus domesticus)*	2	U	FD	42	d	1	d	JV	B	BEH	FCNS	WO		4.58	74
Pathology																		
5	Diaz et al., 1994	90	Chicken *(Gallus domesticus)*	4	M	FD	14	d	1	d	JV	M	PTH	GLSN	WO	13.0	29.0	85
6	Diaz et al., 1994	100	Chicken *(Gallus domesticus)*	2	U	FD	42	d	1	d	JV	B	PTH	ORWT	HE		4.59	74
7	Van Vleet et al., 1981	80	Duck (*Anas sp.)*	3	U	FD	15	d	1	d	JV	M	PTH	GLSN	MB		15.3	72
Growth																		
8	Hill, 1979	397	Chicken *(Gallus domesticus)*	4	U	FD	5	w	1	d	JV	F	GRO	BDWT	WO	3.89	7.80	82
9	Ling et al., 1979	6666	Chicken *(Gallus domesticus)*	4	U	FD	3	w	1	d	JV	M	GRO	BDWT	WO	4.10	8.20	77
10	Hill, 1974	92	Chicken *(Gallus domesticus)*	6	U	FD	2	w	1	d	JV	B	GRO	BDWT	WO	4.29	8.59	82
11	Paulov, 1971	91	Duck (*Anas sp.)*	3	U	FD	8	d	2	d	JV	NR	GRO	BDWT	WO	14.8	148	80
12	Berg and Martinson, 1972	93	Chicken *(Gallus domesticus)*	3	U	FD	2	w	1	d	JV	B	GRO	BDWT	WO	25.2		68
13	Hill, 1979	1370	Chicken *(Gallus domesticus)*	2	U	FD	2	w	1	d	JV	B	GRO	BDWT	WO		17.0	76
14	Diaz et al., 1994	90	Chicken *(Gallus domesticus)*	4	M	FD	14	d	1	d	JV	M	GRO	BDWT	WO		12.0	83
15	Brown and Southern, 1985	6215	Chicken *(Gallus domesticus)*	2	U	FD	14	d	0	d	IM	M	GRO	BDWT	WO		21.5	76
16	Southern and Baker, 1981	81	Chicken *(Gallus domesticus)*	3	U	FD	15	d	8	d	JV	M	GRO	BDWT	WO		22.3	77
17	Diaz et al., 1994	100	Chicken *(Gallus domesticus)*	2	U	FD	14	d	1	d	JV	B	GRO	BDWT	WO		29.5	78
Survival																		
18	Diaz et al., 1994	100	Chicken *(Gallus domesticus)*	2	U	FD	42	d	1	d	JV	B	MOR	MORT	WO	4.59		79
19	Hill, 1974	92	Chicken *(Gallus domesticus)*	6	U	FD	5	w	1	d	JV	B	MOR	MORT	NR	5.74	11.5	83
20	Diaz et al., 1994	90	Chicken *(Gallus domesticus)*	4	M	FD	14	d	1	d	JV	M	MOR	MORT	WO	12.3	26.7	90
21	Hill, 1979	1370	Chicken *(Gallus domesticus)*	2	U	FD	2	w	1	d	JV	B	MOR	MORT	NR	17.0		77
22	Van Vleet et al., 1981	80	Duck (*Anas sp.)*	3	U	FD	15	d	1	d	JV	M	MOR	MORT	WO	15.0		77
23	Ling et al., 1979	6666	Chicken *(Gallus domesticus)*	4	U	FD	3	w	1	d	JV	M	MOR	SURV	WO	22.0		72
24	Van Vleet et al., 1981	80	Duck (*Anas sp.)*	2	U	FD	28	d	1	d	JV	M	MOR	MORT	WO		38.0	77

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 Advese Effect Level; NR = Not reported; ORWT = organ weight changes; PTH = pathology; SURV = survival; U = unmeasured; w = weeks; WO = whole organism.

Figure 5.1 Avian TRV Derivation for Cobalt



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 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					
Surrogate Receptor Group	**TRV for Cobalt (mg dw/kg bw/d) [1]**	**Food Ingestion Rate (FIR)[2] (kg dw/kg bw/d)**	**Soil Ingestion as Proportion of Diet (P_s)[2]**	**Concentration of Cobalt in Biota Type (i)[2,3] (B_i) (mg/kg dw)**	**Eco-SSL (mg/kg dw)[4]**
Avian herbivore (dove)	7.61	0.190	0.139	$B_i = 0.0075 * Soil_j$ where i = plants	270
Avian ground insectivore (woodcock)	7.61	0.214	0.164	$B_i = 0.122 * Soil_j$ where i = earthworms	120
Avian carnivore (hawk)	7.61	0.0353	0.057	$\ln(B_i) = 1.307 * \ln(Soil_j) - 4.4669$ where i = mammals	1300

[1] The process for derivation of wildlife TRVs is described in Attachment 4-5 of U.S. EPA (2003).
[2] Parameters (FIR, P_s, 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 * ($Soil_j$ * P_s + B_i) / TRV) solved for HQ=1 where $Soil_j$ = 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.

