# Ecological Soil Screening Levels for Nickel

## Interim Final

**OSWER Directive 9285.7-76**

**U.S. Environmental Protection Agency**
**Office of Solid Waste and Emergency Response**
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**TABLE OF CONTENTS**

## LIST OF TABLES



## LIST OF FIGURES



## LIST OF APPENDICES

## 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, 2005). The derivation procedures represent the collaborative effort of a multi-stakeholder group consisting of federal, state, consulting, industry, and academic participants led by what is now the U.S. EPA Office of Solid Waste and Emergency Response (OSWER).

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

Nickel is a naturally occurring element which can be found in all environmental media: air, soil, sediment, and water. In the metal state, nickel is silvery white, hard, malleable, and ductile. It is somewhat ferromagnetic, and a fair conductor of heat and electricity. Nickel occurs in numerous minerals as sulfides, arsenides, antimonides and oxides or silicates. Primary sources include chalcopyrite, pyrrhotite, pentlandite, and garnierite (Budavari, 1996; HSDB).

Nickel is released to the environment through the extraction, processing and use of nickel compounds (HSDB). The single largest use of nickel is in the manufacture of stainless steels (Alloway, 1990). Nickel is also used in the production of alloys with other metals such as iron, copper, chromium, and zinc (ATSDR, 1988; HSDB). Other major uses are in electroplating alloys, nickel-cadmium batteries, electronic components, fuel cells, specialty ceramics, magnets, specialty chemicals, filters for gases, hydrogenation of fats, petroleum products, preparation of colored pigments and for color stabilization of color copy paper (ATSDR, 1988; Alloway, 1990). Nickel may also be released from natural sources, such as volcanoes, windblown dusts, the weathering of rocks, forest fires, and decaying vegetation (Davies, 1974; HSDB).

In the atmosphere, nickel is expected to exist in the particulate phase and is released to soils through wet and dry deposition. The species of nickel present in deposition include soil minerals, oxides and sulphates (Alloway, 1990). The largest anthropogenic sources of nickel to the atmosphere result from the burning of fuel and residual oils followed by diesel exhaust, the combustion of coal and nickel mining and smelting (Alloway, 1990).

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 provides a plot of the typical background concentrations of nickel in U.S. soils in the eastern and western portions of the country.

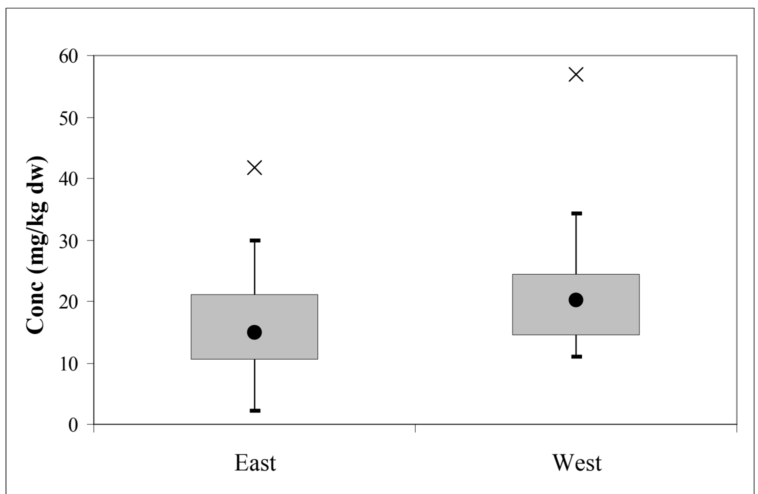
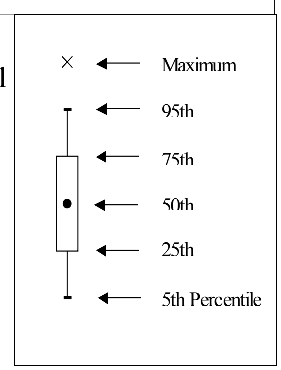



**Figure 2.1** Typical Background Concentrations of Nickel in U.S. Soils




In soils, nickel may be present as soluble compounds including chlorides and nitrates, and insoluble compounds such as oxides and sulfides. Soluble nickel compounds tend to exhibit greater mobility than insoluble nickel compounds (Dean, 1985; HSDB). The degree of mobility is influenced by the formation of complexes in the presence of organic substances and sulfates (Anderson and Christensen, 1988). The distribution of nickel between solid and solution phases is primarily controlled by pH with secondary factors being clay content, and the amount of hydrous iron and manganese oxides. Soluble nickel increases with decreases in pH. Increases in metal loading and cation exchange capacity (CEC) increase the amount of metal adsorbed by soil (Alloway, 1990). Due to low vapor pressures, most nickel compounds are not expected to volatilize from moist or dry soil surfaces, with one notable exception being nickel carbonyl (Ohe, 1976; HSDB). The concentration of nickel in plants generally reflects the concentration in soil although the relationship is more related to soluble and exchanged forms of nickel. Factors that increase solubility and exchangeability of nickel in soils also result in an increase of the element in plant tissue (Alloway, 1990).

In plants nickel is necessary for healthy growth and is essential for metabolic processes (Alloway, 1990; NRC, 2005). Nickel is generally not accepted an essential trace element for mammals and birds as there is no clearly defined biochemical function. Under laboratory experimental conditions nickel deprivation can result in adverse effects including growth depression, impaired reproduction, and other biochemical changes (NRC, 2005).

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

**Table 2.1 Nickel Eco-SSLs (mg/kg dry weight in soil)**

| Plants | Soil Invertebrates | Wildlife | |
|---|---|---|---|
| | | Avian | Mammalian |
| 38 | 280 | 210 | 130 |

Eco-SSL values were derived for plants, soil invertebrates, avian and mammalian wildlife. The Eco-SSL values for nickel range from 38 mg/kg dry weight (dw) for plants to 280 mg/kg dw for soil invertebrates. All values are higher than the 95$^{th}$ percentile of reported background soil concentrations in eastern and western U.S. soils (Figure 2.1).

## 3.0 ECO-SSL FOR TERRESTRIAL PLANTS

Of the papers identified from the literature search process, 252 papers were selected for acquisition for further review. Of those papers acquired, 26 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). Thirty-nine study results received an Evaluation Score greater than ten (U.S. EPA, 2003; Attachment 3-1). These studies are listed in Table 3.1.

The studies in Table 3.1 are sorted by bioavailability score. There are 11 studies eligible for Eco-SSL derivation with a bioavailability score of two. These results are used to derive the plant Eco-SSL for nickel (U.S. EPA, 2003; Attachment 3-2). The Eco-SSL is the geometric mean of the maximum acceptable toxicant concentration (MATC) and 20% effective concentration ($EC_{20}$) values for 6 species under different test conditions (pH and % organic matter (OM)) and is equal to 38 mg/kg dw.

## Table 3.1 Plant Toxicity Data - Nickel

| Reference | IP Number | Study ID | Test Organism | | Soil pH | OM % | Bio-availability Score | ERE | Tox Parameter | Tox Value-Soil Conc. (mg/kg dw) | Total Evaluation Score | Eligible for Eco-SSL Derivation? | Used for Eco-SSL? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TN&Associates Inc., 2000 | 56444 | G | Alfalfa | *Medicago sative* | 5.0 | 5.0 | 2 | GRO | $EC_{20}$ | 17 | 18 | Y | Y |
| TN&Associates Inc., 2000 | 56444 | H | Barley | *Hordeum vilgare* | 5.0 | 5.0 | 2 | GRO | $EC_{20}$ | 7 | 18 | Y | Y |
| TN&Associates Inc., 2000 | 56444 | I | Brassica | *Brassica rapa* | 5.0 | 5.0 | 2 | GRO | $EC_{20}$ | 10 | 18 | Y | Y |
| TN&Associates Inc., 2000 | 56444 | J | Alfalfa | *Medicago sative* | 6.3 | 0.1 | 2 | GRO | $EC_{20}$ | 25 | 18 | Y | Y |
| TN&Associates Inc., 2000 | 56444 | K | Barley | *Hordeum vilgare* | 6.3 | 0.1 | 2 | GRO | $EC_{20}$ | 65 | 18 | Y | Y |
| TN&Associates Inc., 2000 | 56444 | L | Brassica | *Brassica rapa* | 6.3 | 0.1 | 2 | GRO | $EC_{20}$ | 32 | 18 | Y | Y |
| Dixon, 1988 | 7450 | -- | Red Oak | *Quercus rubra* | 6.0 | 1.5 | 2 | GRO | MATC | 32 | 16 | Y | Y |
| Taylor and Allinson, 1981 | 2790 | B | Alfalfa | *Medicago sativa* | 6.9 | 1.7 | 2 | GRO | MATC | 177 | 15 | Y | Y |
| Khalid and Tinsley, 1980 | 7481 | -- | Ryegrass | *Lelium perenne* | 4.7 | 4.5 | 2 | GRO | MATC | 52 | 15 | Y | Y |
| Taylor, 1974 | 9645 | -- | Alfalfa | *Medicago sativa* | 6.4 | 1.0 | 2 | GRO | MATC | 177 | 11 | Y | Y |
| Halstead et al, 1969 | 7465 | B | Oat | *Avena sativa* | 6.1 | 1.4 | 2 | REP | MATC | 71 | 13 | Y | Y |
| | | | | | | | | | Geometric Mean | 38 | | | |
| **Data Not Used to Derive Plant Eco-SSL** | | | | | | | | | | | | | |
| Narwal et al, 1996 | 11707 | A | Corn | *Zea mays* | 8.0 | 0.3 | 1 | GRO | MATC | 141 | 15 | Y | N |
| Narwal et al, 1996 | 11707 | B | Corn | *Zea mays* | 7.8 | 0.2 | 1 | GRO | MATC | 71 | 15 | Y | N |
| Narwal et al, 1996 | 11707 | C | Corn | *Zea mays* | 7.7 | 1.2 | 1 | GRO | MATC | 71 | 15 | Y | N |
| Taylor and Allinson, 1981 | 2790 | A | Alfalfa | *Medicago sativa* | 6.9 | 4.8 | 1 | GRO | MATC | 177 | 14 | Y | N |
| Halstead et al, 1969 | 7465 | C | Oat | *Avena sativa* | 5.7 | 4.1 | 1 | REP | MATC | 224 | 12 | Y | N |
| Halstead et al, 1969 | 7465 | F | Alfalfa | *Medicago sativa* | 5.7 | 4.1 | 1 | GRO | MATC | 32 | 12 | Y | N |
| Halstead et al, 1969 | 7465 | D | Alfalfa | *Medicago sativa* | 7.8 | 4.0 | 0 | GRO | MATC | 224 | 11 | Y | N |
| Tikhomirov et al, 1988 | 4757 | B | Oat | *Avena sativa* | 4.6 | 2.5 | 2 | GRO | LOAEC | 100 | 14 | N | N |
| Singh and Jeng, 1993 | 12400 | -- | Ryegrass | *Lelium perenne* | 6.0 | 0.7 | 2 | GRO | NOAEC | 50 | 14 | N | N |
| Halstead et al, 1969 | 7465 | E | Alfalfa | *Medicago sativa* | 6.1 | 1.4 | 2 | GRO | LOAEC | 20 | 13 | N | N |
| Wallace et al, 1977 | 57304 | A | Bush Beans | *Phaseolus vulgaris* | 4.0 | 2.8 | 2 | GRO | NOAEC | 250 | 12 | N | N |
| Rehab and Wallace, 1978 | 7523 | A | Cotton | *Gossypium barbadense* | 6.8 | 2.2 | 1 | GRO | LOAEC | 100 | 12 | N | N |
| Metwally and Rabie, 1989 | 1536 | D | Corn | *Zea mays* | 8.2 | 1.2 | 1 | GRO | MATC | 57 | 11 | N | N |
| Wallace et al, 1977 | 57304 | B | Bush Beans | *Phaseolus vulgaris* | 5.8 | 2.8 | 1 | GRO | LOAEC | 100 | 11 | N | N |
| Elmosly and Abdel-Sabour, 1997 | 4094 | A | Red Clover | *Trifolium pratense L.* | 8.2 | 1.0 | 1 | GRO | NOAEC | 100 | 14 | N | N |
| Elmosly and Abdel-Sabour, 1997 | 4094 | B | Red Clover | *Trifolium pratense L.* | 7.9 | 0.6 | 1 | GRO | NOAEC | 100 | 14 | N | N |
| Elmosly and Abdel-Sabour, 1997 | 4094 | C | Red Clover | *Trifolium pratense L.* | 7.6 | 0.1 | 1 | GRO | NOAEC | 100 | 14 | N | N |
| Tikhomirov et al, 1988 | 4757 | A | Oat | *Avena sativa* | 5.9 | 2.9 | 1 | GRO | LOAEC | 400 | 13 | N | N |

