

Ecological Soil Screening Levels for Silver

Interim Final

OSWER Directive 9285.7-77



**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, birds, 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, 2005). The derivation procedures represent the group 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 silver and the documentation for their derivation. This document provides guidance and is designed to communicate national policy on identifying silver 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 SILVER

Silver is a rare, naturally occurring metal, often found deposited as a mineral ore in association with other elements (ATSDR, 1990). In nature, silver compounds occur as halides, cyanide, thiocyanate, oxides, hydroxides, carbonates, nitrate, sulfate, sulfides, ferrocyanide complexes, and thiosulfate complexes (Bodek et al., 1988 HSDB). The oxides, sulfates, carbonates, and phosphates of silver are moderately soluble. Other silver compounds are insoluble, with the exception of nitrate which is miscible (Bodek et al., 1988 HSDB). Silver is found in minerals

such as cerargyrite (AgCl), pyrargyrite ($2\text{Ag}_2\text{S}\cdot\text{Sb}_2\text{S}_3$), proustite ($3\text{Ag}_2\text{S}\cdot\text{Ag}_2\text{S}_3$), and stephanite ($5\text{Ag}_2\text{S}\cdot\text{Sb}_2\text{S}_2$) (Bodek et al. 1988 HSDB). From these natural sources, silver is released to air and water through the weathering of rocks and the erosion of soils.

Silver may also enter the environment from the production and use of silver compounds in batteries, catalysts, medical preparations, electroplating and photography (Cappel, 1997 HSDB). The primary use of silver (about 40% of the total U.S. supply) is in photographic film and chemicals. Another 20% is used in electrical contacts and conductors. Other uses of the metal, its alloys and compounds include sterling ware, solder, jewelry, coins, medallions, dental and medical applications (Bodek et al., 1988). Other anthropogenic sources include smelting operations, cloud seeding operations, coal combustion, steel and iron production, cement manufacturing, urban refuse incineration, and cigarette tobacco (HSDB).

When released to soils, silver exists as Ag^+ ions or as insoluble silver complexes. the behavior of silver is strongly influenced by pH, redox conditions, and interactions with soil organic matter. Silver is highly immobile in soils relative to other metals. This immobility is due to precipitation of silver to form insoluble salts and adsorb to organic matter, clays, and manganese and iron oxides (Smith and Carson, 1977). The mobility of silver is increased by humus decomposition or by lowering pH (Alloway, 1990). The speciation of Ag^+ ions are affected by the concentration of chloride and under reducing environments the concentration of sulfide ions. Silver compounds have a range of mobilities with partitioning controlled by silver speciation both in solution and on soil surfaces. Manganese oxide has a strong affinity to adsorb silver ions followed by $\text{Fe}(\text{OH})_3$, clays, Fe_2O_3 and organic colloids. Relatively large amounts of organic colloids will substantially lower the partitioning of silver and remobilize adsorbed silver. Silver compounds are not expected to volatilize from moist or dry soil surfaces based upon their ionic character and low vapor pressures (HSDB).

Accumulation of silver from soil to plants is low and studies have shown the roots to be the main site of silver accumulation (Ratte, 1999). Silver accumulation in leaves results from deposition from airborne sources such as a smelter (Ward et al., 1979). Data on the accumulation of silver from soils by soil invertebrates is limited (Ratte, 1999). Silver is toxic in laboratory studies to avian and mammalian species with effects including reduced growth and reproduction and increased mortality.

Table 2.1 Silver Eco-SSLs (mg/kg dry weight in soil)			
Plants	Soil Invertebrates	Wildlife	
		Avian	Mammalian
560	NA	4.2	14
NA = Not Available. Data were insufficient to derive an Eco-SSL.			

Eco-SSL values were derived for silver for plants, and avian and mammalian wildlife. Eco-SSL values for silver could not be derived for soil invertebrates. For this receptor group, data were insufficient to derive soil screening values. Eco-SSL values calculated for Silver range from 4.2 mg/kg dry weight (dw) for avian wildlife to 560 mg/kg dw for plants. These concentrations are higher than the reported background soil concentrations of silver in eastern and western U.S. soils (Figure 2.1). Background concentrations reported for many metals in U.S. soils are described in Attachment 1-4 of the Eco-SSL guidance (U.S. EPA, 2003).

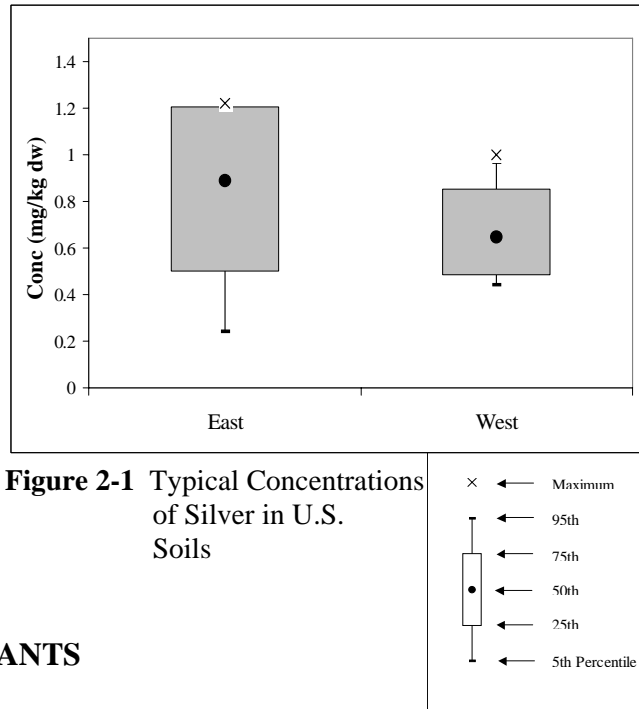


Figure 2-1 Typical Concentrations of Silver in U.S. Soils

3.0 ECO-SSL FOR TERRESTRIAL PLANTS

Of the papers identified from the literature search process, 61 were selected for acquisition for further review. Of those papers acquired, two 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). Three studies received an Evaluation Score greater than ten. These studies are listed in Table 3.1.

There are four studies eligible for Eco-SSL derivation that were used to derive the plant Eco-SSL for Silver (U.S. EPA, 2003; Attachment 3-2). The Eco-SSL is the geometric mean of the MATC values for 4 test species under different test conditions (pH and OM%) and is equal 560 mg/kg dw.

Table 3.1 Plant Toxicity Data - Silver

Reference	IP Number	Study ID	Test Organism		Soil pH	OM%	Bio-availability Score	ERE	Tox Parameter	Tox Value (Soil Conc at mg/kg dw)	Total Evaluation Score	Eligible for Eco-SSL Derivation?	Used for Eco-SSL?
Weaver and Klarich, 1973	20195	c	soybeans	<i>Glycine max</i>	7.4	0.17 - 2.8	0	GRO	MATC	3162	11	Y	Y
Weaver and Klarich, 1973	20195	e	wheat	<i>Triticum aestivum</i>	7.4	0.17 - 2.8	0	GRO	MATC	316	11	Y	Y
Weaver and Klarich, 1973	20195	f	corn	<i>Zea mays</i>	7.4	0.17 - 2.8	0	GRO	MATC	316	11	Y	Y
Weaver and Klarich, 1973	20195	g	sunflower	<i>Helianthus annus</i>	7.4	0.17 - 2.8	0	GRO	MATC	316	11	Y	Y
Geometric Mean										560			

EC₁₀ = Effect concentration for 10% of test population

EC₂₀ = Effect concentration for 10% of test population

EC₅₀ = Effect concentration for 50% of test population

ERE = Ecologically relevant endpoint

GRO = Growth

LOAEC = Lowest observed adverse effect concentration

MATC = Maximum acceptable toxicant concentration. Geometric mean of NOAEC and LOAEC.