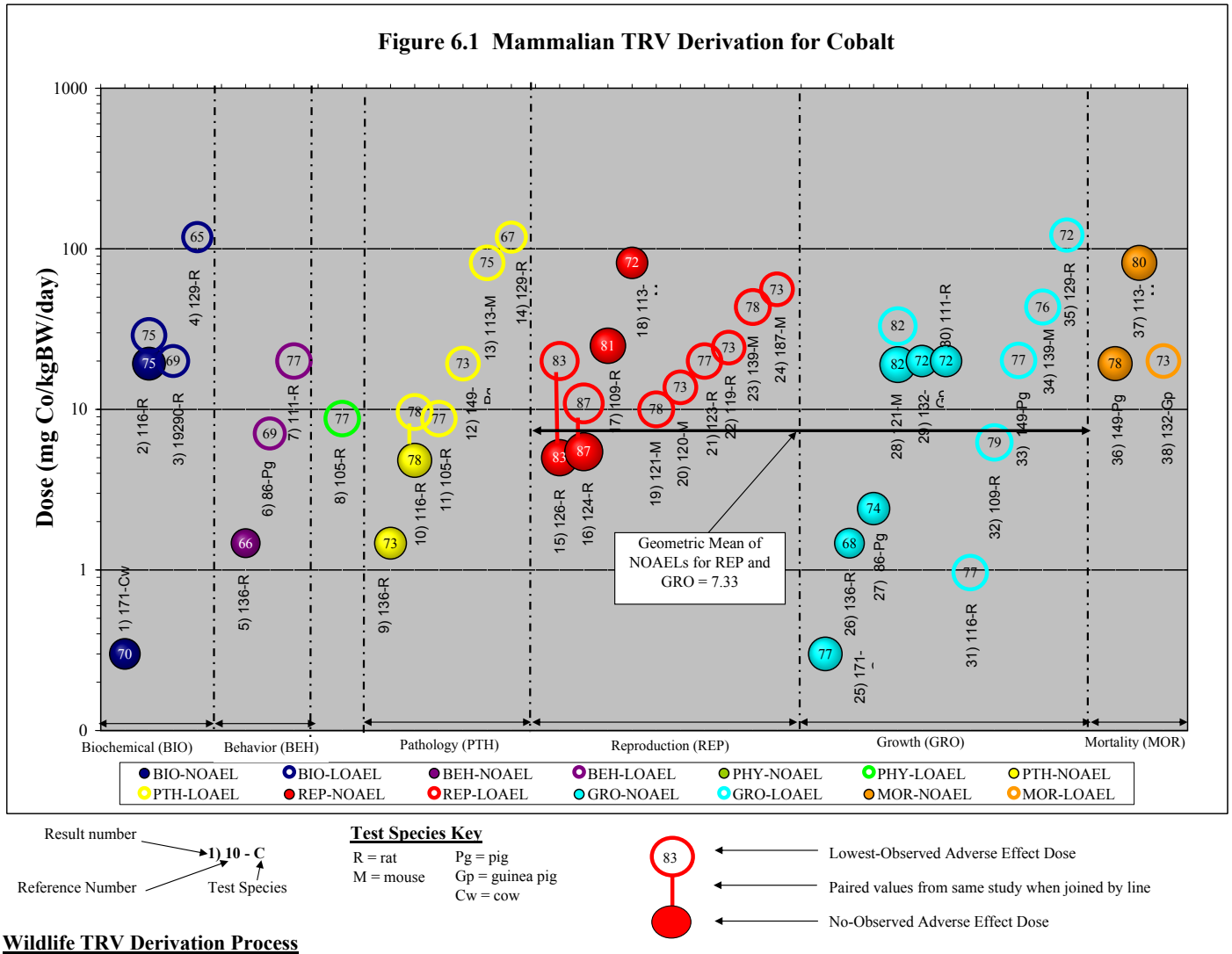
Within the 20 papers there are 38 results for biochemical (BIO), behavioral (BEH), physiology (PHY), pathology (PTH), reproduction (REP), growth (GRO), and survival (MOR) endpoints with a total Data Evaluation Score >65 that were used to derive the TRV (U.S. EPA 2003; Attachment 4-3). These data are 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 Toxiicty Data Extracted for Wildlife Toxicity Reference Value (TRV)
Cobalt
Page 1 of 1