## Table 3.1 Plant Toxicity Data - Nickel

| Reference | IP Number | Study ID | Test Organism | | Soil pH | OM % | Bio-availability Score | ERE | Tox Parameter | Tox Value-Soil Conc. (mg/kg dw) | Total Evaluation Score | Eligible for Eco-SSL Derivation? | Used for Eco-SSL? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dang et al, 1990 | 12906 | A | Onion | *Allium cepa* | 8.3 | 0.5 | 1 | GRO | LOAEC | 50 | 11 | N | N |
| Dang et al, 1990 | 12906 | B | Fenugreek | *Trigonella poenum* | 8.3 | 0.5 | 1 | GRO | LOAEC | 50 | 11 | N | N |
| Metwally and Rabie, 1989 | 1536 | C | Fava Bean | *Vicia faba* | 8.2 | 1.2 | 1 | GRO | NOAEC | 50 | 11 | N | N |
| Wallace et al, 1977 | 57304 | C | Barley | *Hordeum vilgare* | 5.8 | 2.8 | 1 | GRO | MATC | 50 | 11 | N | N |
| Genovese, 1978 | 58147 | B | Jack Pine | *Pinus banksiana* | 7.7 | 0.1 | 1 | GRO | NOAEC | 150 | 11 | N | N |
| Genovese, 1978 | 58147 | D | Black Spruce | *Picea mariana* | 7.7 | 0.1 | 1 | GRO | NOAEC | 150 | 11 | N | N |
| Halstead et al, 1969 | 7465 | A | Oat | *Avena sativa* | 7.8 | 4.0 | 0 | REP | NOAEC | 500 | 11 | N | N |
| Gupta et al, 1996 | 13146 | A | Chickpea | *Cicer arietinum* | 8.0 | 2.0 | 0 | GRO | MATC | 6 | 11 | N | N |
| Gupta et al, 1996 | 13146 | B | Lentil | *Lens esculentum* | 8.0 | 2.0 | 0 | GRO | MATC | 4 | 11 | N | N |
| Gupta et al, 1996 | 13146 | C | Mustard | *Brassica juncia* | 8.0 | 2.0 | 0 | GRO | MATC | 14 | 11 | N | N |

$EC_{20}$ = Effect concentration for 20% 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
-- Study ID number not assigned
OM = Organic matter content
PHY = Physiology
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, 46 papers were selected for acquisition for further review. Of those papers acquired, 9 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). Twelve studies received an Evaluation Score greater than ten. These studies are listed in Table 4.1. The studies in Table 4.1 are sorted by bioavailability score. There are five studies eligible for Eco-SSL derivation. The Eco-SSL is the geometric mean of the maximum acceptable toxicant concentrations (MATCs) for five species under different test conditions (pH and % organic matter (OM)) and is equal to 280 mg/kg dw.

## 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 surrogate species representing different trophic levels 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 4-1) identified 1,169 papers with possible toxicity data for either avian or mammalian species. Of these studies, 1,101 were rejected for use as described in Section 7.5. Of the remaining studies, 11 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 provided as Table 5.1. The complete results are included as Appendix 5-1.

Within the reviewed papers, there are 28 results for biochemical (BIO), behavior (BEH), physiology (PHY), pathology (PTH), reproduction (REP), 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 4-4). 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. 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 reproduction and growth was calculated at 6.71 mg nickel/kg bw/day. This value is lower than the lowest bounded LOAEL for reproduction, growth, or survival. Therefore, the TRV is equal to the geometric mean of the NOAEL values for reproduction and growth and is equal to 6.71 mg nickel/kg bw/day.

## Table 4.1 Invertebrate Toxicity Data - Nickel

| Reference | IP Number | Study ID | Test Organism | | Soil pH | OM % | Bio-availability Score | ERE | Tox Parameter | Tox Value-Soil Conc. (mg/kg dw) | Total Evaluation Score | Eligible for Eco-SSL Derivation? | Used for Eco-SSL? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scott-Fordsmand et al, 1999 | 15163 | -- | Springtail | *Folsomia fimetaria L.* | 5.8 | 4.0 | 1 | REP | MATC | 387 | 16 | Y | Y |
| Scott-Fordsmand et al, 1998 | 18892 | a | Earthworm | *Eisenia veneta* | 5.8 | 4.0 | 1 | REP | MATC | 173 | 13 | Y | Y |
| Lock and Janssen, 2002 | 66195 | a | Earthworm | *Eisenia fetida* | 6.0 | 10.0 | 1 | REP | MATC | 240 | 14 | Y | Y |
| Lock and Janssen, 2002 | 66195 | b | Earthworm | *Enchytraeus albidus* | 6.0 | 10.0 | 1 | REP | MATC | 240 | 14 | Y | Y |
| Lock and Janssen, 2002 | 66195 | c | Springtail | *Folsomia candida* | 6.0 | 10.0 | 1 | REP | MATC | 423 | 14 | Y | Y |
| | | | | | | | | | Geometric Mean | 280 | | | |
| **Data Not Used to Derive Invertebrate Eco-SSL** | | | | | | | | | | | | | |
| Peredney and Williams, 2000b | 56449 | m | Roundworm | *Caenorhabditis elegans* | 4 | 1.14 | 2 | MOR | $LC_{50}$ | 144 | 13 | N | N |
| Peredney and Williams, 2000b | 56449 | n | Roundworm | *Caenorhabditis elegans* | 4 | 1.14 | 2 | MOR | $LC_{50}$ | 44 | 13 | N | N |
| Peredney and Williams, 2000b | 56449 | o | Roundworm | *Caenorhabditis elegans* | 4 | 4.2 | 2 | MOR | $LC_{50}$ | 387 | 13 | N | N |
| Peredney and Williams, 2000b | 56449 | p | Roundworm | *Caenorhabditis elegans* | 4 | 4.2 | 2 | MOR | $LC_{50}$ | 165 | 13 | N | N |
| Neuhauser et al, 1985 | 6812 | -- | Earthworm | *E. fetida* | 6.0 | 10.0 | 1 | MOR | $LC_{50}$ | 242 | 11 | N | N |
| Korthals et al, 1996 | 4402 | -- | Nematodes | nematoda (various sp.) | 4.1 | 1.9 | 1 | POP | LOAEC | 100 | 14 | N | N |
| Peredney and Williams, 2000a | 53082 | -- | Roundworm | *Caenorhabditis elegans* | 4 | 10 | 1 | MOR | $LC_{50}$ | 797 | 12 | N | N |
| Peredney and Williams, 2000b | 56449 | q | Roundworm | *Caenorhabditis elegans* | 4 | 10 | 1 | MOR | $LC_{50}$ | 800 | 12 | N | N |
| Peredney and Williams, 2000b | 56449 | r | Roundworm | *Caenorhabditis elegans* | 4 | 10 | 1 | MOR | $LC_{50}$ | 348 | 12 | N | N |
| Neuhauser et al, 1986 | 17707 | -- | Earthworm | *E. fetida* | 6.0 | 10.0 | 0 | MOR | $LC_{50}$ | 242 | 14 | N | N |

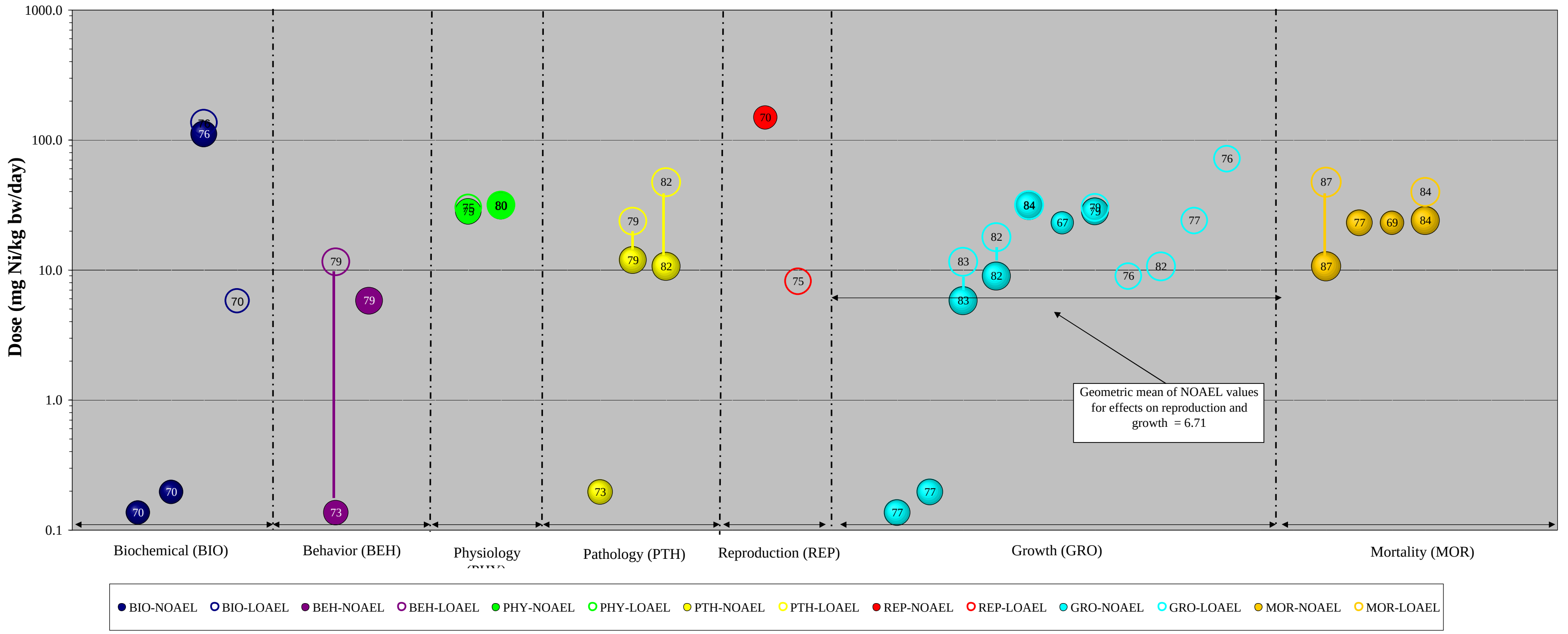
ERE = Ecologically relevant endpoint
$LC_{50}$ = Concentration lethal to 50% of test populatior
LOAEC = Lowest observed adverse effect concentration
MATC = Maximum acceptable toxicant concentration
MOR = Mortality
N = No
-- Study ID not assigned
NOAEC = No observed adverse effect concentration
OM = Organic matter content
POP = Population
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)