N = No

NOAEC = No observed adverse effect concentration

ns = Not specified

OM = Organic matter content

REP = Reproduction

Y = Yes

Bioavailability Score described in *Guidance for Developing Eco-SSLs* (U.S. EPA, 2003)

Total Evaluation Score described in *Guidance for Developing Eco-SSLs* (U.S. EPA, 2003)

4.0 ECO-SSL FOR SOIL INVERTEBRATES

Of the papers identified from the literature search process, 61 papers were acquired for further review. Of those papers acquired, two met all 11 Study Acceptance Criteria (U.S. EPA, 2003; Attachment 3-1). Each of these papers were reviewed and there were no studies scored according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 3-2) that received an Evaluation Score greater than ten. An Eco-SSL could not be derived for soil invertebrates for Silver.

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 4,009 papers with possible toxicity data for either avian or mammalian species. Of these papers, 2,526 were unrelated to toxicity testing and contained information on the use of silver nitrate staining of cells. These papers are not listed in Section 7.5. Of the remaining 1,483 papers, 1,463 were rejected for use as described in Section 7.5. Of the 20 remaining papers, seven contained data for avian 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 5.1. The complete results are included as Appendix 5-1.

Within the three papers there are 22 results for biochemical (BIO), behavior (BEH), pathology (PTH), reproduction (REP), growth (GRO), and survival (MOR) endpoints that meet the Data Evaluation Score of > 65 for use to derive the TRV. These data are plotted in Figure 5.1 and correspond directly with the data presented in Table 5.1. The no-observed adverse effect level (NOAEL) results for growth and reproduction are used to calculate a geometric mean NOAEL. This mean NOAEL is examined in relationship to the lowest bounded lowest-observed adverse effect level (LOAEL) for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-5).

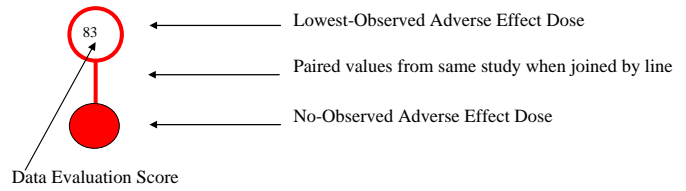
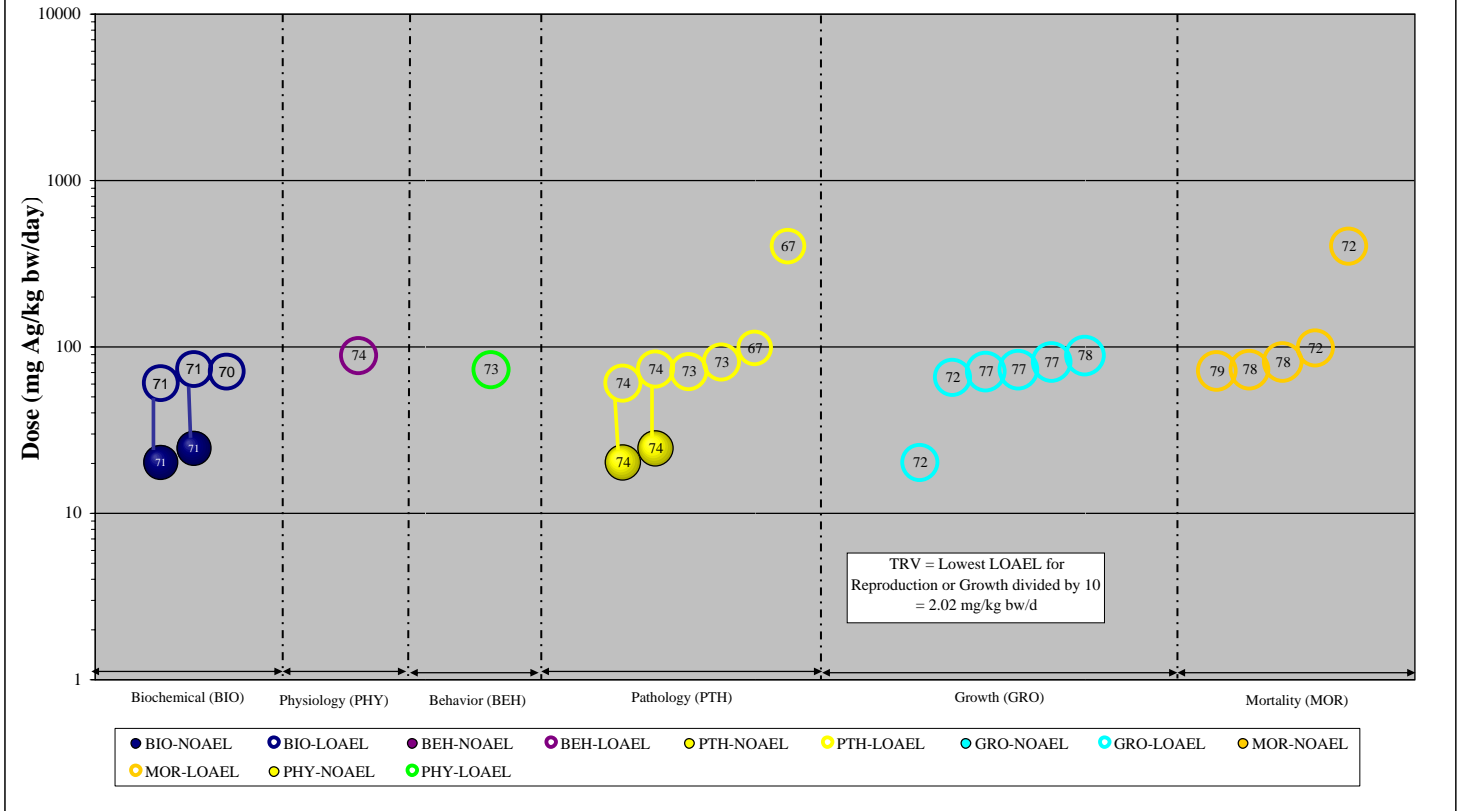
There are not three NOAEL values within the growth and reproduction effect groups. A geometric mean could not be calculated. There is not at least one NOAEL for reproduction or growth. There are at least three LOAEL values within the growth and reproduction effect groups. The avian TRV for Silver is equal to the lowest LOAEL for reproduction or growth divided by 10 and is equal to 2.02 mg/kg bw/d.