Result #	Reference	Ref No.	Test Organism	# of Conc/ Doses	Method of Analyses	Route of Exposure	Exposure Duration	Duration Units	Age	Age Units	Lifestage	Sex	General Effect Group	Effect Measure	Response Site	NOAEL Dose (mg/kg/day)	LOAEL Dose (mg/kg/day)	Data Evaluation Score
Biochemical																		
1	Maro et al., 1980	171	Cow (*Bos taurus*)	2	M	FD	45	d	7	mo	JV	F	BIO	HMGL	BL	0.300		70
2	Chetty et al., 1979	116	Rat (*Rattus norvegicus*)	6	U	FD	4	w	NR	NR	NR	B	BIO	HMGL	BL	19.3	28.9	75
3	Kadiiska et al., 1985	19290	Rat (*R. norvegicus*)	2	U	DR	30	d	NR	NR	JV	M	BIO	P450	LI		20.0	69
4	Derr et al., 1970	129	Rat (*R. norvegicus*)	2	U	DR	35	d	NR	NR	JV	M	BIO	HMCT	BL		118	65
Behavior																		
5	Gershbein et al., 1983	136	Rat (*R. norvegicus*)	2	U	FD	80	d	44	d	JV	M	BEH	NMVM	WO	1.47		66
6	Huck and Clawson, 1976	86	Pig (*Sus scrofa)*	4	U	FD	28	d	NR	NR	NR	NR	BEH	FCNS	WO		7.08	69
7	Bourg et al., 1985	111	Rat (*R. norvegicus*)	2	M	DR	57	d	80	d	JV	M	BEH	ACTP	WO		20.0	77
Physiology																		
8	Haga et al., 1996	105	Rat (*R. norvegicus*)	2	U	FD	16	w	NR	NR	NR	M	PHY	Other	HE		8.76	77
Pathology																		
9	Gershbein et al., 1983	136	Rat (*R. norvegicus*)	2	U	FD	80	d	44	d	JV	M	PTH	GHIS	NR	1.47		73
10	Chetty et al., 1979	116	Rat (*R. norvegicus*)	6	U	FD	4	w	NR	NR	NR	B	PTH	SMIX	TS	4.81	9.63	78
11	Haga et al., 1996	105	Rat (*R. norvegicus*)	2	U	FD	16	w	NR	NR	NR	M	PTH	BDWT	WO		8.76	77
12	Van Vleet et al., 1981	149	Pig (*S. scrofa)*	2	U	FD	10	w	NR	NR	JV	M	PTH	GLSN	HE		19.3	73
13	Seidenberg et al., 1986	113	Mouse (*Mus musculus*)	2	U	GV	5	d	NR	NR	GE	F	PTH	BDWT	WO		81.7	75
14	Derr et al., 1970	129	Rat (*R. norvegicus*)	2	U	DR	35	d	NR	NR	JV	M	PTH	SMIX	HE		118	67
Reproduction																		
15	Nation et al., 1983	126	Rat (*R. norvegicus*)	3	U	FD	69	d	80	d	MA	M	REP	TEWT	TE	5.00	20.0	83
16	Domingo et al., 1985	124	Rat (*R. norvegicus*)	4	U	GV	28	d	NR	NR	MA	F	REP	PRWT	WO	5.45	10.9	87
17	Paternain et al., 1988	109	Rat (*R. norvegicus*)	4	U	GV	9	d	NR	NR	GE	F	REP	PRWT	WO	24.9		81
18	Seidenberg et al., 1986	113	Mouse (*M. musculus*)	2	U	GV	5	d	NR	NR	GE	F	REP	PROG	WO	81.7		72
19	Pedigo et al., 1988	121	Mouse (*M. musculus*)	4	U	DR	13	w	12	w	SM	M	REP	RSUC	WO		10.0	78
20	Anderson et al., 1992	120	Mouse (*M. musculus*)	2	U	DR	9	w	12	w	MA	M	REP	TEWT	TE		13.7	73
21	Corrier et al., 1985	123	Rat (*R. norvegicus*)	2	U	FD	70	d	100	d	SM	M	REP	TEDG	TE		20.0	77
22	Mollenhauer et al., 1985	119	Rat (*R. norvegicus*)	2	U	FD	98	d	100	d	MA	M	REP	TEWT	TE		24.2	73
23	Anderson et al., 1993	139	Mouse (*M. musculus*)	2	U	DR	13	w	12	w	MA	M	REP	TEWT	TE		43.4	78
24	Pedigo et al., 1993	187	Mouse (*M. musculus*)	2	U	DR	10	w	8 to 10	w	JV	M	REP	PRFM	WO		55.9	73
Growth																		
25	Maro et al., 1980	171	Cow (*Bos taurus*)	2	M	FD	45	d	7	mo	JV	F	GRO	BDWT	WO	0.300		77
26	Gershbein et al., 1983	136	Rat (*R. norvegicus*)	2	U	FD	80	d	44	d	JV	M	GRO	BDWT	WO	1.47		68
27	Huck and Clawson, 1976	86	Pig (*S. scrofa)*	4	U	FD	16	w	NR	NR	NR	NR	GRO	BDWT	WO	2.41		74
28	Pedigo et al., 1988	121	Mouse (*M. musculus*)	4	U	DR	5	w	12	w	SM	M	GRO	BDWT	WO	19.0	33.0	82
29	Mohiuddin et al., 1970	132	Guinea pig (*Cavia porcellus*	2	U	OR	5	w	NR	NR	MA	M	GRO	BDWT	WO	20.0		72
30	Bourg et al., 1985	111	Rat (*R. norvegicus*)	2	M	DR	57	d	80	d	JV	M	GRO	BDWT	WO	20.0		72
31	Chetty et al., 1979	116	Rat (*R. norvegicus*)	6	U	FD	4	w	NR	NR	NR	B	GRO	BDWT	WO		0.963	77
32	Paternain et al., 1988	109	Rat (*R. norvegicus*)	4	U	GV	9	d	NR	NR	GE	F	GRO	BDWT	WO		6.23	79
33	Van Vleet et al., 1981	149	Pig (*Sus scrofa)*	2	U	FD	5	w	NR	NR	JV	M	GRO	BDWT	WO		20.2	77
34	Anderson et al., 1993	139	Mouse (*M. musculus*)	2	U	DR	13	w	12	w	MA	M	GRO	BDWT	WO		43.4	76
35	Derr et al., 1970	129	Rat (*R. norvegicus*)	2	U	DR	24	d	NR	NR	JV	M	GRO	BDWT	WO		122	72
Survival																		
36	Van Vleet et al., 1981	149	Pig (*S. scrofa)*	2	U	FD	10	w	NR	NR	JV	M	MOR	MORT	WO	19.3		78
37	Seidenberg et al., 1986	113	Mouse (*M. musculus*)	2	U	GV	5	d	NR	NR	GE	F	MOR	MORT	WO	81.7		80
38	Mohiuddin et al., 1970	132	Guinea pig (*Cavia porcellus*	2	U	OR	5	w	NR	NR	MA	M	MOR	SURV	WO		20.0	73

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; TEDG = testes degeneration; TEWT = testes weight; TS = Thymus; U = unmeasured; w = weeks; WO = whole organism

Figure 6.1 Mammalian TRV Derivation for Cobalt



Wildlife TRV Derivation Process

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 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 6.2 Calculation of the Mammalian Eco-SSLs for Cobalt

Surrogate Receptor Group	TRV for Cobalt (mg dw/kg bw/d) [1]	Food Ingestion Rate (FIR)[2] (kg dw/kg bw/d)	Soil Ingestion as Proportion of Diet (P_s)[2]	Concentration of Cobalt in Biota Type (i)[2,3] (B_i) (mg/kg dw)	Eco-SSL (mg/kg dw)[4]
Mammalian herbivore (vole)	7.33	0.0875	0.032	$B_i = 0.0075 * Soil_j$ where i = plants	2100
Mammalian ground insectivore (shrew)	7.33	0.209	0.030	$B_i = 0.122 * Soil_j$ where i = earthworms	230
Mammalian carnivore (weasel)	7.33	0.130	0.043	$\ln(B_i) = 1.307 * \ln(Soil_j) - 4.4669$ where i = mammals	470

[1] The process for derivation of wildlife TRVs is described in Attachment 4-5 of U.S. EPA (2003).
[2] Parameters (FIR, P_s, 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] $HQ = FIR * (Soil_j * P_s + B_i) / TRV$ solved for HQ=1 where $Soil_j$ = Eco-SSL (Equation 4-2; U.S. EPA, 2003).
NA = Not Applicable