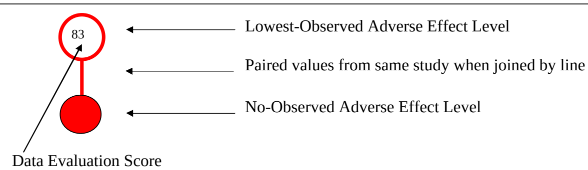
## Table 5.1
## Avian Toxicity Data Extracted for Wildlife Toxicity Reference Value (TRV)
## Nickel

| 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 | Oscar and Mitchell, 1995 | 5407 | Chicken (*Gallus domesticus* ) | 3 | U | FD | 28 | d | 21 | d | JV | F | CHM | LIPD | WO | 0.136 | | 70 |
| 2 | Nielsen et al, 1975 | 6885 | Chicken (*Gallus domesticus* ) | 4 | U | FD | 3 | w | 1 | d | JV | M | CHM | HMCT | BL | 0.195 | | 70 |
| 3 | Ling and Leach, 1979 | 6666 | Chicken (*Gallus domesticus* ) | 6 | U | FD | 3 | w | 1 | d | JV | M | CHM | HMGL | BL | 110 | 135 | 76 |
| 4 | Martinez and Diaz, 1996 | 5345 | Chicken (*Gallus domesticus* ) | 4 | U | FD | 42 | d | 1 | d | JV | M | CHM | HMGL | BL | | 5.76 | 70 |
| **Behavior (BEH)** | | | | | | | | | | | | | | | | | | |
| 5 | Oscar and Mitchell, 1995 | 5407 | Chicken (*Gallus domesticus* ) | 3 | U | FD | 28 | d | 21 | d | JV | F | FDB | FCNS | WO | 0.136 | | 73 |
| 6 | Martinez and Diaz, 1996 | 5345 | Chicken (*Gallus domesticus* ) | 4 | U | FD | 42 | d | 1 | d | JV | M | FDB | FCNS | WO | 5.76 | 11.5 | 79 |
| **Physiology (PHY)** | | | | | | | | | | | | | | | | | | |
| 7 | Weber and Reid, 1968 | 60 | Chicken (*Gallus domesticus* ) | 8 | U | FD | 4 | w | 1 | d | JV | B | PHY | FDCV | WO | 28.3 | 30.2 | 75 |
| 8 | Weber and Reid, 1968 | 60 | Chicken (*Gallus domesticus* ) | 8 | U | FD | 4 | w | 1 | d | JV | B | PHY | META | WO | 31.0 | 31.5 | 80 |
| **Pathology (PTH)** | | | | | | | | | | | | | | | | | | |
| 9 | Nielsen et al, 1975 | 6885 | Chicken (*Gallus domesticus* ) | 4 | U | FD | 3 | w | 1 | d | JV | M | ORW | SMIX | SK | 0.195 | | 73 |
| 10 | Cain and Pafford, 1981 | 6461 | Duck (*Anas platyrhynchos* ) | 4 | M | FD | 28 | d | 1 | d | JV | B | ITX | ATAX | WO | 10.7 | 47.0 | 82 |
| 11 | Martinez and Diaz, 1996 | 5345 | Chicken (*Gallus domesticus* ) | 4 | U | FD | 42 | d | 1 | d | JV | M | HIS | GHIS | HE | 11.9 | 23.8 | 79 |
| **Reproduction (REP)** | | | | | | | | | | | | | | | | | | |
| 12 | Eastin and O'Shea, 1981 | 6492 | Duck (*Anas platyrhynchos* ) | 5 | U | FD | 90 | d | 20 | mo | LB | F | REP | HTCH | EG | 149 | | 70 |
| 13 | Meluzzi et al, 1996 | 2771 | Chicken (*Gallus domesticus* ) | 4 | U | FD | 60 | d | 22 | w | LB | F | EGG | ESWT | EG | | 8.16 | 75 |
| **Growth (GRO)** | | | | | | | | | | | | | | | | | | |
| 14 | Oscar et al, 1995 | 5407 | Chicken (*Gallus domesticus* ) | 3 | U | FD | 28 | d | 21 | d | JV | F | GRO | BDWT | WO | 0.136 | | 77 |
| 15 | Nielsen et al, 1975 | 6885 | Chicken (*Gallus domesticus* ) | 4 | U | FD | 3 | w | 1 | d | JV | M | GRO | BDWT | WO | 0.195 | | 77 |
| 16 | Martinez and Diaz, 1996 | 5345 | Chicken (*Gallus domesticus* ) | 4 | U | FD | 42 | d | 1 | d | JV | M | GRO | BDWT | WO | 5.76 | 11.5 | 83 |
| 17 | Hill, 1979 | 397 | Chicken (*Gallus domesticus* ) | 3 | U | FD | 5 | w | 1 | d | JV | F | GRO | BDWT | WO | 8.95 | 17.9 | 82 |
| 18 | Blalock and Hill, 1985 | 36697 | Chicken (*Gallus domesticus* ) | 2 | U | FD | 25 | d | 1 | d | JV | B | GRO | BDWT | WO | 22.9 | | 67 |
| 19 | Weber and Reid, 1968 | 60 | Chicken (*Gallus domesticus* ) | 8 | U | FD | 4 | w | 1 | d | JV | B | GRO | BDWT | WO | 28.3 | 30.2 | 79 |
| 20 | Weber and Reid, 1968 | 60 | Chicken (*Gallus domesticus* ) | 8 | U | FD | 4 | w | 1 | d | JV | B | GRO | BDWT | WO | 31.0 | 31.5 | 84 |
| 21 | Hill, 1979 | 397 | Chicken (*Gallus domesticus* ) | 3 | U | FD | 5 | w | 1 | d | JV | F | GRO | BDWT | WO | | 8.95 | 76 |
| 22 | Cain and Pafford, 1981 | 6461 | Duck (*Anas platyrhynchos* ) | 4 | M | FD | 60 | d | 1 | d | JV | F | MPH | HULT | HM | | 10.7 | 82 |
| 23 | Ling and Leach, 1979 | 6666 | Chicken (*Gallus domesticus* ) | 6 | U | FD | 3 | w | 1 | d | JV | M | GRO | BDWT | WO | | 23.9 | 77 |
| 24 | Hill, 1985 | 36708 | Chicken (*Gallus domesticus* ) | 2 | U | FD | 19 | d | NR | NR | JV | B | GRO | BDWT | WO | | 71.8 | 76 |
| **Survival (MOR)** | | | | | | | | | | | | | | | | | | |
| 25 | Cain and Pafford, 1981 | 6461 | Duck (*Anas platyrhynchos* ) | 4 | M | FD | 30 | d | 1 | d | JV | B | MOR | SURV | WO | 10.7 | 47.0 | 87 |
| 26 | Blalock and Hill, 1985 | 36697 | Chicken (*Gallus domesticus* ) | 2 | U | FD | 25 | d | 1 | d | JV | B | MOR | MORT | WO | 22.9 | | 77 |
| 27 | Martinez and Diaz, 1996 | 5345 | Chicken (*Gallus domesticus* ) | 4 | U | FD | 42 | d | 1 | d | JV | M | MOR | MORT | WO | 23.0 | | 69 |
| 28 | Ling and Leach, 1979 | 6666 | Chicken (*Gallus domesticus* ) | 6 | U | FD | 3 | w | 1 | d | JV | M | MOR | SURV | WO | 23.9 | 39.9 | 84 |

AD = adult; ATAX = ataxia; B = both; BDWT = body weight changes; BEH = behavior; BIO = biochemical effects; BL = blood; bw = body weight; CHM = chemical changes; d day; EGG = effects on eggs; EG = egg; ESWT = eggshell weight; F = female; FCNS = food consumption; FD = food; FDB = feeding behavior; FDCV = food conversion efficiency; GHIS = general histology; GRO = growth; HE = heart; HIS = histological changes; HM = humerus; HMCT = hematocrit; HMGL = hemoglobin; HTCH = hatch; HULT = humerus length; ITX = intoxication; JV = juvenile; kg = kilograms; LB = egg laying bird; LIPD = lipid; LOAEL = lowest observed adverse effect level; M = male; M = measured; META = metabolic rate; mo = months; MOR = effects on mortality and survival; MORT = mortality; MPH = morphology effects; NOAEL = No Observed Advese Effect Level; NR = Not reported; ORW = organ weight changes; ORWT = organ weight changes; PHY = physiology; PTH = pathology; REP = reproduction; SK = skin, epidermis; SMIX = weight relative to body weight; SURV = survival;U = unmeasured; w = weeks; WO = whole organism.

**Figure 5.1 Avian TRV Derivation for Nickel**




**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 at least three NOAEL results available within the growth and reproduction effect groups for calculation of a geometric mean.

3) The geometric mean is equal to 6.71 mg nickel/kg bw/d and is lower than the lowest bounded LOAEL for results within the reproduction, growth, and survival (MOR) effect groups.

3) The avian wildlife TRV for nickel is equal to 6.71 mg nickel/kg bw/day which is the geometric mean of NOAEL values for effects on reproduction and growth.

## 5.2 Estimation of Dose and Calculation of the Eco-SSL

Two separate Eco-SSL values were calculated for avian wildlife, one for each of two surrogate receptor species representing different trophic levels. The avian Eco-SSLs were calculated according to the Eco-SSL guidance (U.S. EPA, 2003) and are summarized in Table 5.2. An Eco-SSL value could not be calculated for the avian ground insectivore (woodcock) as a reliable method to estimate uptake of nickel from soil into soil invertebrates could not be identified (see Attachment 4-1 of the Eco-SSL guidance; U.S. EPA, 2003).

**Table 5.2 Calculation of the Avian Eco-SSLs for Nickel**

| Surrogate Receptor Group | TRV for Nickel (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 Nickel in Biota Type (i)[2,3] ($B_i$) (mg/kg dw) | Eco-SSL (mg/kg dw)[4] |
|---|---|---|---|---|---|
| Avian herbivore (dove) | 6.71 | 0.190 | 0.139 | $\ln(B_i) = 0.748 * \ln(Soil_j) - 2.223$ where i = plants | 210 |
| Avian ground insectivore (woodcock) | 6.71 | 0.214 | 0.164 | NA | NA |
| Avian carnivore (hawk) | 6.71 | 0.0353 | 0.057 | $\ln(B_i) = 0.4658 * \ln(Soil_j) - 0.2462$ where i = mammals | 2800 |

[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 Available.

# 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 surrogate receptor 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 1,169 papers with possible toxicity data for nickel for either avian or mammalian species. Of these studies, 1,101 were rejected for use as described in Section 7.5. Of the remaining papers, 52 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 as Appendix 6-1.