Table 5.1
Avian Toxicity Data Extracted for Wildlife Toxicity Reference Value (TRV)
Silver
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Result #	Reference	Ref No.	Test Organism	# of Conc/ Doses	Method of Analyses	Route of Exposure	Exposure Duration	Duration Units	Age	Age Units	Lifestage	Sex	Effect Type	Effect Measure	Response Site	NOAEL Dose (mg/kg bw/day)	LOAEL Dose (mg/kg bw/day)	Data Evaluation Score	
Biochemical (BIO)																			
1	Jensen et al, 1974	9892	Turkey (<i>Meleagris gallopavo</i>)	3	U	FD	5	w	1	d	JV	B	CHM	PCLV	BL	20.2	60.5	71	
2	Jensen et al, 1974	9892	Turkey (<i>Meleagris gallopavo</i>)	4	U	FD	4	w	1	d	JV	B	CHM	PCLV	BL	24.5	73.4	71	
3	Peterson et al, 1973	9232	Turkey (<i>Meleagris gallopavo</i>)	2	U	FD	4	w	1	d	JV	B	CHM	HMGL	BL		70.8	70	
Behavior (BEH)																			
4	Jensen, 1975	1403	Chicken (<i>Gallus domesticus</i>)	2	U	FD	14	d	1	d	JV	NR	FDB	FCNS	WO		88.4	74	
Physiology (PHY)																			
5	Petersen and Jensen, 1975	6899	Chicken (<i>Gallus domesticus</i>)	2	U	FD	28	d	1	d	JV	NR	PHY	GPHY	WO		72.8	73	
Pathology (PTH)																			
6	Jensen et al, 1974	9892	Turkey (<i>Meleagris gallopavo</i>)	3	U	FD	5	w	1	d	JV	B	HIS	GHIS	HE	20.2	60.5	74	
7	Jensen et al, 1974	9892	Turkey (<i>Meleagris gallopavo</i>)	4	U	FD	4	w	1	d	JV	B	HIS	GHIS	HE	24.5	73.4	74	
8	Peterson et al, 1973	9232	Turkey (<i>Meleagris gallopavo</i>)	2	U	FD	4	w	1	d	JV	B	ORW	SMIX	IHE		70.8	73	
9	Peterson and Jensen, 1975	6901	Chicken (<i>Gallus domesticus</i>)	2	U	FD	28	d	1	d	JV	B	ORW	ORWT	HE		81.1	73	
10	Van Vleet, 1977	6778	Duck (<i>Anas platyrhynchos</i>)	2	U	FD	3	w	1	d	JV	M	HIS	GHIS	MU		98.6	67	
11	Van Vleet et al, 1981	80	Duck (<i>Anas platyrhynchos</i>)	2	U	FD	15	d	1	d	JV	M	HIS	NCRO	GZ		401	67	
Growth (GRO)																			
12	Jensen et al, 1974	9892	Turkey (<i>Meleagris gallopavo</i>)	3	U	FD	5	w	1	d	JV	B	GRO	BDWT	WO		20.2	72	
13	Jensen et al, 1974	9892	Turkey (<i>Meleagris gallopavo</i>)	2	U	FD	5	w	1	d	JV	B	GRO	BDWT	WO		65.5	72	
14	Peterson et al, 1973	9232	Turkey (<i>Meleagris gallopavo</i>)	2	U	FD	4	w	1	d	JV	B	GRO	BDWT	WO		70.8	77	
15	Petersen and Jensen, 1975	6899	Chicken (<i>Gallus domesticus</i>)	2	U	FD	28	d	1	d	JV	NR	GRO	BDWT	WO		72.8	77	
16	Peterson and Jensen, 1975	6901	Chicken (<i>Gallus domesticus</i>)	2	U	FD	28	d	1	d	JV	B	GRO	BDWT	WO		81.1	77	
17	Jensen, 1975	1403	Chicken (<i>Gallus domesticus</i>)	2	U	FD	14	d	1	d	JV	NR	GRO	BDWT	WO		88.4	78	
Survival (MOR)																			
18	Jensen, 1975	1403	Chicken (<i>Gallus domesticus</i>)	2	U	FD	14	d	1	d	JV	NR	MOR	MORT	WO		71.4	79	
19	Petersen and Jensen, 1975	6899	Chicken (<i>Gallus domesticus</i>)	2	U	FD	28	d	1	d	JV	NR	MOR	MORT	WO		72.8	78	
20	Peterson and Jensen, 1975	6901	Chicken (<i>Gallus domesticus</i>)	2	U	FD	28	d	1	d	JV	B	MOR	MORT	WO		81.1	78	
21	Van Vleet, 1977	6778	Duck (<i>Anas platyrhynchos</i>)	2	U	FD	3	w	1	d	JV	F	MOR	MORT	WO		98.6	72	
22	Van Vleet et al, 1981	80	Duck (<i>Anas platyrhynchos</i>)	2	U	FD	15	d	1	d	JV	M	MOR	MORT	WO		401	72	

JV = juvenile; w = week; FD = food; U = unmeasured; M = Male; B = both; GRO = growth; F = female; d = day; MORT = mortality; NR = not reported; MU = multiple; HE = heart; NCRO = necrosis; WO = whole organism; GZ = gizzard; SMIX = relative to body weight; GHIS = general histological changes; ORWT = organ weight; FCNS = food consumption; FDB = feeding behavior; PHY = physiology; GPHY = general physiological changes; HMGL = hemoglobin; BL = blood; PCLV = packed cell volume; CHM = chemical changes.

Figure 5.1 Avian TRV Derivation for Silver



Wildlife TRV Derivation Process

- 1) There are at least three results available for two test species within the growth, reproduction, and mortality effect groups. There are enough data to derive a TRV.
- 2) There are not three NOAEL results available within the growth and reproduction effect groups for calculation of a geometric mean.
- 3) There is not a NOAEL for reproduction or growth.
- 4) There are at least three LOAEL values for reproduction or growth.
- 5) The avian TRV for Silver is equal to the lowest LOAEL for reproduction or growth divided by 10 and is equal to 2.02 mg/kg bw/d.

5.2 Estimation of Dose and Calculation of the Eco-SSL

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

Table 5.2 Calculation of the Avian Eco-SSLs for Silver						
Surrogate Receptor Group	TRV for Silver (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 Silver in Biota Type (i) ^{2,3} (B _i) (mg/kg dw)	Silver in Diet of Prey (C _{diet})	Eco-SSL (mg/kg dw) ⁴
Avian herbivore (dove)	2.02	0.190	0.139	B _i = 0.014 * Soil _j where i = plants	NA	69
Avian ground insectivore (woodcock)	2.02	0.214	0.164	B _i = 2.045 * Soil _j where i = earthworms	NA	4.2
Avian carnivore (hawk)	2.02	0.0353	0.057	B _i = 0.004 * Soil _j where i = mammals	NA	930

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 completed according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-2) identified 4,009 papers with possible toxicity data for either avian or mammalian species. Of these papers, 2,526 were unrelated to toxicity testing and contained information on the use of silver nitrate staining of cells. These papers are not listed in Section 7.5. Of the remaining 1,483 papers, 1,463 were rejected for use as described in Section 7.5. Of the 20 remaining papers, 13 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 13 papers there are 15 results for biochemical (BIO), behavior (BEH), 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 4-4). These data are plotted in Figure 6.1 and correspond directly with the data presented in Table 6.1. The NOAEL results for growth and reproduction are used to calculate a geometric mean NOAEL. This mean NOAEL is examined in relationship to the lowest bounded 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).