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Literature Rejection Categories		
Rejection Criteria	**Description**	**Receptor**
ABSTRACT (Abstract)	Abstracts of journal publications or conference presentations.	Wildlife Plants and Soil Invertebrates
ACUTE STUDIES (Acu)	Single oral dose or exposure duration of three days or less.	Wildlife
AIR POLLUTION (Air P)	Studies describing the results for air pollution studies.	Wildlife Plants and Soil Invertebrates
ALTERED RECEPTOR (Alt)	Studies that describe the effects of the contaminant on surgically-altered or chemically-modified receptors (e.g., right nephrectomy, left renal artery ligature, hormone implant, etc.).	Wildlife
AQUATIC STUDIES (Aquatic)	Studies that investigate toxicity in aquatic organisms.	Wildlife Plants and Soil Invertebrates
ANATOMICAL STUDIES (Anat)	Studies of anatomy. Instance where the contaminant is used in physical studies (e.g., silver nitrate staining for histology).	Wildlife
BACTERIA (Bact)	Studies on bacteria or susceptibility to bacterial infection.	Wildlife Plants and Soil Invertebrates
BIOACCUMULATION SURVEY (Bio Acc)	Studies reporting the measurement of the concentration of the contaminant in tissues.	Wildlife Plants and Soil Invertebrates
BIOLOGICAL PRODUCT (BioP)	Studies of biological toxicants, including venoms, fungal toxins, *Bacillus thuringiensis*, other plant, animal, or microbial extracts or toxins.	Wildlife Plants and Soil Invertebrates
BIOMARKER (Biom)	Studies reporting results for a biomarker having no reported association with an adverse effect and an exposure dose (or concentration).	Wildlife
CARCINOGENICITY STUDIES (Carcin)	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.	Wildlife Plants and Soil Invertebrates
CHEMICAL METHODS (Chem Meth)	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.	Wildlife Plants and Soil Invertebrates
CONFERENCE PROCEEDINGS (CP)	Studies reported in conference and symposium proceedings.	Wildlife Plants and Soil Invertebrates
DEAD (Dead)	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.	Wildlife Plants and Soil Invertebrates
DISSERTATIONS (Diss)	Dissertations are excluded. However, dissertations are flagged for possible future use.	Wildlife
DRUG (Drug)	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.	Wildlife Plants and Soil Invertebrates
DUPLICATE DATA (Dup)	Studies reporting results that are duplicated in a separate publication. The publication with the earlier year is used.	Wildlife Plants and Soil Invertebrates

Literature Rejection Categories		
Rejection Criteria	**Description**	**Receptor**
ECOLOGICAL INTERACTIONS (Ecol)	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).	Wildlife Plants and Soil Invertebrates
EFFLUENT (Effl)	Studies reporting effects of effluent, sewage, or polluted runoff.	Wildlife Plants and Soil Invertebrates
ECOLOGICALLY RELEVANT ENDPOINT (ERE)	Studies reporting a result for endpoints considered as ecologically relevant but is not used for deriving Eco-SSLs (e.g., behavior, mortality).	Plants and Soil Invertebrates
CONTAMINANT FATE/METABOLISM (Fate)	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.	Wildlife Plants and Soil Invertebrates
FOREIGN LANGUAGE (FL)	Studies in languages other than English.	Wildlife Plants and Soil Invertebrates
FOOD STUDIES (Food)	Food science studies conducted to improve production of food for human consumption.	Wildlife
FUNGUS (Fungus)	Studies on fungus.	Wildlife Plants and Soil Invertebrates
GENE (Gene)	Studies of genotoxicity (chromosomal aberrations and mutagenicity).	Wildlife Plants and Soil Invertebrates
HUMAN HEALTH (HHE)	Studies with human subjects.	Wildlife Plants and Soil Invertebrates
IMMUNOLOGY (IMM)	Studies on the effects of contaminants on immunological endpoints.	Wildlife Plants and Soil Invertebrates
INVERTEBRATE (Invert)	Studies that investigate the effects of contaminants on terrestrial invertebrates are excluded.	Wildlife
IN VITRO (In Vit)	*In vitro* studies, including exposure of cell cultures, excised tissues and/or excised organs.	Wildlife Plants and Soil Invertebrates
LEAD SHOT (Lead shot)	Studies administering lead shot as the exposure form. These studies are labeled separately for possible later retrieval and review.	Wildlife
MEDIA (Media)	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 histosoils (e.g., peat muck, humus), are not considered suitable for use in defining soil screening levels.	Plants and Soil Invertebrates
METHODS (Meth)	Studies reporting methods or methods development without usable toxicity test results for specific endpoints.	Wildlife Plants and Soil Invertebrates
MINERAL REQUIREMENTS (Mineral)	Studies examining the minerals required for better production of animals for human consumption, unless there is potential for adverse effects.	Wildlife
MIXTURE (Mix)	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.	Wildlife Plants and Soil Invertebrates

Literature Rejection Categories		
Rejection Criteria	**Description**	**Receptor**
MODELING (Model)	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.	Wildlife Plants and Soil Invertebrates
NO CONTAMINANT OF CONCERN (No COC)	Studies that do not examine the toxicity of Eco-SSL contaminants of concern.	Wildlife Plants and Soil Invertebrates
NO CONTROL (No Control)	Studies which lack a control or which have a control that is classified as invalid for derivation of TRVs.	Wildlife Plants and Soil Invertebrates
NO DATA (No Data)	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).	Wildlife Plants and Soil Invertebrates
NO DOSE or CONC (No Dose)	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.	Wildlife Plants and Soil Invertebrates
NO DURATION (No Dur)	Studies with no exposure duration. These are usually identified after examination of full paper.	Wildlife Plants and Soil Invertebrates
NO EFFECT (No Efct)	Studies with no relevant effect evaluated in a biological test species or data not reported for effect discussed.	Wildlife Plants and Soil Invertebrates
NO ORAL (No Oral)	Studies using non-oral routes of contaminant administration including intraperitoneal injection, other injection, inhalation, and dermal exposures.	Wildlife
NO ORGANISM (No Org) or NO SPECIES	Studies that do not examine or test a viable organism (also see in vitro rejection category).	Wildlife Plants and Soil Invertebrates
NOT AVAILABLE (Not Avail)	Papers that could not be located. Citation from electronic searches may be incorrect or the source is not readily available.	Wildlife Plants and Soil Invertebrates
NOT PRIMARY (Not Prim)	Papers that are not the original compilation and/or publication of the experimental data.	Wildlife Plants and Soil Invertebrates
NO TOXICANT (No Tox)	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.	Wildlife Plants and Soil Invertebrates
NO TOX DATA (No Tox Data)	Studies where toxicant used but no results reported that had a negative impact (plants and soil invertebrates).	Plants and Soil Invertebrates
NUTRIENT (Nutrient)	Nutrition studies reporting no concentration related negative impact.	Plants and Soil Invertebrates
NUTRIENT DEFICIENCY (Nut def)	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.	Wildlife
NUTRITION (Nut)	Studies examining the best or minimum level of a chemical in the diet for improvement of health or maintenance of animals in captivity.	Wildlife
OTHER AMBIENT CONDITIONS (OAC)	Studies which examine other ambient conditions: pH, salinity, DO, UV, radiation, etc.	Wildlife Plants and Soil Invertebrates