**Table 6.1 Mammalian Toxicity Data Extracted for Wildlife Toxicity Reference Value (TRV)**
**Nickel**
**Page 1 of 3**

| 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 | Spears et al, 1984 | 19671 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 21 | d | 1 | d | JV | NR | ENZ | ALPH | SR | 0.265 | 1.32 | 74 |
| 2 | Chatterjee et al, 1979 | 19098 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 21 | d | NR | NR | JV | M | CHM | ASCA | LI | 0.335 | | 74 |
| 3 | Nielsen, 1980 | 19478 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 10 | w | NR | NR | JV | F | CHM | HMCT | PL | 0.456 | 4.56 | 73 |
| 4 | Pandey et al, 1999 | 19521 | Mouse (*Mus musculus* ) | 3 | U | GV | 35 | d | NR | NR | JV | M | ENZ | LADH | TE | 1.35 | 2.71 | 83 |
| 5 | Spears and Hatfield, 1985 | 19666 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 21 | d | NR | NR | JV | M | CHM | LEUK | BL | 1.47 | 22.0 | 72 |
| 6 | O'Dell et al, 1970 | 14477 | Cattle (*Bos taurus* ) | 4 | U | FD | 8 | w | 14 | w | JV | M | CHM | CALC | NR | 1.63 | 6.53 | 75 |
| 7 | Kadiiska et al, 1985 | 19290 | Rat (*Rattus norvegicus* ) | 2 | U | DR | 30 | d | NR | NR | JV | M | ENZ | P450 | LI | 4.47 | | 67 |
| 8 | Obone et al, 1999 | 19507 | Rat (*Rattus norvegicus* ) | 4 | U | DR | 13 | w | NR | NR | JV | M | CHM | PRTL | PL | 4.70 | 11.7 | 71 |
| 9 | ODell et al, 1970 | 14476 | Cattle (*Bos taurus* ) | 3 | U | FD | 6 | w | NR | NR | LC | F | CHM | PRTL | MK | 6.75 | | 70 |
| 10 | Smith et al, 1993 | 62 | Rat (*Rattus norvegicus* ) | 4 | M | DR | 26 | w | 62 | d | LC | F | CHM | GBCM | PL | 6.80 | 31.6 | 78 |
| 11 | Oosting et al, 1991 | 19514 | Rat (*Rattus norvegicus* ) | 3 | M | FD | 28 | d | 31 | d | JV | M | CHM | HMGL | BL | 7.78 | | 75 |
| 12 | Oosting et al, 1991 | 19514 | Rat (*Rattus norvegicus* ) | 2 | M | FD | 28 | d | 31 | d | JV | M | CHM | HMGL | BL | 8.20 | | 75 |
| 13 | Whanger, 1973 | 63 | Rat (*Rattus norvegicus* ) | 4 | U | FD | 6 | w | 35 | d | JV | NR | CHM | HMGL | BL | 9.49 | 47.4 | 69 |
| 14 | Nation et al, 1985 | 19460 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 14 | d | 80 | d | JV | M | CHM | GBCM | LI | 20.0 | | 74 |
| 15 | Uthus and Poellot, 1997 | 19764 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 57 | d | NR | NR | JV | M | ENZ | GENZ | LI | | 0.0844 | 70 |
| 16 | Spears et al, 1986 | 19664 | Cattle (*Bos taurus* ) | 2 | U | FD | 28 | d | 50 | d | JV | M | CHM | AMMO | GT | | 0.101 | 71 |
| 17 | Milne et al, 1990 | 19437 | Sheep (*Ovis aries* ) | 2 | U | GV | 4 | w | 5 | mo | JV | F | ENZ | GENZ | SH | | 0.147 | 73 |
| 18 | Nielsen et al, 1979 | 19461 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 9 | w | 21 | d | JV | F | CHM | HMCT | BL | | 0.456 | 69 |
| 19 | Pandey and Singh, 1999 | 19522 | Mouse (*Mus musculus* ) | 3 | U | GV | 35 | d | NR | NR | JV | M | ENZ | LADH | TE | | 0.797 | 72 |
| 20 | Spears and Hatfield, 1985 | 19666 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 42 | d | NR | NR | JV | M | CHM | HMGL | BL | | 2.63 | 70 |
| 21 | Tandon and Mathur, 1986 | 19746 | Rat (*Rattus norvegicus* ) | 2 | U | GV | 4 | w | NR | NR | JV | M | ENZ | MADH | KI | | 3.00 | 77 |
| 22 | Vyskocil et al, 1994 | 19787 | Rat (*Rattus norvegicus* ) | 2 | U | DR | 6 | mo | 10 | w | JV | M | CHM | ALBM | UR | | 6.25 | 66 |
| 23 | Novelli et al, 1998 | 19496 | Rat (*Rattus norvegicus* ) | 2 | U | DR | 2 | mo | 15 | w | JV | M | ENZ | AATT | SR | | 12.5 | 66 |
| 24 | Waltschewa et al, 1972 | 19792 | Rat (*Rattus norvegicus* ) | 2 | U | GV | 120 | d | 5 | mo | JV | M | ENZ | GENZ | TE | | 25.0 | 77 |
| 25 | Dieter,et al, 1988 | 61 | Mouse (*Mus musculus* ) | 4 | UX | DR | 180 | d | 6-8 | w | JV | F | ENZ | G6PD | BM | | 43.3 | 71 |
| 26 | Mathur, 1987 | 19416 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 3 | w | 3 | w | JV | M | ENZ | GOTR | LI | | 44.5 | 69 |
| 27 | Weber and Reid, 1969 | 14485 | Mouse (*Mus musculus* ) | 3 | U | FD | 4 | w | NR | NR | JV | B | ENZ | CCOX | LI | | 179 | 66 |
| **Behavior (BEH)** | | | | | | | | | | | | | | | | | | |
| 28 | Spears et al, 1986 | 19664 | Cattle (*Bos taurus* ) | 2 | U | FD | 140 | d | 50 | d | JV | M | FDB | FCNS | WO | 0.101 | | 72 |
| 29 | O'Dell et al, 1970 | 14477 | Cattle (*Bos taurus* ) | 4 | U | FD | 8 | w | 14 | w | JV | M | FDB | FCNS | WO | 1.63 | 6.53 | 78 |
| 30 | Gershbein et al 1983 | 136 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 80 | d | 44 | d | JV | M | BEH | NMVM | WO | 5.89 | | 66 |
| 31 | Vyskocil et al, 1994 | 19787 | Rat (*Rattus norvegicus* ) | 2 | U | DR | 6 | mo | 10 | w | JV | M | FDB | WCON | WO | 6.25 | | 69 |
| 32 | Smith et al, 1993 | 62 | Rat (*Rattus norvegicus* ) | 4 | M | DR | 11 | w | 62 | d | LC | F | FDB | WCON | WO | 6.80 | 31.63 | 81 |
| 33 | O'Dell et al, 1971 | 14479 | Cattle (*Bos taurus* ) | 4 | UX | FD | 8 | w | 13-21 | w | JV | M | FDB | FCNS | WO | 7.00 | 14.6 | 88 |
| 34 | Oosting et al, 1991 | 19514 | Rat (*Rattus norvegicus* ) | 3 | M | FD | 28 | d | 31 | d | JV | M | FDB | FCNS | WO | 7.78 | | 78 |
| 35 | Oosting et al, 1991 | 19514 | Rat (*Rattus norvegicus* ) | 2 | M | FD | 28 | d | 31 | d | JV | M | FDB | FCNS | WO | 8.20 | | 78 |
| 36 | Nation et al, 1985 | 19460 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 14 | d | 80 | d | JV | M | BEH | ACTP | WO | 10.0 | 20.0 | 83 |
| 37 | Alexander et al, 1978 | 36694 | Meadow vole (*Microtus pennsylvanicus* ) | 4 | M | FD | 49 | d | 14 | d | JV | NR | FDB | FCNS | WO | 29.4 | 309 | 81 |
| 38 | Dieter,et al, 1988 | 61 | Mouse (*Mus musculus* ) | 4 | UX | DR | 180 | d | 6-8 | w | JV | F | FDB | WCON | WO | 43.3 | 107 | 80 |
| 39 | Weber and Reid, 1969 | 14485 | Mouse (*Mus musculus* ) | 3 | U | FD | 4 | w | NR | NR | JV | M | FDB | FCNS | WO | 179 | 265 | 75 |
| 40 | Cempel and Janicka, 2002 | 36331 | Rat (Rattus norvegicus) | 3 | U | DR | 90 | d | NR | NR | JV | M | FDB | WCON | WO | | 37.6 | 69 |
| **Physiology (PHY)** | | | | | | | | | | | | | | | | | | |
| 41 | Szakmary et al, 1995 | 19729 | Rat (*Rattus norvegicus* ) | 2 | U | GV | 8 | d | NR | NR | GE | F | PHY | BLPR | HE | 1.36 | | 80 |
| 42 | O'Dell et al, 1971 | 14479 | Cattle (*Bos taurus* ) | 4 | UX | FD | 8 | w | 13 | w | JV | M | PHY | EXCR | UR | 1.80 | 7.00 | 86 |
| 43 | Obone et al, 1999 | 19507 | Rat (*Rattus norvegicus* ) | 4 | U | DR | 13 | w | NR | NR | JV | M | PHY | EXCR | UR | 4.70 | 11.7 | 74 |
| 44 | O'Dell et al, 1970 | 14477 | Cattle (*Bos taurus* ) | 4 | U | FD | 8 | w | 14 | w | JV | M | PHY | DIFD | WO | 6.55 | | 74 |
| 45 | ODell et al, 1970 | 14476 | Cattle (*Bos taurus* ) | 3 | U | FD | 6 | w | NR | NR | LC | F | PHY | GPHY | MK | 6.75 | | 73 |
| **Pathology (PTH)** | | | | | | | | | | | | | | | | | | |
| 46 | Chatterjee et al, 1979 | 19098 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 21 | d | NR | NR | JV | M | ORW | SMIX | LI | 0.335 | | 77 |
| 47 | Nielsen, 1980 | 19478 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 10 | w | NR | NR | JV | F | ORW | SMIX | LI | 0.456 | 4.56 | 76 |
| 48 | O'Dell et al, 1970 | 14477 | Cattle (*Bos taurus* ) | 4 | U | FD | 8 | w | 14 | w | JV | M | ORW | ORWT | LU | 1.64 | 6.55 | 78 |
| 49 | Ambrose et al, 1976 | 14474 | Rat (*Rattus norvegicus* ) | 4 | U | FD | 24 | mo | 28 | d | JV | B | ORW | SMIX | HE | 8.06 | 80.6 | 77 |
| 50 | Ambrose et al, 1976 | 14474 | Dog (*Canis familiaris* ) | 4 | U | FD | 24 | mo | 6 | mo | JV | B | ORW | SMIX | KI | 45.0 | 112 | 78 |
| 51 | Schroeder and Mitchener, 1975 | 1858 | Mouse (*Mus musculus* ) | 2 | U | DR | 520 | d | 19-20 | d | JV | M | HIS | EDMA | WO | | 0.705 | 68 |
| 52 | Pandey et al, 1999 | 19521 | Mouse (*Mus musculus* ) | 3 | U | GV | 35 | d | NR | NR | JV | M | ORW | ORWT | PG | | 1.35 | 80 |
| 53 | Kakela et al, 1999 | 19293 | Rat (*Rattus norvegicus* ) | 3 | U | DR | 62 | d | 3.5-9 | mo | GE | F | ORW | SMIX | LI | | 3.40 | 68 |
| 54 | Obone et al, 1999 | 19507 | Rat (*Rattus norvegicus* ) | 4 | U | DR | 13 | w | NR | NR | JV | M | ORW | ORWT | HE | | 4.70 | 68 |
| 55 | Schroeder et al, 1974 | 14484 | Rat (*Rattus norvegicus* ) | 2 | M | DR | 1217 | d | 30 | d | JV | B | HIS | GHIS | HE | | 5.44 | 71 |
| 56 | Vyskocil et al, 1994 | 19787 | Rat (*Rattus norvegicus* ) | 2 | U | DR | 6 | mo | 10 | w | JV | M | ORW | SMIX | KI | | 6.25 | 69 |
| 57 | Dieter,et al, 1988 | 61 | Mouse (*Mus musculus* ) | 4 | UX | DR | 180 | d | 6-8 | w | JV | F | ORW | ORWT | LI | | 43.3 | 74 |
| 58 | Seidenberg et al 1986 | 113 | Mouse (*Mus musculus* ) | 2 | U | GV | 4 | d | NR | NR | GE | F | GRS | BDWT | WO | | 90.6 | 80 |