There are not three NOAEL values within the growth and reproduction effect groups. A geometric mean could not be calculated. There is not at least one NOAEL for reproduction or growth. There are at least three LOAEL values within the growth and reproduction effect groups. The mammalian TRV for Silver is equal to the lowest LOAEL for reproduction or growth divided by 10 and is equal to 6.02 mg/kg bw/d.

6.2 Estimation of Dose and Calculation of the Eco-SSL

Three separate Eco-SSL values were calculated for mammalian wildlife, one for each of three surrogate species representing different trophic groups. The mammalian Eco-SSLs derived for Silver were calculated according to the Eco-SSL guidance (U.S. EPA, 2003) and are summarized in Table 6.2.

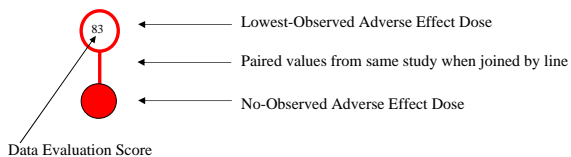
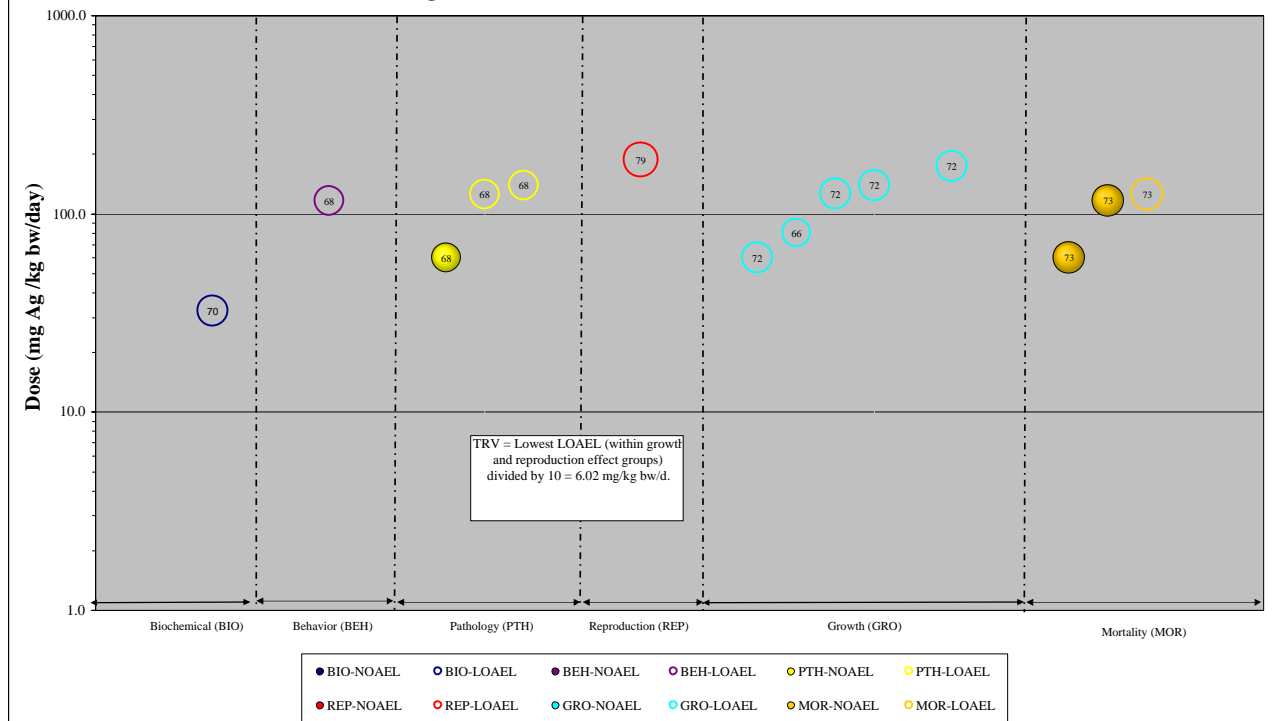
Table 6.1 Mammalian Toxicity Data Extracted for Wildlife Toxicity Reference Value (TRV)

Silver

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Result #	Reference	Ref No.	Test Organism	# of Conc/ Doses	Method of Analyses	Route of Exposure	Exposure Duration	Duration Units	Age	Age Units	Lifestage	Sex	Effect Type	Effect Measure	Response Site	NOAEL Dose (mg/kg bw/day)	LOAEL Dose (mg/kg bw/day)	Total
Biochemical (BIO)																		
1	Pribyl et al, 1980	23825	Rat (<i>Rattus norvegicus</i>)	2	U	FD	4	d	NR	NR	JV	M	ENZ	GENZ	SR		32.3	70
Behavior (BEH)																		
2	Cabe, et al., 1979	1244	Rat (<i>Rattus norvegicus</i>)	2	U	DR	13	w	50	d	JV	M	FDB	WCON	WO		116	68
Pathology (PTH)																		
3	Van Vleet, 1976	22589	Pig (<i>Sus scrofa</i>)	2	U	FD	40	d	NR	NR	JV	NR	HIS	NCRO	LI	60.2		68
4	Van Vleet et al, 1981	149	Pig (<i>Sus scrofa</i>)	2	U	FD	25	d	NR	NR	JV	M	HIS	GLSN	HE		125	68
5	Van Vleet, 1976	22589	Pig (<i>Sus scrofa</i>)	2	U	FD	28	d	NR	NR	JV	NR	HIS	NCRO	LI		140	68
Reproduction (REP)																		
6	Shavlovski et al, 1995	21093	Rat (<i>Rattus norvegicus</i>)	2	U	FD	20	d	NR	NR	GE	F	REP	PROG	WO		188	79
Growth (GRO)																		
7	Van Vleet, 1976	22589	Pig (<i>Sus scrofa</i>)	2	U	FD	40	d	NR	NR	JV	NR	GRO	BDWT	WO		60.2	72
8	Wagner et al, 1975	14503	Rat (<i>Rattus norvegicus</i>)	2	U	DR	15	w	21	d	JV	B	GRO	BDWT	WO		80.2	66
9	Van Vleet et al, 1981	149	Pig (<i>Sus scrofa</i>)	2	U	FD	4	w	NR	NR	JV	M	GRO	BDWT	WO		126	72
10	Van Vleet, 1976	22589	Pig (<i>Sus scrofa</i>)	2	U	FD	28	d	NR	NR	JV	NR	GRO	BDWT	WO		140	72
11	Matuk et al, 1981	22823	Rat (<i>Rattus norvegicus</i>)	2	U	DR	16	w	NR	NR	JV	M	GRO	BDWT	WO		174	72
Survival (MOR)																		
12	Van Vleet, 1976	22589	Pig (<i>Sus scrofa</i>)	2	U	FD	40	d	NR	NR	JV	NR	MOR	MORT	WO	60.2		73
13	Cabe, et al., 1979	1244	Rat (<i>Rattus norvegicus</i>)	2	U	DR	13	w	50	d	JV	M	MOR	MORT	WO	116		73
14	Van Vleet et al, 1981	149	Pig (<i>Sus scrofa</i>)	2	U	FD	25	d	NR	NR	JV	M	MOR	MORT	WO		125	73
15	Van Vleet, 1976	22589	Pig (<i>Sus scrofa</i>)	2	U	FD	28	d	NR	NR	JV	NR	MOR	MORT	WO		140	73

Figure 6.1 Mammalian TRV Derivation for Silver



Wildlife TRV Derivation Process

Step 1: There are at least three results available for two test species within the growth, reproduction, and mortality effect groups. There are enough data to derive a TRV.