Literature Rejection Categories		
Rejection Criteria	**Description**	**Receptor**
OIL (Oil)	Studies which examine the effects of oil and petroleum products.	Wildlife Plants and Soil Invertebrates
OM, pH (OM, pH)	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.	Plants and Soil Invertebrates
ORGANIC METAL (Org Met)	Studies which examine the effects of organic metals. This includes tetraethyl lead, triethyl lead, chromium picolinate, phenylarsonic acid, roxarsone, 3-nitro-4-phenylarsonic acid,, zinc phosphide, 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.	Wildlife
LEAD BEHAVIOR OR HIGH DOSE MODELS (Pb Behav)	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.	Wildlife
PHYSIOLOGY STUDIES (Phys)	Physiology studies where adverse effects are not associated with exposure to contaminants of concern.	Wildlife
PLANT (Plant)	Studies of terrestrial plants are excluded.	Wildlife
PRIMATE (Prim)	Primate studies are excluded.	Wildlife
PUBL AS (Publ as)	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.	Wildlife Plants and Soil Invertebrates
QSAR (QSAR)	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.	Wildlife Plants and Soil Invertebrates
REGULATIONS (Reg)	Regulations and related publications that are not a primary source of data.	Wildlife Plants and Soil Invertebrates
REVIEW (Rev)	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.	Wildlife Plants and Soil Invertebrates

Literature Rejection Categories		
Rejection Criteria	**Description**	**Receptor**
SEDIMENT CONC (Sed)	Studies in which the only exposure concentration/dose reported is for the level of a toxicant in sediment.	Wildlife Plants and Soil Invertebrates
SCORE (Score)	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).	Plants and Soil Invertebrates
SEDIMENT CONC (Sed)	Studies in which the only exposure concentration/dose reported is for the level of a toxicant in sediment.	Wildlife Plants and Soil Invertebrates
SLUDGE	Studies on the effects of ingestion of soils amended with sewage sludge.	Wildlife Plants and Soil Invertebrates
SOIL CONC (Soil)	Studies in which the only exposure concentration/dose reported is for the level of a toxicant in soil.	Wildlife
SPECIES	Studies in which the species of concern was not a terrestrial invertebrate or plant or mammal or bird.	Plants and Soil Invertebrates Wildlife
STRESSOR (QAC)	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.	Wildlife Plants and Soil Invertebrates
SURVEY (Surv)	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.	Wildlife Plants and Soil Invertebrates
REPTILE OR AMPHIBIAN (Herp)	Studies on reptiles and amphibians. These papers flagged for possible later review.	Wildlife Plants and Soil Invertebrates
UNRELATED (Unrel)	Studies that are unrelated to contaminant exposure and response and/or the receptor groups of interest.	Wildlife
WATER QUALITY STUDY (Wqual)	Studies of water quality.	Wildlife Plants and Soil Invertebrates
YEAST (Yeast)	Studies of yeast.	Wildlife Plants and Soil Invertebrates