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


| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reproduction (REP)** | | | | | | | | | | | | | | | | | | |
| 59 | Kakela et al, 1999 | 19293 | Rat (*Rattus norvegicus* ) | 4 | U | DR | 28 | d | 3.5-9 | mo | SM | M | REP | GIDX | WO | 1.10 | 3.31 | 80 |
| 60 | Pandey and Srivastava, 2000 | 36722 | Mouse (*Mus musculus* ) | 4 | U | OR | 35 | d | NR | mo | JV | M | REP | SPCL | SM | 1.35 | 2.71 | 92 |
| 61 | Pandey and Srivastava, 2000 | 36722 | Mouse (*Mus musculus* ) | 4 | U | OR | 35 | d | NR | NR | JV | M | REP | SPCL | SM | 1.70 | 3.40 | 92 |
| 62 | Phatak and Patwardhan, 1950 | 14480 | Rat (*Rattus norvegicus* ) | 4 | U | FD | 4 | mo | 4 | w | GE | F | REP | PRWT | WO | 9.30 | | 71 |
| 63 | Chernoff and Kavlock, 1982 | 1260 | Mouse (*Mus musculus* ) | 2 | U | GV | 5 | d | 60 | d | GE | F | REP | PROG | WO | 45.3 | | 86 |
| 64 | Berman and Rehnberg, 1983 | 19064 | Mouse (*Mus musculus* ) | 3 | U | DR | 15 | d | NR | NR | GE | F | REP | PRFM | WO | 85.3 | 171 | 81 |
| 65 | Seidenberg et al 1986 | 113 | Mouse (*Mus musculus* ) | 2 | U | GV | 4 | d | NR | NR | GE | F | REP | PRWT | WO | 90.6 | | 82 |
| 66 | Ambrose et al, 1976 | 14474 | Dog (*Canis familiaris* ) | 4 | U | FD | 24 | mo | 6 | mo | JV | B | REP | TEWT | TE | 112 | | 74 |
| 67 | Ambrose et al, 1976 | 14474 | Rat (*Rattus norvegicus* ) | 4 | U | FD | 118 | d | 28 | d | GE | F | REP | PRWT | WO | 164 | 327 | 84 |
| 68 | Ambrose et al, 1976 | 14474 | Rat (*Rattus norvegicus* ) | 4 | U | FD | 2 | yr | 28 | d | JV | M | REP | TEWT | TE | 205 | | 70 |
| 69 | Schroeder and Mitchener, 1971 | 66 | Rat (*Rattus norvegicus* ) | 2 | U | DR | 9 | mo | 21 | d | GE | F | REP | DEYO | WO | | 0.551 | 67 |
| 70 | Pandey and Singh, 1999 | 19522 | Mouse (*Mus musculus* ) | 3 | U | GV | 35 | d | NR | NR | JV | M | REP | SPCV | SM | | 0.797 | 81 |
| 71 | Smith et al, 1993 | 62 | Rat (*Rattus norvegicus* ) | 4 | M | DR | 23 | w | 62 | d | LC | F | REP | DEYO | WO | | 1.33 | 83 |
| 72 | Pandey et al, 1999 | 19521 | Mouse (*Mus musculus* ) | 3 | U | GV | 35 | d | NR | NR | JV | M | REP | TEWT | TE | | 1.35 | 86 |
| 73 | Pandey et al, 1999 | 19520 | Mouse (*Mus musculus* ) | 2 | U | GV | 35 | d | NR | NR | AD | M | REP | RSUC | WO | | 1.59 | 86 |
| 74 | Obone et al, 1999 | 19507 | Rat (*Rattus norvegicus* ) | 4 | U | DR | 13 | w | NR | NR | JV | M | REP | TEWT | TE | | 4.70 | 74 |
| 75 | Waltschewa et al, 1972 | 19792 | Rat (*Rattus norvegicus* ) | 2 | U | GV | 120 | d | 5 | mo | JV | M | REP | SPCL | SM | | 25.0 | 86 |
| **Growth (GRO)** | | | | | | | | | | | | | | | | | | |
| 76 | Uthus and Poellot, 1997 | 19764 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 57 | d | NR | NR | JV | M | GRO | BDWT | WO | 0.0844 | | 77 |
| 77 | Spears et al, 1986 | 19664 | Cattle (*Bos taurus* ) | 2 | U | FD | 140 | d | 50 | d | JV | M | GRO | BDWT | WO | 0.101 | | 78 |
| 78 | Chatterjee et al, 1979 | 19098 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 21 | d | NR | NR | JV | M | GRO | BDWT | WO | 0.335 | | 81 |
| 79 | Spears et al, 1984 | 19671 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 49 | d | 1 | d | JV | NR | GRO | BDWT | WO | 1.17 | | 77 |
| 80 | Smith et al, 1993 | 62 | Rat (*Rattus norvegicus* ) | 4 | M | DR | 15 | w | 62 | d | LC | F | GRO | BDWT | WO | 1.33 | 6.80 | 85 |
| 81 | Szakmary et al, 1995 | 19729 | Rat (*Rattus norvegicus* ) | 2 | U | GV | 8 | d | NR | NR | GE | F | GRO | BDWT | WO | 1.36 | | 84 |
| 82 | Spears and Hatfield, 1985 | 19666 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 21 | d | NR | NR | JV | M | GRO | BDWT | WO | 1.47 | 22.0 | 79 |
| 83 | O'Dell et al, 1970 | 14477 | Cattle (*Bos taurus* ) | 4 | U | FD | 8 | w | 14 | w | JV | M | GRO | BDWT | WO | 1.64 | 6.55 | 82 |
| 84 | Cikrt et al, 1992 | 19109 | Rat (*Rattus norvegicus* ) | 2 | U | DR | 90 | d | NR | NR | JV | F | GRO | BDWT | WO | 2.97 | | 73 |
| 85 | Nielsen et al, 1979 | 19461 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 9 | w | 21 | d | JV | F | GRO | BDWT | WO | 4.56 | | 67 |
| 86 | Nielsen, 1980 | 19479 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 10 | w | NR | NR | JV | F | GRO | BDWT | WO | 4.56 | | 67 |
| 87 | Schroeder et al, 1974 | 14484 | Rat (*Rattus norvegicus* ) | 2 | M | DR | 1217 | d | 30 | d | JV | B | GRO | BDWT | WO | 5.44 | | 75 |
| 88 | Gershbein et al 1983 | 136 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 80 | d | 44 | d | JV | M | GRO | BDWT | WO | 5.89 | | 68 |
| 89 | ODell et al, 1970 | 14476 | Cattle (*Bos taurus* ) | 3 | U | FD | 6 | w | NR | NR | LC | F | GRO | BDWT | WO | 6.75 | | 68 |
| 90 | O'Dell et al, 1971 | 14479 | Cattle (*Bos taurus* ) | 4 | UX | FD | 8 | w | 13-21 | w | JV | M | GRO | BDWT | WO | 7.00 | 14.6 | 92 |
| 91 | Oosting et al, 1991 | 19514 | Rat (*Rattus norvegicus* ) | 3 | M | FD | 28 | d | 31 | d | JV | M | GRO | BDWT | WO | 7.78 | | 82 |
| 92 | Ambrose et al, 1976 | 14474 | Rat (*Rattus norvegicus* ) | 4 | U | FD | 6 | w | 28 | d | JV | B | GRO | BDWT | WO | 9.11 | 91.1 | 81 |
| 93 | Phatak and Patwardhan, 1950 | 14480 | Rat (*Rattus norvegicus* ) | 4 | U | FD | 8 | w | 4 | w | JV | B | GRO | BDWT | WO | 9.30 | | 69 |
| 94 | Whanger, 1973 | 63 | Rat (*Rattus norvegicus* ) | 4 | U | FD | 6 | w | 35 | d | JV | NR | GRO | BDWT | WO | 9.49 | 47.4 | 76 |
| 95 | Kakela et al, 1999 | 19293 | Rat (*Rattus norvegicus* ) | 3 | U | DR | 62 | d | 3.5-9 | mo | GE | F | GRO | BDWT | WO | 11.4 | | 70 |
| 96 | Obone et al, 1999 | 19507 | Rat (*Rattus norvegicus* ) | 4 | U | DR | 13 | w | NR | NR | JV | M | GRO | BDWT | WO | 11.7 | 23.4 | 78 |
| 97 | Alexander et al, 1978 | 36694 | Meadow vole (*Microtus pennsylvanicus* ) | 3 | U | FD | 45 | d | 14 | d | JV | NR | GRO | BDWT | WO | 12.5 | | 68 |
| 98 | Nation et al, 1985 | 19460 | Rat (*Rattus norvegicus* ) | 3 | U | FD | 14 | d | 80 | d | JV | M | GRO | BDWT | WO | 20.0 | | 72 |
| 99 | Alexander et al, 1978 | 36694 | Meadow vole (*Microtus pennsylvanicus* ) | 4 | M | FD | 49 | d | 14 | d | JV | NR | GRO | BDWT | WO | 29.4 | 309 | 85 |
| 101 | Ambrose et al, 1976 | 14474 | Dog (*Canis familiaris* ) | 4 | U | FD | 65 | w | 6 | mo | JV | B | GRO | BDWT | WO | 45.0 | 112 | 82 |
| 100 | Chernoff and Kavlock, 1982 | 1260 | Mouse (*Mus musculus* ) | 2 | U | GV | 5 | d | 60 | d | GE | F | GRO | BDWT | WO | 45.3 | | 82 |
| 102 | Berman and Rehnberg, 1983 | 19064 | Mouse (*Mus musculus* ) | 3 | U | DR | 15 | d | NR | NR | GE | F | GRO | BDWT | WO | 85.3 | 171 | 79 |
| 103 | Dieter,et al, 1988 | 61 | Mouse (*Mus musculus* ) | 4 | UX | DR | 180 | d | 6-8 | w | JV | F | GRO | BDWT | WO | 107 | 148 | 84 |
| 104 | Spears and Hatfield, 1985 | 19666 | Rat (*Rattus norvegicus* ) | 2 | U | FD | 21 | d | NR | NR | JV | M | GRO | BDWT | WO | | 2.81 | 77 |
| 105 | Oosting et al, 1991 | 19514 | Rat (*Rattus norvegicus* ) | 2 | M | FD | 28 | d | 31 | d | JV | M | GRO | BDWT | WO | | 8.20 | 82 |
| 106 | Clary, 1975 | 19111 | Rat (*Rattus norvegicus* ) | 2 | U | DR | 4 | mo | NR | NR | JV | M | GRO | BDWT | WO | | 24.7 | 72 |
| 107 | Weber and Reid, 1969 | 14485 | Mouse (*Mus musculus* ) | 3 | U | FD | 4 | w | NR | NR | JV | F | GRO | BDWT | WO | | 208 | 73 |

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


| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Survival (MOR)** | | | | | | | | | | | | | | | |
| 108 | Pandey et al, 1999 | 19521 | Mouse (*Mus musculus*) | 3 | U | GV | 35 | d | NR | NR | JV | M | MOR | MORT | WO | 2.71 | | 85 |
| 109 | Nielsen et al 1982 | 19483 | Rat (*Rattus norvegicus*) | 3 | U | FD | 11 | w | NR | NR | JV | F | MOR | MORT | WO | 4.56 | | 77 |
| 110 | Pandey and Srivastava, 2000 | 36722 | Mouse (*Mus musculus*) | 4 | U | OR | 35 | d | NR | NR | JV | M | MOR | MORT | WO | 5.42 | | 85 |
| 111 | Pandey and Srivastava, 2000 | 36722 | Mouse (*Mus musculus*) | 4 | U | OR | 35 | d | NR | NR | JV | M | MOR | MORT | WO | 6.47 | | 85 |
| 112 | Alexander et al, 1978 | 36694 | Meadow vole (*Microtus pennsylvanicus*) | 4 | M | FD | 14 | d | 14 | d | JV | NR | MOR | MORT | WO | 29.4 | 309 | 86 |
| 113 | Chernoff and Kavlock, 1982 | 1260 | Mouse (*Mus musculus*) | 2 | U | GV | 5 | d | 60 | d | GE | F | MOR | MORT | WO | 45.3 | | 76 |
| 114 | Seidenberg et al 1986 | 113 | Mouse (*Mus musculus*) | 2 | U | GV | 4 | d | NR | NR | GE | F | MOR | MORT | WO | 90.6 | | 85 |
| 115 | Ambrose et al, 1976 | 14474 | Dog (*Canis familiaris*) | 4 | U | FD | 24 | mo | 6 | mo | JV | B | MOR | MORT | WO | 112 | | 77 |
| 116 | Cempel and Janicka, 2002 | 36331 | Rat (Rattus norvegicus) | 3 | U | DR | 90 | d | NR | NR | JV | M | MOR | MORT | WO | 138 | | 74 |
| 117 | Ambrose et al, 1976 | 14474 | Rat (*Rattus norvegicus*) | 4 | U | FD | 24 | mo | 28 | d | JV | B | MOR | MORT | WO | 205 | | 78 |
| 118 | Schroeder et al, 1964 | 14447 | Mouse (*Mus musculus*) | 2 | U | DR | 16 | mo | 21 | d | JV | B | MOR | SURV | WO | | 0.620 | 73 |
| 119 | Schroeder and Mitchener, 1975 | 1858 | Mouse (*Mus musculus*) | 2 | U | DR | 520 | d | 19-20 | d | AD | F | MOR | LFSP | WO | | 0.716 | 68 |

AATT = alanine aminotransferase; ACTP = accuracy of learned behavior; AD = adult; ALBM = albumins; ALPH = alkaline phosphatase; AMMO = ammonia; ASCA = ascorbic acid; B = both; BDWT = body weight changes; BEH = behavior; BL = blood; BLPR = blood pressure; BM = bone marrow; bw = body weight; CALC = calcium; CCOX = cytochrome C-oxidase; CHM = chemical changes; d - day; DEYO = development of young; DIFD = digestibility of food; DR = Drinking water; EDMA = edema; ENZ = enyzme level changes; EXCR = excretion; F = female; FCNS = food consumption; FD = food; FDB = feeding behavior; G6PD = glucose-6-phosphate dehydrogenase; GBCM = general biochemical changes; GE = gestation; GENZ = general enzyme changes; GHIS = general histology; GIDX = gestation index; GOTR = glutamic-oxaloacetic transaminase; GPHY = general pysiology changes; GRO = growth; GRS = gross body weight changes; GT = gastrointestinal tract; GV = gavage; HE = heart; HIS = histological changes; HMCT = hematocrit; HMGL = hemoglobin; JV = juvenile; kg = kilograms; KI = kidney; L = liter; LADH = lactate dehydrogenase; LEUK = leukocytes; LFSP = lifespan; LI = liver; LOAEL = lowest observed adverse effect level; LU = lungs; M = male; M = measured; MADH = malic dehydrogenase; MK = milk; mo = months; MOR = effects on mortality and survival; M( NMVM = number of movements; NOAEL = No Observed Advese Effect Level; NR = Not reported; OR = other oral; ORW = organ weight changes; ORWT = organ weight changes; P450 = cytochrome P450 proteins; PG = prostrate gland; PHY = physiology; PL = plasma; PRFM = pregnant females in a population; PROG = progeny numbers/counts; PRTL = protein, total; PRWT = progeny weight; PTH = pathology; REP = reproduction; RSUC = reproductive success (general); SH = stomach; SM = sperm; SM = sexually mature SMIX = weight relative to body weight; SPCL = sperm cell counts; SPCV = sperm cell volume; SR = serum; SURV = survival; TE = testes; TEWT = testes weight; U = unmeasured; UR = urine; UX = measured but values not reported; w = weeks; WCON = water consumption; WO = whole organism; yr = year.