Step 2: There are not three NOAEL results available within the growth and reproduction effect groups for calculation of a geometric mean.

Step 3: There is not at least one NOAEL results within the growth and reproduction effect groups.

Step 5: There are at least 3 LOAEL results within growth and reproduction effect groups.

TRV = Lowest LOAEL (within growth and reproduction effect groups) divided by 10 = 6.02 mg/kg bw/d.

Table 6.2 Calculation of the Mammalian Eco-SSL for Silver						
Surrogate Receptor Group	TRV for Silver (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 Silver in Biota Type (i) ^{2,3} (B _i) (mg/kg dw)	Silver in Diet of Prey ⁴ (C _{diet})	Eco-SSL (mg/kg dw) ⁵
Mammalian herbivore (vole)	6.02	0.0875	0.032	B _i = 0.014 * Soil _j where i = plants	NA	1500
Mammalian ground insectivore (shrew)	6.02	0.209	0.030	B _i = 2.045 * Soil _j where i = earthworms	NA	14
Mammalian carnivore (weasel)	6.02	0.130	0.043	B _i = 0.004 * Soil _j where i = mammals	NA	990

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 C_{diet} = Concentration in the diet of small mammals consumed by predatory species (weasel).
⁵ 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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- Diss** assimilation of metals by sediment-ingesting invertebrates: effects of natural sediment qualities and intrinsic metal characteristics (metal uptake, leptocheirus plumulosus, exopolymers, assimilation efficiency). *01658736 ORDER NO: AAD98-41765*
- HHE** autoradiographic and immunofluorescent detection of low concentrations of actinomycin d bound to human metaphase chromosomes. *791581 ORDER NO: AAD82-23004*
- Diss** behavioural ecology of the silver leaf monkey, trachypithecus auratus sondaicus, in the pangandaran nature reserve, west java, indonesia (monkey). *01146037 ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.*
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- Diss** characterisation of nuclear proteins interacting with the trout protamine genes (*salmo gardnerii*). 01208366 ORDER NO: AADNN-61681
- Diss** characterization of lymphocyte-produced macrophage growth factor and its action on the proliferation of macrophages (colony stimulating factor, csf type 1). 933649 ORDER NO: AAD86-24554
- Diss** characterization of membrane-associated molecules of the retinal pigmented epithelium in rat retina. 01183980 ORDER NO: AAD91-33217
- Diss** the characterization of the biological and mechanical properties of porous calcium phosphate ceramics used as bone implants|. 01213302 ORDER NO: AAD92-11183
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- No Oral** comparative toxicity of trimethyltin in four "normal" inbred strains of mice (neurodegeneration). 01440993 ORDER NO: AADAA-19536479
- Diss** corelease of acetylcholine and gaba by an amacrine cell: evidence for independent mechanisms. 1083525 ORDER NO: AAD89-26150
- Diss** cytogenetic analysis of chromosomal heterozygosity in the *peromyscus maniculatus* species group . 1040764 ORDER NO: AAD89-03346
- Diss** dental primary afferent connectivity in the brain stem trigeminal nuclear complex (degeneration, transganglionic). 894164 ORDER NO: AAD85-21606
- Diss** development and distribution of neuroepithelial bodies in the fetal hamster lung. 833519 ORDER NO: AAD84-01837
- Diss** development and evaluation of monoclonal antibodies to *acanthamoeba* spp. (dot-immunobinding assay. 880026 ORDER NO: AAD85-08639
- Diss** development of a cryosection em autoradiography technique and its application for the subcellular localization of receptors (methyl cellulose). 01618626 ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.

- Diss** the development of order in the rat trigeminal system. 1052958 ORDER NO: AAD82-07023
- An Prod** drinking water containing rare earth metals and silver-plated metals for acceleration of egg production in hens. *Jpn. Kokai Tokkyo Koho* : 4 pp.
- Diss** early events in the mechanism of action of nerve growth factor (neural development, map2 kinase, phosphorylation, tyrosine kinase). 01174076 ORDER NO: AAD91-25949
- Diss** ecological and population genetic studies of forest-dwelling bats (louisiana, phylogenetic, corynorhinus rafinesquii, lasionycteris noctivagans, nycticeius humeralis, lasiurus seminolus, nyssa sylvatica). 01698859 ORDER NO: AAD99-25307
- Diss** an ecology of the bahamian hutia (geocapromys ingrahami) (hutia).
- Diss** the effect of dietary fiber on canine colonic motility. 693085 ORDER NO: AAD80-18529
- Diss** effect of irradiation on proliferation of endothelial cells during neovascularization of the cornea: an autoradiographic study. 826684 ORDER NO: AAD83-25722
- Diss** the effect of surface charge on arterial thrombosis. 696335 ORDER NO: AAD80-21695
- Diss** effects of dietary fat on production performance, body fat composition and skin storage in farm-raised mink and foxes. 01215369 ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.
- Diss** Effects of dietary glycine and copper on metabolic symptoms INDUCED BY A METHIONINE TOXICITY IN THE CHICK :
- Diss** the effects of lesions of sensory and motor cortex on ingestive behavior in rats. 762801 ORDER NO: AAD81-20898
- Diss** an enzyme histochemical and histopathological study of the degenerative and regenerative changes in the transected or hemisected spinal cord of the rat. 793806 ORDER NO: AAD82-12771
- Diss** the evaluation of marine by-products for use as feedstuffs in mink diets. 01573034 ORDER NO: AADMM-15783
- Diss** the evoked response and the modulation of cortical arousal in the visual neglect phenomenon. 794018 ORDER NO: AAD82-23730
- Diss** an examination of the development and maintenance of the deafferented olfactory cortex. 1053096 ORDER NO: AAD82-12323
- Diss** experimental infection of the white-footed mouse (peromyscus leucopus) with the lyme disease spirochete (borrelia burgdorferi). 0975757 ORDER NO: AAD87-28911
- Diss** foraging ecology and behavior of atlantic bottlenose dolphins (tursiops truncatus) in the indian river lagoon, florida (activity budgets, habitat utilization, passive listening)]. 1593265 ORDER NO: AAD97-30127
- Diss** gaze movements and the thalamic internal medullary lamina in the cat. 794459 ORDER NO: AAD82-25597