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Appendix 5-1

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

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

Ref		Exposure														Effects					Conversion to mg/kg bw/day				Result		Data Evaluation Score										
Result #	Ref #	Chemical Form	MW%	Common Name	Phase #	# of Conc/ Doses	Conc/ Doses	Conc/Dose Units	Method of Analyses	Route of Exposure	Exposure Duration	Duration Units	Age	Age Units	Lifestage	Sex	Effect Type	Effect Measure	Response Site	Study NOAEL	Study LOAEL	Body Weight Reported	Body Weight (kg)	Ingestion Rate Reported?	Ingestion Rate (kg or L/day)	NOAEL Dose (mg/kg/day)	LOAEL Dose (mg/kg/day)	Data Source	Dose Route	Test Concentrations	Chemical form	Dose Quantification	Endpoint	Dose Range	Statistical Power	Exposure Duration	Test Conditions	Total
Biochemical																																						
1	100	Cobalt chloride hexahydrate	24.90%	Chicken *(Gallus domesticus)*	1	4	0/10/100/500	mg/kg	U	FD	42	d	1	d	JV	B	CHM	RBCE	BL	100	500	N	1.6255	Y	0.038	0.920	4.59	10	10	5	10	6	1	8	10	10	4	74
2	6666	Cobalt	100%	Chicken *(Gallus domesticus)*	1	4	0/50/100/200	mg/kg	U	FD	3	w	1	d	JV	M	CHM	HMCT	BL	100	200	Y	0.2587	N	0.024	9.30	18.7	10	10	5	4	6	1	10	10	10	4	70
Behavior																																						
3	90	Cobalt chloride hexahydrate	100%	Chicken *(Gallus domesticus)*	1	4	0/116/251/472	mg/kg	M	FD	14	d	1	d	JV	M	FDB	FCNS	WO	116	251	Y	0.1238	Y	0.014	13.0	29.0	10	10	10	10	7	4	10	10	10	4	85
4	100	Cobalt chloride hexahydrate	24.9%	Chicken *(Gallus domesticus)*	2	2	0/500	mg/kg	U	FD	42	d	1	d	JV	B	FDB	FCNS	WO		500	Y	1.6255	Y	0.038		4.58	10	10	5	10	7	4	4	10	10	4	74
Pathology																																						
5	90	Cobalt chloride hexahydrate	100%	Chicken *(Gallus domesticus)*	1	4	0/116/251/472	mg/kg	M	FD	14	d	1	d	JV	M	HIS	GLSN	WO	116	251	Y	0.1238	Y	0.014	13.0	29.0	10	10	10	10	7	4	10	10	10	4	85
6	100	Cobalt chloride hexahydrate	24.90%	Chicken *(Gallus domesticus)*	2	2	0/500	mg/kg	U	FD	42	d	1	d	JV	B	ORW	ORWT	HE		500	Y	1.6255	Y	0.038		4.59	10	10	5	10	7	4	4	10	10	4	74
7	80	Cobalt chloride hexahydrate	100%	Duck (*Anas sp.)*	1	3	0/200	mg/kg	U	FD	15	d	1	d	JV	M	HIS	GLSN	MB		200	N	0.46	N	0.035		15.3	10	10	5	10	5	4	4	10	10	4	72
Growth																																						
8	397	Cobalt chloride	45.39%	Chicken *(Gallus domesticus)*	3	4	0/100/200/300	mg/kg	U	FD	5	w	1	d	JV	F	GRO	BDWT	WO	100	200	N	0.328	N	0.028	3.89	7.80	10	10	5	10	5	8	10	10	10	4	82
9	6666	Cobalt	100%	Chicken *(Gallus domesticus)*	1	4	0/50/100/200	mg/kg	U	FD	3	w	1	d	JV	M	GRO	BDWT	WO	50	100	Y	0.3738	N	0.030	4.10	8.20	10	10	5	4	6	8	10	10	10	4	77
10	92	Cobalt chloride hexahydrate	100%	Chicken *(Gallus domesticus)*	1	6	0/50/100/200/300/400	mg/kg	U	FD	2	w	1	d	JV	B	GRO	BDWT	WO	50	100	Y	0.328	N	0.00031	4.29	8.59	10	10	5	10	6	8	10	10	10	4	82
11	91	Cobalt chloride hexahydrate	100%	Duck (*Anas sp.)*	1	3	0/0.02/0.2	% in diet	U	FD	8	d	2	d	JV	NR	GRO	BDWT	WO	0.02	0.2	Y	0.5	Y	0.037	14.8	148	10	10	5	10	7	8	6	10	10	4	80
12	93	Cobalt carbonate	100%	Chicken *(Gallus domesticus)*	1	3	0/100/200	mg/kg	U	FD	2	w	1	d	JV	B	GRO	BDWT	WO	200		Y	0.109	N	0.014	25.2		10	10	5	10	6	8	4	1	10	4	68
13	1370	Cobolt chloride	100%	Chicken *(Gallus domesticus)*	1	2	0/200	mg/kg	U	FD	2	w	1	d	JV	B	GRO	BDWT	WO		200	N	0.328	N	0.028		17.0	10	10	5	10	5	8	4	10	10	4	76
14	90	Cobalt chloride hexahydrate	100%	Chicken *(Gallus domesticus)*	1	4	0/116/251/472	mg/kg	M	FD	14	d	1	d	JV	M	GRO	BDWT	WO		116	Y	0.2532	Y	0.027		12.0	10	10	10	10	7	8	4	10	10	4	83
15	6215	Cobalt chloride hexahydrate	100%	Chicken *(Gallus domesticus)*	1	2	0/250	mg/kg	U	FD	14	d	0	d	IM	M	GRO	BDWT	WO		250	N	0.328	N	0.028		21.5	10	10	5	10	5	8	4	10	10	4	76
16	81	Cobalt chloride heptahydrate	100%	Chicken *(Gallus domesticus)*	1	3	0/250/500	ug/g	U	FD	15	d	8	d	JV	M	GRO	BDWT	WO		250	Y	0.296	N	0.026		22.3	10	10	5	10	6	8	4	10	10	4	77
17	100	Cobalt chloride hexahydrate	24.9%	Chicken *(Gallus domesticus)*	2	2	0/500	mg/kg	U	FD	14	d	1	d	JV	B	GRO	BDWT	WO		500	Y	0.2532	Y	0.038		29.5	10	10	5	10	7	8	4	10	10	4	78
Survival																																						
18	100	Cobalt chloride hexahydrate	24.9%	Chicken *(Gallus domesticus)*	2	2	0/500	mg/kg	U	FD	42	d	1	d	JV	B	MOR	MORT	WO	500		Y	1.6255	Y	0.059	4.59		10	10	5	10	7	9	4	10	10	4	79
19	92	Cobalt chloride hexahydrate	100%	Chicken *(Gallus domesticus)*	1	6	0/50/100/200/300/400	mg/kg	U	FD	5	w	1	d	JV	B	MOR	MORT	WO	100	200	N	1.042	N	0.060	5.74	11.5	10	10	5	10	5	9	10	10	10	4	83
20	90	Cobalt chloride hexahydrate	100%	Chicken *(Gallus domesticus)*	1	4	0/116/251/472	mg/kg	M	FD	14	d	1	d	JV	M	MOR	MORT	WO	116	251	Y	0.2532	Y	0.027	12.3	26.7	10	10	10	10	7	9	10	10	10	4	90
21	1370	Cobolt chloride	100%	Chicken *(Gallus domesticus)*	1	2	0/200	mg/kg	U	FD	2	w	1	d	JV	B	MOR	MORT	WO	200		N	0.328	N	0.028	17.0		10	10	5	10	5	9	4	10	10	4	77
22	80	Cobalt chloride hexahydrate	100%	Duck (*Anas sp.)*	1	3	0/200	mg/kg	U	FD	15	d	1	d	JV	M	MOR	MORT	WO	200		N	0.46	N	0.035	15.0		10	10	5	10	5	9	4	10	10	4	77
23	6666	Cobalt	100%	Chicken *(Gallus domesticus)*	1	4	0/50/100/200	mg/kg	U	FD	3	w	1	d	JV	M	MOR	SURV	WO	200		Y	0.1662	N	0.018	22.0		10	10	5	4	6	9	4	10	10	4	72
24	80	Cobalt chloride hexahydrate	100%	Duck (*Anas sp.)*	2	2	0/200	mg/kg	U	FD	28	d	1	d	JV	M	MOR	MORT	WO		500	N	0.46	N	0.035		38.0	10	10	5	10	5	9	4	10	10	4	77

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

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March 2005

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Appendix 6-1 Mammalian Toxicity Data Extracted and Reviewed for Wildlife Toxicity Reference Value (TRV)
Cobalt