*NOAEL and LOAEL values that are equal and from the same reference represent different experimental designs.

Within the reviewed papers there are 119 results for biochemical (BIO), behavior (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 4-4). 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 geometric mean is examined in relationship to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to the Eco-SSL guidance (U.S. EPA 2003; Attachment 4-5).

A geometric mean of the NOAEL values for reproduction and growth was calculated at 7.70 mg nickel/kg bw/day. However this value is higher than the lowest bounded LOAEL for reproduction, growth, or mortality results. Therefore, the TRV is equal to the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth, or survival, and is equal to 1.70 mg nickel/kg bw/day.

## 6.2 Estimation of Dose and Calculation of the Eco-SSL

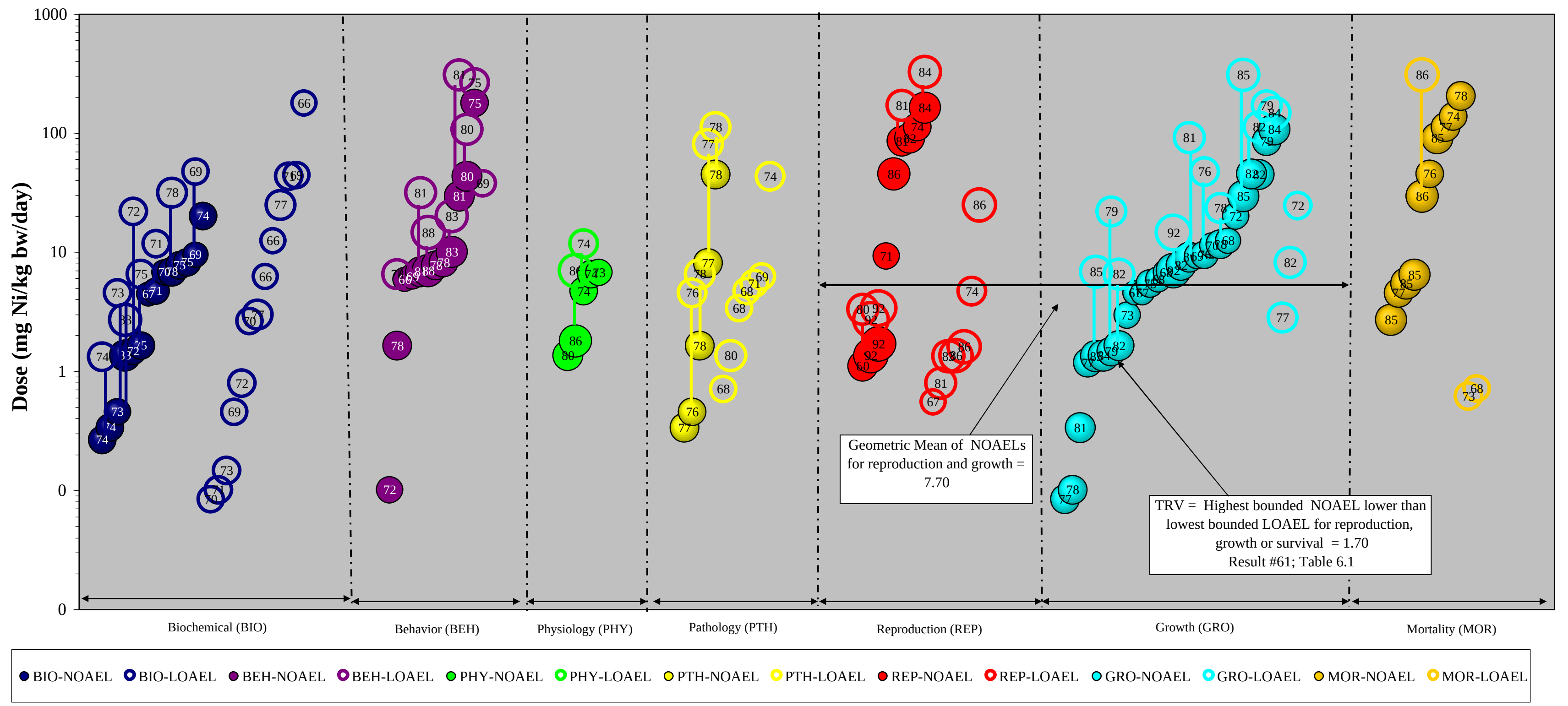
Two separate Eco-SSL values were calculated for mammalian wildlife, one for each of two surrogate receptor groups representing different trophic levels. The mammalian Eco-SSLs derived for nickel were calculated according to the Eco-SSL guidance (U.S. EPA, 2003; Attachment 4-5) and are summarized in Table 6.2. An Eco-SSL value could not be calculated for the mammalian ground insectivore (shrew) as a reliable method to estimate uptake of nickel from soil into soil invertebrates could not be identified (see Attachment 4-1 of the Eco-SSL guidance (U.S. EPA, 2003).

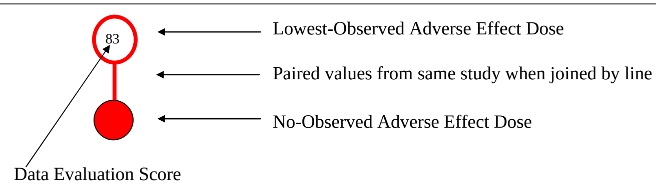
**Table 6.2 Calculation of the Mammalian Eco-SSLs for Nickel**

| Surrogate Receptor Group | TRV for Nickel (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 Nickel in Biota Type (i)[2,3] ($B_i$) (mg/kg dw) | Eco-SSL (mg/kg dw)[4] |
|---|---|---|---|---|---|
| Mammalian herbivore (vole) | 1.70 | 0.0875 | 0.032 | $\ln(B_i) = 0.748 * \ln(Soil_j) - 2.223$ where i = plants | 340 |
| Mammalian ground insectivore (shrew) | 1.70 | 0.209 | 0.030 | NA | NA |
| Mammalian carnivore (weasel) | 1.70 | 0.130 | 0.043 | $\ln(B_i) = 0.4658 * \ln(Soil_j) - 0.2462$ where i = mammals | 130 |

[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 Available

**Figure 6.1 Mammalian TRV Derivation for Nickel**




**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 three NOAEL results available within the growth and reproduction effect groups for calculation of a geometric mean.

3) The geometric mean is equal to 7.70 mg nickel/kg bw/d. However this value is higher than the lowest bounded LOAEL for results within the reproduction, growth, and survival (MOR) effect groups.

4) The mammalian wildlife TRV for nickel is equal to 1.70 mg nickel/kg bw/day which is the highest bounded NOAEL lower than the lowest bounded LOAEL within the reproduction, growth or survival effect groups.

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## 7.5 References Rejected for Use in Derivation of Wildlife TRV

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

**Unrel** addition of calcium ions for enhancing the safety of metal-ligand chelates as magnetic resonance imaging agents and x-ray contrast agents.    *PCT Int. Appl.*    10 pp.

**Diss** arsenic:  an analytical procedure to determine its total content in biological samples and signs of its deprivation in rats and chicks.    *788794  ORDER NO: AAD82-20750*

**Diss** aspects of crack growth in structural materials in light water reactors (stainless steel, nickel alloys).  *01642159  ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.*

**Diss** attempts to isolate with gas liquid chromatography chemical differences between reward and frustrative nonreward odor emissions in the rat.    *699745  ORDER NO: AAD80-25899*

**CP** 1971.*Bulletin of the Chemical Society - Belgrade. Volume 34, Number 8-9-10, 1969.  SFCSI-COMM(TT-69-51006/8-9-10)*

**Diss** content and evolution of cadmium, cobalt, chromium, copper, nickel, lead, and zinc in soils of l'horta and ribera baixa regions (valencia) (spain) original title:  contenido y evolucion de cadmio, cobalto, cromo, cobre, niquel, plomo, cinc en suelos de las comarcas de l'horta y la baixa (valencia).  *01269400  ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.*

**Diss** ecophysiology of the common cockle (cerastoderma edule l.) in southampton water, with particular reference to pollution (england).    *1092481  ORDER NO: AADDX-87466*

**Diss** effects of ethanol on muscarinic receptor-induced responses in astroglia (carbachol, calcium). *01698206 ORDER NO: AAD99-24077*

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**Diss** immune response to orthopaedic biomaterials. *01440048 ORDER NO: AADAA-I9534554*

**Diss** the murine dna methyltransferase: purification, heterologous expression, steady-state kinetics and post-translational processing. *01572339 ORDER NO: AAD97-27712*

**No COC** news about chemicals. *IRPTC Bull. V8, N1, P17(16)*

**No Oral** nickel permeation pathways in the small intestine and the olfactory system (iron deficiency). *01626234 ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.*

**Diss** nickelous nitrate hexahydrate and its effect on reproduction in the mouse. *702149 ORDER NO: AAD13-01167*

**Mix** 1993. ntp technical report on toxicity studies of a chemical mixture of 25 groundwater contaminants administered in ***drinking*** ***water*** to f344/n ***rats*** and b6c3f1 ***mice***. *Natl. Toxicol. Program Toxic. Rep. Ser.* 35: 184 pp.

**FL** 1978. (on the use of radioisotopic methods in an hygienic experiment).| au- moscow, ussr. *GIGIENA I SANITARIYA* No. 9: 72-75.

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**Diss** the role of the nmda receptor and cyclic guanosine 3',5'-monophosphate (cgmp) in the pathophysiological mechanisms of experimental brain injury: a time-course study (trauma, intracellular signaling, memory). *01603489 ORDER NO: AAD98-04188*

**No Oral** soft actuators and artificial muscles. *PCT Int. Appl.* 53 pp..

**Diss** studies on the muscarinic receptors in neuroblastoma cells. *750140 ORDER NO: AAD81-14988*

**Diss** a study of the chemistry and mutagenicity of welding fume. *910380 ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.*

**Diss** the susceptibility of pulmonary immunologic phenomena to the toxic effects of nickel subsulfide. *933904 ORDER NO: AAD86-25095*

**Diss** the synthesis and characterization of some polymer-supported macrocylic complexes and their interaction with oxygen. *01134166 ORDER NO: AADDX-90556*

**Diss** theoretical studies of the electronic structure and bonding in some transition metal complexes of

vanadium, chromium, iron, nickel and palladium. *765403 ORDER NO: AAD81-24610*

**Drug** treatment of septic shock with transition metal complexes. *PCT Int. Appl.* 13 pp.

**Diss** ultraviolet radiation and allergic contact dermatitis: an experimental and clinical study. *0997098 ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.*

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**Unrel** Yu, Ping, Yan, Jinling, and Huang, Meng. extraction of the active constituents of fugus ovary and their properties. *Tianran Chanwu Yanjiu Yu Kaifa (1999)* 11(5): 51-54

**Meth** Zaret Kenneth S(A) and Stevens Kimberly. 1995. expression of a highly unstable and insoluble transcription factor in escherichia coli: purification and characterization of the fork head homolog hnf3-alpha. *Protein Expression and Purification* 6(6): 821-825.

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**Unrel** Zurbruegg Heinz Robert(A), Wied Markus, Angelini Gianni D, and Hetzer Roland. 1999. reduction of intimal and medial thickening in sheathed vein grafts. *Annals of Thoracic Surgery* 68(1): 79-83.