- Diss** genetic and cytogenetic studies of the aprt locus of mouse friend cells. 01154302 ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.
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- Diss** geschlechtsdifferenzierung des vogelhirns: auswirkung original title: sexual dimorphism in the avian brain: effects of prenatal hormone treatment on sexual dimorphic organization and japanese quail (coturnix coturnix japonica) original title: sexual dimorphism in the avian brain: effects of prenatal hormone treatment on sexual dimorphic organization and behaviour in the japanese quail (coturnix coturnix japonica). 01464445 ORDER NO: AADAA-IC467461
- Diss** glutathione transport in epithelial cells: biochemical, toxicological, and nutritional aspects . 01108242 ORDER NO: AAD90-15647
- Diss** habitat use and mortality of mule deer fawns in western south dakota. 760816 ORDER NO: AAD81-24765
- Diss** hereditary striatonigral and cerebello-olivary degeneration of the kerry blue terrier. 765972 ORDER NO: AAD81-28912
- Diss** immunochemical studies of lipopolysaccharides isolated from strains of campylobacter jejuni and campylobacter coli (bacteria, antigen). 1019408 ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.
- Diss** immunological studies of stage specificity of erythrocytic and exoerythrocytic merozoites of plasmodium fallax|. 879287 ORDER NO: AAD85-07138
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- Diss** intermediate filament proteins in the developing rat optic nerve. 830836 ORDER NO: AAD83-24841
- Diss** intrahemispheric and commissural connections between and within commissurally and noncommissurally interconnected regions in the primary and secondary somatic sensory cerebral cortex: their possible role in interhemispheric transfer of learning in the raccoon. 694114 ORDER NO: AAD80-20707
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- Diss** iron hands: the internal sources of international cooperation (cartels). 01133901 ORDER NO: AAD90-35561
- Diss** local communication in an introduced colony of feral rhesus monkeys (macaca mulatta) (florida) . 825360 ORDER NO: AAD83-24996
- Diss** mechanisms of axonal guidance: the problem of intersecting fiber systems (corpus callosum, glial sling, perforating fibers).

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- Diss** nerve axon outgrowth as a model for studying cell movement . 776064 ORDER NO: AAD82-07748
- Diss** neural mechanisms for behavioral response specificity in the siphon-withdrawal response of aplysia. 01419071 ORDER NO: AADAA-19519105
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- Diss** synthesis of potential prostacyclin receptor antagonist. 01679353 ORDER NO: AAD99-13188
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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 ligation, 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, <i>Bacillus thuringiensis</i> , 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)	<i>In vitro</i> 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 Efect)	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 than 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) - Silver*