Ref		Exposure															Effects					onversion to mg/kg bw/day Do				Result		Data Evaluation Score										
Result #	Ref #	Chemical Form	MW%	Test Organism	Phase #	# of Conc/ Doses	Conc or Doses	Conc or Dose Units	Method of Analyses	Route of Exposure	Exposure Duration	Duration Units	Age	Age Units	Lifestage	Sex	Effect Type	Effect Measure	Response Site	Study NOAEL	Study LOAEL	Body Weight Reported?	Body Weight (kg)	Ingestion Rate Reported?	Ingestion Rate (kg or Lday)	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	Data Source	Dose Route	Test Substrate	Chemical form	Dose Quantification	Endpoint	Dose Range	Statistical Power	Exposure Duration	Test Conditions	Total Score
Biochemical																																						
1	171	Cobalt nitrate	100	Cow (*Bos taurus*)	1	2	0/0.3	mg/kg bw/d	M	FD	45	d	7	mo	JV	F	CHM	HMGL	BL	0.3		Y	99	N	3.00	0.300		10	10	10	10	10	1	4	1	10	4	70
2	116	Cobaltous chloride	100	Rat (*Rattus norvegicus*)	1	6	0/10/50/100/200/300	ppm in mg/kg	U	FD	4	w	NR	NR	NR	B	CHM	HMGL	BL	200	300	Y	0.15	N	0.014	19.3	28.9	10	10	5	10	5	1	10	10	10	4	75
3	19290	Cobalt nitrate	100	Rat (*R. norvegicus*)	1	2	0/20	mg/kg bw/d	U	DR	30	d	NR	NR	JV	M	ENZ	P450	LI		20	Y	0.175	N	0.020		20.0	10	5	5	10	10	1	4	10	10	4	69
4	129	Cobalt chloride	100	Rat (*R. norvegicus*)	1	2	1	mg/ml	U	DR	35	d	NR	NR	JV	M	CHM	HMCT	BL		1	Y	0.1697	N	0.020		118	10	5	5	10	6	1	4	10	10	4	65
Behavior																																						
5	136	Cobalt chloride hexahydrate	24.9	Rat (*R. norvegicus*)	1	2	0/75	ppm in mg/kg	U	FD	80	d	44	d	JV	M	BEH	NMVM	WO	75		Y	0.47	N	0.037	1.47		10	10	5	10	6	4	4	3	10	4	66
6	86	Cobalt chloride hexahydrate	100	Pig (*Sus scrofa)*	2	4	0/200/400/600	mg/kg	U	FD	28	d	NR	NR	NR	NR	FDB	FCNS	WO		200	Y	41.58	N	1.47		7.08	10	10	5	10	6	4	4	10	6	4	69
7	111	Cobalt chloride	100	Rat (*R. norvegicus*)	1	2	0/20	mg/kg bw/d	M	DR	57	d	80	d	JV	M	BEH	ACTP	WO		20	Y	0.347	Y	0.035		20.0	10	5	10	10	10	4	4	10	10	4	77
Physiology																																						
8	105	Cobalt sulfate heptahydrate	21.91	Rat (*R. norvegicus*)	1	2	0/40	mg/kg bw/d	U	FD	16	w	NR	NR	NR	M	PHY	Other	HE		40	Y	0.387	N	0.031		8.76	10	10	5	10	10	4	4	10	10	4	77
Pathology																																						
9	136	Cobalt chloride hexahydrate	24.9	Rat (*R. norvegicus*)	1	2	0/75	ppm in mg/kg	U	FD	80	d	44	d	JV	M	HIS	GHIS	NR	75		Y	0.47	N	0.037	1.47		10	10	5	10	6	4	4	10	10	4	73
10	116	Cobaltous chloride	100	Rat (*R. norvegicus*)	1	6	0/10/50/100/200/300	ppm in mg/kg	U	FD	4	w	NR	NR	NR	B	ORW	SMIX	TS	50	100	Y	0.15	N	0.014	4.81	9.63	10	10	5	10	5	4	10	10	10	4	78
11	105	Cobalt sulfate heptahydrate	21.91	Rat (*R. norvegicus*)	1	2	0/40	mg/kg bw/d	U	FD	16	w	NR	NR	NR	M	GRS	BDWT	WO		40	Y	0.387	N	0.031		8.76	10	10	5	10	10	4	4	10	10	4	77
12	149	Cobalt chloride	100	Pig (*S. scrofa)*	1	2	0/500	ppm in mg/kg	U	FD	10	w	NR	NR	JV	M	HIS	GLSN	HE		500	Y	25.8	N	0.99		19.3	10	10	5	10	6	4	4	10	10	4	73
13	113	Cobalt chloride	45.39	Mouse (*Mus musculus*)	1	2	0/180	mg/kg bw/d	U	GV	5	d	NR	NR	GE	F	GRS	BDWT	WO		180	N	0.036	N	0.0045		81.7	10	8	5	10	10	4	4	10	10	4	75
14	129	Cobalt chloride	100	Rat (*R. norvegicus*)	1	2	1	mg/ml	U	DR	35	d	NR	NR	JV	M	ORW	SMIX	HE		1	N	0.1697	N	0.020		118	10	5	5	10	5	4	4	10	10	4	67
Reproduction																																						
15	126	Cobalt chloride	100	Rat (*R. norvegicus*)	1	3	0/5/20	mg/kg bw/d	U	FD	69	d	80	d	MA	M	REP	TEWT	TE	5	20	N	0.00021	N	0.000065	5.00	20.0	10	10	5	10	10	10	8	10	6	4	83
16	124	Cobalt chloride	45.39	Rat (*R. norvegicus*)	1	4	0/12/24/48	mg/kg bw/d	U	GV	28	d	NR	NR	MA	F	REP	PRWT	WO	12	24	Y	0.3	N	0.026	5.45	10.9	10	8	5	10	10	10	10	10	10	4	87
17	109	Cobalt chloride hexahydrate	24.9	Rat (*R. norvegicus*)	1	4	0/25/50/100	mg/kg bw/d	U	GV	9	d	NR	NR	GE	F	REP	PRWT	WO	100		Y	0.28	N	0.024	24.9		10	8	5	10	10	10	4	10	10	4	81
18	113	Cobalt chloride	45.39	Mouse (*M. musculus*)	1	2	0/180	mg/kg bw/d	U	GV	5	d	NR	NR	GE	F	REP	PROG	WO	180		Y	0.036	N	0.0045	81.7		10	8	5	10	10	10	4	1	10	4	72
19	121	Cobalt chloride hexahydrate	45.39	Mouse (*M. musculus*)	1	4	0/23/42/72	mg/kg bw/d	U	DR	13	w	12	w	SM	M	REP	RSUC	WO		23	Y	0.0375	N	0.0052		10.0	10	5	5	10	10	10	4	10	10	4	78