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| Literature Rejection Categories | | |
|---|---|---|
| **Rejection Criteria** | **Description** | **Receptor** |
| ABSTRACT (Abstract) | Abstracts of journal publications or conference presentations. | Wildlife<br>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<br>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<br>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<br>Plants and Soil Invertebrates |
| BIOACCUMULATION SURVEY (Bio Acc) | Studies reporting the measurement of the concentration of the contaminant in tissues. | Wildlife<br>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<br>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<br>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<br>Plants and Soil Invertebrates |
| CONFERENCE PROCEEDINGS (CP) | Studies reported in conference and symposium proceedings. | Wildlife<br>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<br>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<br>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<br>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<br>Plants and Soil Invertebrates |
| EFFLUENT (Effl) | Studies reporting effects of effluent, sewage, or polluted runoff. | Wildlife<br>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<br>Plants and Soil Invertebrates |
| FOREIGN LANGUAGE (FL) | Studies in languages other than English. | Wildlife<br>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<br>Plants and Soil Invertebrates |
| GENE (Gene) | Studies of genotoxicity (chromosomal aberrations and mutagenicity). | Wildlife<br>Plants and Soil Invertebrates |
| HUMAN HEALTH (HHE) | Studies with human subjects. | Wildlife<br>Plants and Soil Invertebrates |
| IMMUNOLOGY (IMM) | Studies on the effects of contaminants on immunological endpoints. | Wildlife<br>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<br>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<br>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<br>Plants and Soil Invertebrates |

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

| Literature Rejection Categories | | |
|---|---|---|
| **Rejection Criteria** | **Description** | **Receptor** |
| OIL<br>(Oil) | Studies which examine the effects of oil and petroleum products. | Wildlife<br>Plants and Soil Invertebrates |
| OM, pH<br>(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).<br><br>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<br>(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<br>(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<br>(Phys) | Physiology studies where adverse effects are not associated with exposure to contaminants of concern. | Wildlife |
| PLANT<br>(Plant) | Studies of terrestrial plants are excluded. | Wildlife |
| PRIMATE<br>(Prim) | Primate studies are excluded. | Wildlife |
| PUBL AS<br>(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<br>Plants and Soil Invertebrates |
| QSAR<br>(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<br>Plants and Soil Invertebrates |
| REGULATIONS<br>(Reg) | Regulations and related publications that are not a primary source of data. | Wildlife<br>Plants and Soil Invertebrates |
| REVIEW<br>(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<br>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<br>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<br>Plants and Soil Invertebrates |
| SLUDGE | Studies on the effects of ingestion of soils amended with sewage sludge. | Wildlife<br>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<br>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<br>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<br>Plants and Soil Invertebrates |
| REPTILE OR AMPHIBIAN (Herp) | Studies on reptiles and amphibians. These papers flagged for possible later review. | Wildlife<br>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<br>Plants and Soil Invertebrates |
| YEAST (Yeast) | Studies of yeast. | Wildlife<br>Plants and Soil Invertebrates |

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# Appendix 5-1

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

***March 2007***

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## Appendix 5.1 Avian Toxicity Data Extracted for Wildlife Toxicity Reference Value (TRV)
## Nickel
## Page 1 of 1

| Ref | | | Exposure | | | | | | | | | | | | | | | | | | | | Effects | | | | | | Conversion to mg/kg bw/day | | | | Result | | Data Evaluation Score | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Result # | Ref N. | Reference | Chemical Form | MW% | Test Species | 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/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 | 5407 | Oscar et al, 1995 | Nickel chloride hexahydrate | 24.69 | Chicken (*Gallus domesticus*) | 1 | 3 | 0/6/12 | mg/kg diet | N | na | DLY | U | FD | 28 | d | 21 | d | JV | F | C | Lab | BIO | CHM | LIPD | WO | 12.0 | | Y | 1.98 | N | 0.09079 | 0.136 | | 10 | 10 | 5 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 70 |
| 2 | 6885 | Nielsen et al, 1975 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/50/250/2500 | ng/g diet | N | na | NR | U | FD | 3 | w | 1 | d | JV | M | C | Lab | BIO | CHM | HMCT | BL | 2500 | | Y | 0.433 | N | 0.03375 | 0.195 | | 10 | 10 | 5 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 70 |
| 3 | 6666 | Ling and Leach, 1979 | Nickel chloride | 100 | Chicken (*Gallus domesticus*) | 1 | 6 | 0/300/500/700/900/1100 | mg/kg diet | N | na | ADL | U | FD | 3 | w | 1 | d | JV | M | C | Lab | BIO | CHM | HMGL | BL | 900 | 1100 | Y | 0.1179 | N | 0.01447 | 110 | 135 | 10 | 10 | 5 | 10 | 6 | 1 | 10 | 10 | 10 | 4 | 76 |
| 4 | 5345 | Martinez and Diaz, 1996 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/123.5/247/494 | mg/kg diet | N | na | ADL | U | FD | 42 | d | 1 | d | JV | M | C | Lab | BIO | CHM | HMGL | BL | | 124 | Y | 1.8901 | N | 0.08809 | | 5.76 | 10 | 10 | 5 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 70 |
| **Behavior** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 5407 | Oscar et al, 1995 | Nickel chloride hexahydrate | 24.69 | Chicken (*Gallus domesticus*) | 1 | 3 | 0/6/12 | mg/kg diet | N | na | DLY | U | FD | 28 | d | 21 | d | JV | F | C | Lab | BEH | FDB | FCNS | WO | 12.0 | | Y | 1.98 | N | 0.09079 | 0.136 | | 10 | 10 | 5 | 10 | 6 | 4 | 4 | 10 | 10 | 4 | 73 |
| 6 | 5345 | Martinez and Diaz, 1996 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/123.5/247/494 | mg/kg diet | N | na | ADL | U | FD | 42 | d | 1 | d | JV | M | C | Lab | BEH | FDB | FCNS | WO | 123.5 | 247 | Y | 1.8901 | N | 0.08809 | 5.76 | 11.5 | 10 | 10 | 5 | 10 | 6 | 4 | 10 | 10 | 10 | 4 | 79 |
| **Physiology** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 60 | Weber and Reid, 1968 | Nickel acetate | 100 | Chicken (*Gallus domesticus*) | 2 | 8 | 0/3.04/9.25/13.68/14.61/15.86/16.21/17.25 | mg/org/d | N | na | ADL | U | FD | 4 | w | 1 | d | JV | B | C | Lab | PHY | PHY | FDCV | WO | 13.7 | 14.6 | Y | 0.484 | Y | 0.001 | 28.3 | 30.2 | 10 | 10 | 5 | 5 | 7 | 4 | 10 | 10 | 10 | 4 | 75 |
| 8 | 60 | Weber and Reid, 1968 | Nickel sulfate | 100 | Chicken (*Gallus domesticus*) | 1 | 8 | 0/3.11/9.61/13.32/14.14/14.50/14.71/17.07 | mg/org/d | N | na | ADL | U | FD | 4 | w | 1 | d | JV | B | C | Lab | PHY | PHY | META | WO | 14.5 | 14.71 | Y | 0.467 | Y | 0.001 | 31.0 | 31.5 | 10 | 10 | 5 | 10 | 7 | 4 | 10 | 10 | 10 | 4 | 80 |
| **Pathology** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | 6885 | Nielsen et al, 1975 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/50/250/2500 | ng/g diet | N | na | NR | U | FD | 3 | w | 1 | d | JV | M | C | Lab | PTH | ORW | SMIX | SK | 2500 | | Y | 0.433 | N | 0.03375 | 0.195 | | 10 | 10 | 5 | 10 | 6 | 4 | 4 | 10 | 10 | 4 | 73 |
| 10 | 6461 | Cain and Pafford, 1981 | Nickel sulfate | 100 | Duck (*Anas platyrhynchos*) | 1 | 4 | 0/176/774/1069 | mg/kg diet | N | na | ADL | M | FD | 28 | d | 1 | d | JV | B | C | Lab | PTH | ITX | ATAX | WO | 176 | 774 | Y | 1.023 | N | 0.05907 | 10.7 | 47.0 | 10 | 10 | 10 | 10 | 6 | 4 | 8 | 10 | 10 | 4 | 82 |
| 11 | 5345 | Martinez and Diaz, 1996 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/123.5/247/494 | mg/kg diet | N | na | ADL | U | FD | 42 | d | 1 | d | JV | M | C | Lab | PTH | HIS | GHIS | HE | 247 | 494 | Y | 1.7285 | N | 0.08311 | 11.9 | 23.8 | 10 | 10 | 5 | 10 | 6 | 4 | 10 | 10 | 10 | 4 | 79 |
| **Reproduction** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 6492 | Eastin and O'Shea, 1981 | Nickel sulfate | 100 | Duck (*Anas platyrhynchos*) | 1 | 5 | 0/12.5/50/200/800 | mg/kg diet | N | na | ADL | U | FD | 90 | d | 20 | mo | LB | F | V | Lab | REP | REP | HTCH | EG | 800 | | N | 1.1 | Y | 0.20470 | 149 | | 10 | 10 | 5 | 10 | 6 | 10 | 4 | 1 | 10 | 4 | 70 |
| 13 | 2771 | Meluzzi et al, 1996 | Nickel sulfate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/100/300/500 | mg/kg diet | N | na | NR | U | FD | 60 | d | 22 | w | LB | F | C | Lab | REP | EGG | ESWT | EG | | 100 | N | 1.6 | Y | 0.1306 | | 8.16 | 10 | 10 | 5 | 10 | 6 | 10 | 4 | 10 | 6 | 4 | 75 |
| **Growth** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 5407 | Oscar et al, 1995 | Nickel chloride hexahydrate | 24.69 | Chicken (*Gallus domesticus*) | 1 | 3 | 0/6/12 | mg/kg diet | N | na | DLY | U | FD | 28 | d | 21 | d | JV | F | C | Lab | GRO | GRO | BDWT | WO | 12.0 | | Y | 1.98 | N | 0.09079 | 0.136 | | 10 | 10 | 5 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 77 |
| 15 | 6885 | Nielsen et al, 1975 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/50/250/2500 | ng/g diet | N | na | NR | U | FD | 3 | w | 1 | d | JV | M | C | Lab | GRO | GRO | BDWT | WO | 2500 | | Y | 0.433 | N | 0.03375 | 0.195 | | 10 | 10 | 5 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 77 |
| 16 | 5345 | Martinez and Diaz, 1996 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/123.5/247/494 | mg/kg diet | N | na | ADL | U | FD | 42 | d | 1 | d | JV | M | C | Lab | GRO | GRO | BDWT | WO | 123.5 | 247 | Y | 1.8901 | N | 0.08809 | 5.76 | 11.5 | 10 | 10 | 5 | 10 | 6 | 8 | 10 | 10 | 10 | 4 | 83 |
| 17 | 397 | Hill, 1979 | Nickelous chloride | 45.29 | Chicken (*Gallus domesticus*) | 1 | 3 | 0/400/800 | mg/kg diet | N | na | ADL | U | FD | 5 | w | 1 | d | JV | F | C | NR | GRO | GRO | BDWT | WO | 400 | 800 | N | 1.042 | N | 0.05978 | 8.95 | 17.9 | 10 | 10 | 5 | 10 | 5 | 8 | 10 | 10 | 10 | 4 | 82 |
| 18 | 36697 | Blalock and Hill, 1985 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 2 | 0/400 | mg/kg diet | N | na | ADL | U | FD | 25 | d | 1 | d | JV | B | C | Lab | GRO | GRO | BDWT | WO | 400 | | N | 1.042 | N | 0.05978 | 22.9 | | 10 | 10 | 5 | 10 | 5 | 8 | 4 | 1 | 10 | 4 | 67 |
| 19 | 60 | Weber and Reid, 1968 | Nickel acetate | 100 | Chicken (*Gallus domesticus*) | 2 | 8 | 0/3.04/9.25/13.68/14.61/15.86/16.21/17.25 | mg/org/d | N | na | ADL | U | FD | 4 | w | 1 | d | JV | B | C | Lab | GRO | GRO | BDWT | WO | 13.7 | 14.6 | Y | 0.484 | Y | 0.001 | 28.3 | 30.2 | 10 | 10 | 5 | 5 | 7 | 8 | 10 | 10 | 10 | 4 | 79 |
| 20 | 60 | Weber and Reid, 1968 | Nickel sulfate | 100 | Chicken (*Gallus domesticus*) | 1 | 8 | 0/3.11/9.61/13.32/14.14/14.50/14.71/17.07 | mg/org/d | N | na | ADL | U | FD | 4 | w | 1 | d | JV | B | C | Lab | GRO | GRO | BDWT | WO | 14.5 | 14.71 | Y | 0.467 | Y | 0.001 | 31.0 | 31.5 | 10 | 10 | 5 | 10 | 7 | 8 | 10 | 10 | 10 | 4 | 84 |
| 21 | 397 | Hill, 1979 | Nickelous chloride | 45.29 | Chicken (*Gallus domesticus*) | 1 | 3 | 0/400/800 | mg/kg diet | N | na | ADL | U | FD | 5 | w | 1 | d | JV | F | C | NR | GRO | GRO | BDWT | WO | | 400 | N | 1.042 | N | 0.05978 | | 8.95 | 10 | 10 | 5 | 10 | 5 | 8 | 4 | 10 | 10 | 4 | 76 |
| 22 | 6461 | Cain and Pafford, 1981 | Nickel sulfate | 100 | Duck (*Anas platyrhynchos*) | 1 | 4 | 0/176/774/1069 | mg/kg diet | N | na | ADL | M | FD | 60 | d | 1 | d | JV | F | C | Lab | GRO | MPH | HULT | HM | | 176 | Y | 1.023 | N | 0.05907 | | 10.7 | 10 | 10 | 10 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 82 |
| 23 | 6666 | Ling and Leach, 1979 | Nickel chloride | 100 | Chicken (*Gallus domesticus*) | 1 | 6 | 0/300/500/700/900/1100 | mg/kg diet | N | na | ADL | U | FD | 3 | w | 1 | d | JV | M | C | Lab | GRO | GRO | BDWT | WO | | 300 | Y | 0.4046 | N | 0.03229 | | 23.9 | 10 | 10 | 5 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 77 |
| 24 | 36708 | Hill, 1985 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 2 | 0/400 | mg/kg diet | N | na | ADL | U | FD | 19 | d | NR | NR | JV | B | C | Lab | GRO | GRO | BDWT | WO | | 400 | N | 0.0397 | N | 0.00712 | | 71.8 | 10 | 10 | 5 | 10 | 5 | 8 | 4 | 10 | 10 | 4 | 76 |
| **Survival** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | 6461 | Cain and Pafford, 1981 | Nickel sulfate | 100 | Duck (*Anas platyrhynchos*) | 1 | 4 | 0/176/774/1069 | mg/kg diet | N | na | ADL | M | FD | 30 | d | 1 | d | JV | B | C | Lab | MOR | MOR | SURV | WO | 176 | 774 | Y | 1.023 | N | 0.05907 | 10.7 | 47.0 | 10 | 10 | 10 | 10 | 6 | 9 | 8 | 10 | 10 | 4 | 87 |
| 26 | 36697 | Blalock and Hill, 1985 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 2 | 0/400 | mg/kg diet | N | na | ADL | U | FD | 25 | d | 1 | d | JV | B | C | Lab | MOR | MOR | MORT | WO | 400 | | N | 1.042 | N | 0.05978 | 22.9 | | 10 | 10 | 5 | 10 | 5 | 9 | 4 | 10 | 10 | 4 | 77 |
| 27 | 5345 | Martinez and Diaz, 1996 | Nickel chloride hexahydrate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/123.5/247/494 | mg/kg diet | N | na | ADL | U | FD | 42 | d | 1 | d | JV | M | C | Lab | MOR | MOR | MORT | WO | 494 | | Y | 1.8901 | N | 0.08809 | 23.0 | | 10 | 10 | 5 | 10 | 6 | 9 | 4 | 1 | 10 | 4 | 69 |
| 28 | 6666 | Ling and Leach, 1979 | Nickel chloride | 100 | Chicken (*Gallus domesticus*) | 1 | 6 | 0/300/500/700/900/1100 | mg/kg diet | N | na | ADL | U | FD | 3 | w | 1 | d | JV | M | C | Lab | MOR | MOR | SURV | WO | 300 | 500 | Y | 0.4046 | N | 0.03229 | 23.9 | 39.9 | 10 | 10 | 5 | 10 | 6 | 9 | 10 | 10 | 10 | 4 | 84 |
| **Data Not Used to Derive TRV** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 2771 | Meluzzi et al, 1996 | Nickel sulfate | 100 | Chicken (*Gallus domesticus*) | 1 | 4 | 0/100/300/500 | mg/kg diet | N | na | NR | U | FD | 75 | d | 22 | w | AD | F | C | Lab | BEH | FDB | FCNS | WO | 500 | | N | 1.6 | Y | 0.1306 | 40.8 | | 10 | 10 | 5 | 10 | 6 | 4 | 4 | 1 | 6 | 4 | 60 |
| 30 | 6492 | Eastin and O'Shea, 1981 | Nickel sulfate | 100 | Duck (*Anas platyrhynchos*) | 1 | 5 | 0/12.5/50/200/800 | mg/kg diet | N | na | ADL | U | FD | 90 | d | 20 | mo | LB | F | V | Lab | BEH | FDB | FCNS | WO | 800 | | N | 1.1 | Y | 0.20470 | 149 | | 10 | 10 | 5 | 10 | 6 | 4 | 4 | 1 | 6 | 4 | 60 |