September 2006

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

Silver Page 1 of 1

Result #	Ref No.	Reference	Chemical Form	MW%	Test Species	Exposure																	Effects							Conversion to mg/kg bw/day				Result		Data Evaluation Score											
						Phase #	# of Conc/ Doses	Conc/ Doses	Conc/Dose Units	Wet Weight Reported?	Percent Moisture	Application Frequency	Method of Analyses	Route of Exposure	Exposure Duration	Duration Units	Age	Age Units	Lifestage	Sex	Control Type	Test Location	Endpoint #	General Effect Group	Effect Type	Effect Measure	Response Site	Study NOAEL	Study LOAEL	Body Weight Reported?	Body Weight in kg	Ingestion Rate Reported?	Ingestion Rate in kg/day 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	9892	Jensen et al, 1974	Silver acetate	100	Turkey (<i>Meleagris gallopavo</i>)	2	3	0/300/900	mg/kg	N	na	ADL	U	FD	5	w	1	d	JV	B	C	Lab	3	BIO	CHM	PCLV	BL	300	900	Y	0.662	N	0.04449	20.2	60.5	10	10	5	5	6	1	10	10	4	71		
2	9892	Jensen et al, 1974	Silver acetate	100	Turkey (<i>Meleagris gallopavo</i>)	1	4	0/100/300/900	ppm in mg/kg	N	na	ADL	U	FD	4	w	1	d	JV	B	C	Lab	2	BIO	CHM	PCLV	BL	300	900	Y	0.380	N	0.03100	24.5	73.4	10	10	5	5	6	1	10	10	4	71		
3	9232	Peterson et al, 1973	Silver nitrate	100	Turkey (<i>Meleagris gallopavo</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	4	w	1	d	JV	B	C	Lab	3	BIO	CHM	HMGL	BL		900	Y	0.422	N	0.03319		70.8	10	10	5	10	6	1	4	10	10	4	70	
Behavior																																															
4	1403	Jensen , 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/1000	ppm in mg/kg	N	na	ADL	U	FD	14	d	1	d	JV	NR	C	Lab	3	BEH	FDB	FCNS	WO		1000	Y	0.1730	Y	0.0153		88.4	10	10	5	10	7	4	4	10	10	4	74	
Physiology																																															
5	6899	Petersen and Jensen, 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	28	d	1	d	JV	NR	C	Lab	4	PHY	PHY	GPHY	WO		900	Y	0.390	N	0.03153		72.8	10	10	5	10	6	4	4	10	10	4	73	
Pathology																																															
6	9892	Jensen et al, 1974	Silver acetate	100	Turkey (<i>Meleagris gallopavo</i>)	2	3	0/300/900	mg/kg	N	na	ADL	U	FD	5	w	1	d	JV	B	C	Lab	2	PTH	HIS	GHIS	HE	300	900	Y	0.662	N	0.04449	20.2	60.5	10	10	5	5	6	4	10	10	4	74		
7	9892	Jensen et al, 1974	Silver acetate	100	Turkey (<i>Meleagris gallopavo</i>)	1	4	0/100/300/900	ppm in mg/kg	N	na	ADL	U	FD	4	w	1	d	JV	B	C	Lab	3	PTH	HIS	GHIS	HE	300	900	Y	0.380	N	0.03100	24.5	73.4	10	10	5	5	6	4	10	10	4	74		
8	9232	Peterson et al, 1973	Silver nitrate	100	Turkey (<i>Meleagris gallopavo</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	4	w	1	d	JV	B	C	Lab	2	PTH	ORW	SMIX	HE		900	Y	0.422	N	0.03319		70.8	10	10	5	10	6	4	4	10	10	4	73	
9	6901	Peterson and Jensen, 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	28	d	1	d	JV	B	C	Lab	2	PTH	ORW	ORWT	HE		900	Y	0.286	N	0.02576		81.1	10	10	5	10	6	4	4	10	10	4	73	
10	6778	Van Vleet, 1977	Silver acetate	64.6	Duck (<i>Anas platyrhynchos</i>)	1	2	0/0.2	% in diet	N	na	ADL	U	FD	3	w	1	d	JV	M	C	Lab	1	PTH	HIS	GHIS	MU		0.2	N	0.460	N	0.03511		98.6	10	10	5	5	5	4	4	10	10	4	67	
11	80	Van Vleet et al, 1981	Silver acetate	100	Duck (<i>Anas platyrhynchos</i>)	1	2	0/3000	mg/kg	N	na	ADL	U	FD	15	d	1	d	JV	M	C	Lab	1	PTH	HIS	NCRO	GZ		3000	N	0.092	N	0.01231		401	10	10	5	5	5	4	4	10	10	4	67	
Growth																																															
12	9892	Jensen et al, 1974	Silver acetate	100	Turkey (<i>Meleagris gallopavo</i>)	2	3	0/300/900	mg/kg	N	na	ADL	U	FD	5	w	1	d	JV	B	C	Lab	1	GRO	GRO	BDWT	WO		300	Y	0.662	N	0.04449		20.2	10	10	5	5	6	8	4	10	10	4	72	
13	9892	Jensen et al, 1974	Silver acetate	100	Turkey (<i>Meleagris gallopavo</i>)	3	2	0/900	mg/kg	N	na	ADL	U	FD	5	w	1	d	JV	B	C	Lab	1	GRO	GRO	BDWT	WO		900	Y	0.528	N	0.03840		65.5	10	10	5	5	6	8	4	10	10	4	72	
14	9232	Peterson et al, 1973	Silver nitrate	100	Turkey (<i>Meleagris gallopavo</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	4	w	1	d	JV	B	C	Lab	1	GRO	GRO	BDWT	WO		900	Y	0.422	N	0.03319		70.8	10	10	5	10	6	8	4	10	10	4	77	
15	6899	Petersen and Jensen, 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	28	d	1	d	JV	NR	C	Lab	2	GRO	GRO	BDWT	WO		900	Y	0.390	N	0.03153		72.8	10	10	5	10	6	8	4	10	10	4	77	
16	6901	Peterson and Jensen, 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	28	d	1	d	JV	B	C	Lab	1	GRO	GRO	BDWT	WO		900	Y	0.286	N	0.02576		81.1	10	10	5	10	6	8	4	10	10	4	77	
17	1403	Jensen , 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/1000	ppm in mg/kg	N	na	ADL	U	FD	14	d	1	d	JV	NR	C	Lab	1	GRO	GRO	BDWT	WO		1000	Y	0.173	Y	0.01530		88.4	10	10	5	10	7	8	4	10	10	4	78	
Survival																																															
18	1403	Jensen , 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/1000	ppm in mg/kg	N	na	ADL	U	FD	14	d	1	d	JV	NR	C	Lab	2	MOR	MOR	MORT	WO		1000	Y	0.1890	Y	0.0135		71.4	10	10	5	10	7	9	4	10	10	4	79	
19	6899	Petersen and Jensen, 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	28	d	1	d	JV	NR	C	Lab	1	MOR	MOR	MORT	WO		900	Y	0.3900	N	0.0315		72.8	10	10	5	10	6	9	4	10	10	4	78	
20	6901	Peterson and Jensen, 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	28	d	1	d	JV	B	C	Lab	4	MOR	MOR	MORT	WO		900	Y	0.2860	N	0.0258		81.1	10	10	5	10	6	9	4	10	10	4	78	
21	6778	Van Vleet, 1977	Silver acetate	64.6	Duck (<i>Anas platyrhynchos</i>)	1	2	0/0.2	% in diet	N	na	ADL	U	FD	3	w	1	d	JV	F	C	Lab	2	MOR	MOR	MORT	WO		0.2	N	0.4600	N	0.0351		98.6	10	10	5	5	5	9	4	10	10	4	72	
22	80	Van Vleet et al, 1981	Silver acetate	100	Duck (<i>Anas platyrhynchos</i>)	1	2	0/3000	mg/kg	N	na	ADL	U	FD	15	d	1	d	JV	M	C	Lab	3	MOR	MOR	MORT	WO		3000	N	0.0920	N	0.0123		401	10	10	5	5	5	9	4	10	10	4	72	
Data Not Used to Derive TRV																																															
23	6899	Petersen and Jensen, 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	28	d	1	d	JV	M	C	Lab	3	BIO	CHM	PCLV	BL	900		Y	0.3900	N	0.0315		72.8		10	10	5	10	6	1	4	1	10	4	61
24	9892	Jensen et al, 1974	Silver acetate	100	Turkey (<i>Meleagris gallopavo</i>)	1	4	0/100/300/900	ppm in mg/kg	N	na	ADL	U	FD	4	w	1	d	JV	B	C	Lab	1	GRO	GRO	BDWT	WO	900		Y	0.316	N	0.02749		78.3		10	10	5	5	6	8	4	1	10	4	63
25	6901	Peterson and Jensen, 1975	Silver nitrate	100	Chicken (<i>Gallus domesticus</i>)	1	2	0/900	ppm in mg/kg	N	na	ADL	U	FD	28	d	1	d	JV	B	C	Lab	3	BIO	CHM	PCLV	BL	900		Y	0.2860	N	0.0258		81.1		10	10	5	10	6	1	4	1	10	4	61
26	9892	Jensen et al, 1974	Silver acetate	100	Turkey (<i>Meleagris gallopavo</i>)	3	2	0/900	mg/kg	N	na	ADL	U	FD	5	w	1	d	JV	B	C	Lab	2	BIO	CHM	PCLV	BL		900	Y	0.5280	N	0.0384		65.5	10	10	5	5	6	1	4	10	10	4	65	
27	9892	Jensen et al, 1974	Silver acetate	100	Turkey (<i>Meleagris gallopavo</i>)	3	2	0/900	mg/kg	N	na	ADL	U	FD	5	w	1	d	JV	B	C	Lab	3	PTH	HIS	GHIS	HE		900	Y	0.5280	N	0.0384		65.5	10	10	5	5	6	4	4	10	3	4	61	
28	80	Van Vleet et al, 1981	Silver acetate	100	Duck (<i>Anas platyrhynchos</i>)	1	2	0/3000	mg/kg	N	na	ADL	U	FD	15	d	1	d	JV	M	C	Lab	2	BIO	ENZ	GLPX	BL		3000	N	0.0920	N	0.0123		401	10	10	5	5	5	1	4	10	10	4	64	