20	120	Cobalt chloride hexahydrate	24.9	Mouse (*M. musculus*)	1	2	0/400	mg/l	U	DR	9	w	12	w	MA	M	REP	TEWT	TE		400	N	0.037	N	0.0051		13.7	10	5	5	10	5	10	4	10	10	4	73
21	123	Cobalt chloride hexahydrate	100	Rat (*R. norvegicus*)	1	2	0/20	mg/kg bw/d	U	FD	70	d	100	d	SM	M	REP	TEDG	TE		20	N	0.523	N	0.040		20.0	10	10	5	10	10	4	4	10	10	4	77
22	119	Cobalt	100	Rat (*R. norvegicus*)	1	2	0/265	ppm in mg/kg	U	FD	98	d	100	d	MA	M	REP	TEWT	TE		265	Y	0.2	N	0.018		24.2	10	10	5	4	6	10	4	10	10	4	73
23	139	Cobalt chloride hexahydrate	100	Mouse (*M. musculus*)	1	2	0/43.4	mg/kg bw/d	U	DR	13	w	12	w	MA	M	REP	TEWT	TE		43.4	Y	0.045	N	0.0061		43.4	10	5	5	10	10	10	4	10	10	4	78
24	187	Cobalt chloride hexahydrate	100	Mouse (*M. musculus*)	1	2	0/400	mg/l	U	DR	10	w	8 to 10	w	JV	M	REP	PRFM	WO		400	N	0.0316	N	0.0044		55.9	10	5	5	10	5	10	4	10	10	4	73
Growth																																						
25	171	Cobalt nitrate	100	Cow (*Bos taurus*)	1	2	0/0.3	mg/kg bw/d	M	FD	45	d	7	mo	JV	F	GRO	BDWT	WO	0.3		Y	99	N	3.00	0.300		10	10	10	10	10	8	4	1	10	4	77
26	136	Cobalt chloride hexahydrate	24.9	Rat (*R. norvegicus*)	1	2	0/75	ppm in mg/kg	U	FD	80	d	44	d	JV	M	GRO	BDWT	WO	75		Y	0.47	N	0.037	1.47		10	10	5	10	6	8	4	1	10	4	68
27	86	Cobalt chloride hexahydrate	100	Pig (*S. scrofa)*	1	4	0/25/50/100	mg/kg	U	FD	16	w	NR	NR	NR	NR	GRO	BDWT	WO	100		Y	97.5	Y	2.35	2.41		10	10	5	10	7	8	4	10	6	4	74
28	121	Cobalt chloride hexahydrate	45.39	Mouse (*M. musculus*)	1	4	0/23/42/72	mg/kg bw/d	U	DR	5	w	12	w	SM	M	GRO	BDWT	WO	42	72	Y	0.0375	Y	0.0078	19.0	33.0	10	5	5	10	10	8	10	10	10	4	82
29	132	Cobalt sulfate	100	Guinea pig (*Cavia porcellus*)	1	2	0/20	mg/kg bw/d	U	OR	5	w	NR	NR	MA	M	GRO	BDWT	WO	20		Y	0.478	N	0.037	20.0		10	8	5	10	10	8	4	10	3	4	72
30	111	Cobalt chloride	100	Rat (*R. norvegicus*)	1	2	0/20	mg/kg bw/d	M	DR	57	d	80	d	JV	M	GRO	BDWT	WO	20		Y	0.347	Y	0.035	20.0		10	5	10	10	10	8	4	1	10	4	72
31	116	Cobaltous chloride	100	Rat (*R. norvegicus*)	1	6	0/10/50/100/200/300	ppm in mg/kg	U	FD	4	w	NR	NR	NR	B	GRO	BDWT	WO		10	Y	0.15	N	0.014		0.963	10	10	5	10	6	8	4	10	10	4	77
32	109	Cobalt chloride hexahydrate	24.9	Rat (*R. norvegicus*)	1	4	0/25/50/100	mg/kg bw/d	U	GV	9	d	NR	NR	GE	F	GRO	BDWT	WO		25	Y	0.28	N	0.024		6.23	10	8	5	10	10	8	4	10	10	4	79
33	149	Cobalt chloride	100	Pig (*Sus scrofa)*	1	2	0/500	ppm in mg/kg	U	FD	5	w	NR	NR	JV	M	GRO	BDWT	WO		500	Y	19.8	N	0.80		20.2	10	10	5	10	6	8	4	10	10	4	77
34	139	Cobaltous chloride hexahydrate	100	Mouse (*M. musculus*)	1	2	0/43.4	mg/kg bw/d	U	DR	13	w	12	w	MA	M	GRO	BDWT	WO		43.4	Y	0.045	N	0.0061		43.4	10	5	5	10	10	8	4	10	10	4	76
35	129	Cobalt chloride	100	Rat (*R. norvegicus*)	1	2	1	mg/ml	U	DR	24	d	NR	NR	JV	M	GRO	BDWT	WO		1	Y	0.1262	N	0.015		122	10	5	5	10	6	8	4	10	10	4	72
Survival																																						
36	149	Cobalt chloride	100	Pig (*S. scrofa)*	1	2	0/500	ppm in mg/kg	U	FD	10	w	NR	NR	JV	M	MOR	MORT	NR	500		Y	25.8	N	0.99	19.3		10	10	5	10	6	9	4	10	10	4	78
37	113	Cobalt chloride	45.39	Mouse (*M. musculus*)	1	2	0/180	mg/kg bw/d	U	GV	5	d	NR	NR	GE	F	MOR	MORT	NR	180		Y	0.036	N	0.0045	81.7		10	8	5	10	10	9	4	10	10	4	80
38	132	Cobalt sulfate	100	Guinea pig (*Cavia porcellus*)	1	2	0/20	mg/kg bw/d	U	OR	5	w	NR	NR	MA	M	MOR	SURV	WO		20	Y	0.478	N	0.037		20.0	10	8	5	10	10	9	4	10	3	4	73
Data Not Used to Derive TRV																																						
39	86	Cobalt chloride hexahydrate	100	Pig (*S. scrofa)*	1	4	0/25/50/100	mg/kg	U	FD	16	w	NR	NR	NR	M	CHM	HMGL	BL	100		Y	97.5	Y	2.35	2.40		10	10	5	10	7	1	4	3	6	4	60
40	149	Cobalt chloride	100	Pig (*S. scrofa)*	1	2	0/500	ppm in mg/kg	U	FD	10	w	NR	NR	JV	M	ENZ	GLPX	BL	500		Y	25.8	N	0.99	19.3		10	10	5	10	6	1	4	3	10	4	63
41	121	Cobalt chloride hexahydrate	45.39	Mouse (*M. musculus*)	1	4	0/23/42/72	mg/kg bw/d	U	DR	12	w	12	w	SM	M	CHM	HMCT	BL	72		Y	0.038	Y	0.0064	30.6		10	5	5	10	7	1	4	1	10	4	60
42	86	Cobalt chloride hexahydrate	100	Pig (*S. scrofa)*	3	2	0/400	mg/kg	U	FD	2	w	NR	NR	NR	NR	CHM	HMGL	BL		400	Y	23.62	Y	0.97		16.4	10	10	5	10	7	1	4	10	3	4	64

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