Appendix 6-1

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

September 2006

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

Silver
Page 1 of 1

Result #	Ref N.	Reference	Chemical Form	MW%	Test Species	Exposure																Effects					Conversion to mg/kg bw/day				Result		Data Evaluation Score													
						Phase #	# of Conc/Doses	Conc/Doses	Conc/Dose Units	Wet Weight Reported?	Percent Moisture	Application Frequency	Method of Analyses	Route of Exposure	Exposure Duration	Duration Units	Age	Age Units	Lifestage	Sex	Control Type	Test Location	General Effect Group	Effect Type	Effect Measure	Response Site	Study NOAEL	Study LOAEL	Body Weight Reported?	Body Weight in kg	Ingestion Rate Reported?	Ingestion Rate in 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	23825	Pribyl et al, 1980	Silver nitrate	100	Rat (<i>Rattus norvegicus</i>)	1	2	0/6.47	mg/org/d	N	na	ADL	U	FD	4	d	NR	NR	JV	M	C	FieldU	BIO	ENZ	GENZ	SR		6.47	Y	0.2	N	0.018298		32.3	10	10	5	10	6	1	4	10	10	4	70	
Behavior																																														
2	1244	Cabe, et al., 1979	Silver nitrate	100	Rat (<i>Rattus norvegicus</i>)	1	2	0/1000	mg/L	N	na	ADL	U	DR	13	w	50	d	JV	M	C	Lab	BEH	FDB	WCON	WO		1000	Y	0.2	N	0.023257		116	10	5	5	10	6	4	4	10	10	4	68	
Pathology																																														
3	22589	Van Vleet, 1976	Silver acetate	64.63	Pig (<i>Sus scrofa</i>)	2	2	0/0.2	% in diet	N	na	ADL	U	FD	40	d	NR	NR	JV	NR	C	Lab	PTH	HIS	NCRO	LI	0.2		Y	8.86	N	0.41281	60.2		10	10	5	5	6	4	4	10	10	4	68	
4	149	Van Vleet et al, 1981	Silver acetate	100	Pig (<i>Sus scrofa</i>)	1	2	0/3000	mg/kg diet	N	na	ADL	U	FD	25	d	NR	NR	JV	M	C	Lab	PTH	HIS	GLSN	HE		3000	Y	16.4	N	0.68479		125	10	10	5	5	6	4	4	10	10	4	68	
5	22589	Van Vleet, 1976	Silver acetate	64.63	Pig (<i>Sus scrofa</i>)	1	2	0/0.5	% in diet	N	na	ADL	U	FD	28	d	NR	NR	JV	NR	C	Lab	PTH	HIS	NCRO	LI		0.5	Y	13.52	N	0.58428		140	10	10	5	5	6	4	4	10	10	4	68	
Reproduction																																														
6	21093	Shavlovski et al, 1995	Silver chloride	75.2	Rat (<i>Rattus norvegicus</i>)	1	2	0/50	mg/org/d	N	na	DLY	U	FD	20	d	NR	NR	GE	F	C	Lab	REP	REP	PROG	WO		50	Y	0.2	N	0.018298		188	10	10	5	10	6	10	4	10	10	4	79	
Growth																																														
7	22589	Van Vleet, 1976	Silver acetate	64.63	Pig (<i>Sus scrofa</i>)	2	2	0/0.2	% in diet	N	na	ADL	U	FD	40	d	NR	NR	JV	NR	C	Lab	GRO	GRO	BDWT	WO		0.2	Y	8.86	N	0.41281		60.2	10	10	5	5	6	8	4	10	10	4	72	
8	14503	Wagner et al, 1975	Silver acetate	100	Rat (<i>Rattus norvegicus</i>)	1	2	0/751	mg/L	N	na	ADL	U	DR	15	w	21	d	JV	B	C	Lab	GRO	GRO	BDWT	WO		751	N	0.4702	N	0.050198		80.2	10	5	5	5	8	4	10	10	4	66		
9	149	Van Vleet et al, 1981	Silver acetate	100	Pig (<i>Sus scrofa</i>)	1	2	0/3000	mg/kg diet	N	na	ADL	U	FD	4	w	NR	NR	JV	M	C	Lab	GRO	GRO	BDWT	WO		3000	Y	15.8	N	0.66413		126	10	10	5	5	6	8	4	10	10	4	72	
10	22589	Van Vleet, 1976	Silver acetate	64.63	Pig (<i>Sus scrofa</i>)	1	2	0/0.5	% in diet	N	na	ADL	U	FD	28	d	NR	NR	JV	NR	C	Lab	GRO	GRO	BDWT	WO		0.5	Y	13.52	N	0.58428		140	10	10	5	5	6	8	4	10	10	4	72	
11	22823	Matuk et al, 1981	Silver nitrate	63.5	Rat (<i>Rattus norvegicus</i>)	1	2	0/0.25	% in diet	N	na	ADL	U	DR	16	w	NR	NR	JV	M	C	Lab	GRO	GRO	BDWT	WO		0.25	Y	0.365	N	0.039967		174	10	5	5	10	6	8	4	10	10	4	72	
Survival																																														
12	22589	Van Vleet, 1976	Silver acetate	64.63	Pig (<i>Sus scrofa</i>)	2	2	0/0.2	% in diet	N	na	ADL	U	FD	40	d	NR	NR	JV	NR	C	Lab	MOR	MOR	MORT	WO	0.2		Y	8.86	N	0.41281	60.2		10	10	5	5	6	9	4	10	10	4	73	
13	1244	Cabe, et al., 1979	Silver nitrate	100	Rat (<i>Rattus norvegicus</i>)	1	2	0/1000	mg/L	N	na	ADL	U	DR	13	w	50	d	JV	M	C	Lab	MOR	MOR	MORT	WO	1000		Y	0.2	N	0.023257	116		10	5	5	10	6	9	4	10	10	4	73	
14	149	Van Vleet et al, 1981	Silver acetate	100	Pig (<i>Sus scrofa</i>)	1	2	0/3000	mg/kg diet	N	na	ADL	U	FD	25	d	NR	NR	JV	M	C	Lab	MOR	MOR	MORT	WO		3000	Y	16.4	N	0.68479		125	10	10	5	5	6	9	4	10	10	4	73	
15	22589	Van Vleet, 1976	Silver acetate	64.63	Pig (<i>Sus scrofa</i>)	1	2	0/0.5	% in diet	N	na	ADL	U	FD	28	d	NR	NR	JV	NR	C	Lab	MOR	MOR	MORT	WO		0.5	Y	13.52	N	0.58428		140	10	10	5	5	6	9	4	10	10	4	73	
Data Not Used to Derive TRV																																														
16	1244	Cabe, et al., 1979	Silver nitrate	100	Rat (<i>Rattus norvegicus</i>)	1	2	0/1000	mg/L	N	na	ADL	U	DR	13	w	50	d	JV	M	C	Lab	GRO	GRO	BDWT	WO	1000		Y	0.2	N	0.023257	116		10	5	5	10	6	8	4	1	10	10	4	63
17	1244	Cabe, et al., 1979	Silver nitrate	100	Rat (<i>Rattus norvegicus</i>)	1	2	0/1000	mg/L	N	na	ADL	U	DR	13	w	50	d	JV	M	C	Lab	PTH	ITX	INCO	WO	1000		Y	0.2	N	0.023257	116		10	5	5	10	6	4	4	1	10	10	4	59
18	21093	Shavlovski et al, 1995	Silver chloride	75.2	Rat (<i>Rattus norvegicus</i>)	1	2	0/50	mg/org/d	N	na	DLY	U	FD	20	d	NR	NR	GE	B	C	Lab	BIO	ENZ	CCOX	LI	50		Y	0.2	N	0.018298	188		10	10	5	10	6	1	4	1	10	10	4	61
19	14503	Wagner et al, 1975	Silver acetate	100	Rat (<i>Rattus norvegicus</i>)	1	2	0/751	mg/L	N	na	ADL	U	DR	15	w	21	d	JV	B	C	Lab	BIO	ENZ	GLPX	ER	751		N	0.4702	N	0.050198	80.2		10	5	5	5	5	1	4	1	10	10	4	50
20	22300	Whanger and Weswig, 1970	Silver acetate	100	Rat (<i>Rattus norvegicus</i>)	1	5	0/10/25/50/100	mg/kg diet	N	na	ADL	U	FD	8	w	21	d	JV	B	C	Lab	BIO	CHM	GBCM	BL	10		N	0.235	N	0.020892		0.889	10	10	5	5	5	1	4	10	10	4	64	
21	149	Van Vleet et al, 1981	Silver acetate	100	Pig (<i>Sus scrofa</i>)	1	2	0/3000	mg/kg diet	N	na	ADL	U	FD	2	w	NR	NR	JV	M	C	Lab	BIO	ENZ	GLPX	BL		3000	Y	12.7	N	0.55499		131	10	10	5	5	6	1	4	10	10	4	65	