All abbreviations and definitions are used in coding stuides are available from Attachment 4-3 of the Eco-SSL guidance (U.S. EPA 2003).
Duplicate values for NOAELs and LOAELs for the same reference represent results from different experimental designs.

# Appendix 6-1

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

***March 2007***

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| Ref | | Exposure | | | | | | | | | | | | | | | | | | | | Effects | | | | | Conversion to mg/kg bw/day | | | | | Result | | Data Evaluation Score | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Result # | Ref N. | Reference | Chemical Form | MW% | Test Species | # 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 | 19671 | Spears et al, 1984 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/25 | mg/kg diet | N | na | ADL | U | FD | 21 | d | 1 | d | JV | NR | C | Lab | BIO | ENZ | ALPH | SR | 5 | 25 | Y | 4.329 | N | 0.22912 | 0.265 | 1.32 | 10 | 10 | 5 | 10 | 6 | 1 | 8 | 10 | 10 | 4 | 74 |
| 2 | 19098 | Chatterjee et al, 1979 | Nickel sulfate hexahydrate | 22.33 | Rat (*Rattus norvegicus*) | 2 | 0/1.5 | mg/kg bw/d | N | na | NR | U | FD | 21 | d | NR | NR | JV | M | C | Lab | BIO | CHM | ASCA | LI | 1.50 | | Y | 0.0755 | N | 0.008215 | 0.335 | | 10 | 10 | 5 | 10 | 10 | 1 | 4 | 10 | 10 | 4 | 74 |
| 3 | 19478 | Nielsen, 1980 | Nickel chloride trihydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | DLY | U | FD | 10 | w | NR | NR | JV | F | C | Lab | BIO | CHM | HMCT | PL | 5.00 | 50.0 | N | 0.204 | N | 0.0186 | 0.456 | 4.56 | 10 | 10 | 5 | 10 | 5 | 1 | 8 | 10 | 10 | 4 | 73 |
| 4 | 19521 | Pandey et al, 1999 | Nickel sulfate | 37.94 | Mouse (*Mus musculus*) | 3 | 0/3.57/7.14 | mg/kg bw/d | N | na | 5 per w | U | GV | 35 | d | NR | NR | JV | M | C | Lab | BIO | ENZ | LADH | TE | 3.57 | 7.14 | Y | 0.025 | N | 0.00331 | 1.35 | 2.71 | 10 | 8 | 10 | 10 | 10 | 1 | 10 | 10 | 10 | 4 | 83 |
| 5 | 19666 | Spears and Hatfield, 1985 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/15/225 | mg/kg diet | N | na | ADL | U | FD | 21 | d | NR | NR | JV | M | C | Lab | BIO | CHM | LEUK | BL | 15 | 225 | Y | 0.137 | N | 0.01341 | 1.47 | 22.0 | 10 | 10 | 5 | 10 | 6 | 1 | 6 | 10 | 10 | 4 | 72 |
| 6 | 14477 | O'Dell et al, 1970 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 4 | 0/62.5/250/1000 | mg/kg diet | N | na | DLY | U | FD | 8 | w | 14 | w | JV | M | C | Lab | BIO | CHM | CALC | NR | 250 | 1000 | Y | 180.8 | Y | 1.180 | 1.63 | 6.53 | 10 | 10 | 5 | 10 | 7 | 1 | 8 | 10 | 10 | 4 | 75 |
| 7 | 19290 | Kadiiska et al, 1985 | Nickel sulfate hexahydrate | 22.33 | Rat (*Rattus norvegicus*) | 2 | 0/20 | mg/kg bw/d | N | na | DLY | U | DR | 30 | d | NR | NR | JV | M | C | Lab | BIO | ENZ | P450 | LI | 20.0 | | Y | 0.175 | N | 0.02062 | 4.47 | | 10 | 5 | 5 | 10 | 10 | 1 | 4 | 8 | 10 | 4 | 67 |
| 8 | 19507 | Obone et al, 1999 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/44.7/111.75/223.5 | mg/L | N | na | ADL | U | DR | 13 | w | NR | NR | JV | M | C | Lab | BIO | CHM | PRTL | PL | 44.7 | 112 | Y | 0.55 | N | 0.0578 | 4.70 | 11.7 | 10 | 5 | 5 | 10 | 6 | 1 | 10 | 10 | 10 | 4 | 71 |
| 9 | 14476 | ODell et al, 1970 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 3 | 0/365/1835 | mg/org/d | N | na | 1 per d | U | FD | 6 | w | NR | NR | LC | F | C | NR | BIO | CHM | PRTL | MK | 1835 | | N | 272 | Y | 7.350 | 6.75 | | 10 | 10 | 5 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 70 |
| 10 | 62 | Smith et al, 1993 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 4 | 0/1.33/6.8/31.63 | mg/kg bw/d | N | na | ADL | M | DR | 26 | w | 62 | d | LC | F | C | Lab | BIO | CHM | GBCM | PL | 6.80 | 31.6 | Y | 0.3325 | Y | 0.06389 | 6.80 | 31.6 | 10 | 5 | 10 | 10 | 10 | 1 | 8 | 10 | 10 | 4 | 78 |
| 11 | 19514 | Oosting et al, 1991 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 3 | 0/49.5/104.9 | mg/kg diet | N | na | ADL | M | FD | 28 | d | 31 | d | JV | M | C | Lab | BIO | CHM | HMGL | BL | 105 | | N | 0.217 | Y | 0.01610 | 7.78 | | 10 | 10 | 10 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 75 |
| 12 | 19514 | Oosting et al, 1991 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 2 | 0/100 | mg/kg diet | N | na | ADL | M | FD | 28 | d | 31 | d | JV | M | C | Lab | BIO | CHM | HMGL | BL | 100 | | N | 0.217 | Y | 0.0178 | 8.20 | | 10 | 10 | 10 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 75 |
| 13 | 63 | Whanger, 1973 | Nickel acetate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/100/500/1000 | mg/kg diet | N | na | DLY | U | FD | 6 | w | 35 | d | JV | NR | C | Lab | BIO | CHM | HMGL | BL | 100 | 500 | Y | 0.163 | N | 0.01547 | 9.49 | 47.4 | 10 | 10 | 5 | 5 | 6 | 1 | 8 | 10 | 10 | 4 | 69 |
| 14 | 19460 | Nation et al, 1985 | Nickel Chloride | 100 | Rat (*Rattus norvegicus*) | 3 | 0/10/20 | mg/kg bw/d | N | na | DLY | U | FD | 14 | d | 80 | d | JV | M | C | Lab | BIO | CHM | GBCM | LI | 20.0 | | Y | 0.1867 | N | 0.0173 | 20.0 | | 10 | 10 | 5 | 10 | 10 | 1 | 4 | 10 | 10 | 4 | 74 |
| 15 | 19764 | Uthus and Poellot, 1997 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/1 | ug/g diet | N | na | DLY | U | FD | 57 | d | NR | NR | JV | M | C | Lab | BIO | ENZ | GENZ | LI | | 1 | Y | 0.315 | N | 0.0265808 | | 0.0844 | 10 | 10 | 5 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 70 |
| 16 | 19664 | Spears et al, 1986 | Nickel chloride | 100 | Cattle (*Bos taurus*) | 2 | 0/5 | mg/kg diet | N | na | 2 per d | U | FD | 28 | d | 50 | d | JV | M | C | FieldA | BIO | CHM | AMMO | GT | | 5 | Y | 247.6 | Y | 5.00 | | 0.101 | 10 | 10 | 5 | 10 | 7 | 1 | 4 | 10 | 10 | 4 | 71 |
| 17 | 19437 | Milne et al, 1990 | Nickel Chloride hexahydrate | 100 | Sheep (*Ovis aries*) | 2 | 0/5 | mg/org/d | N | na | DLY | U | GV | 4 | w | 5 | mo | JV | F | C | Lab | BIO | ENZ | GENZ | SH | | 5.00 | Y | 34 | N | 1.247 | | 0.147 | 10 | 8 | 10 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 73 |
| 18 | 19461 | Nielsen et al, 1979 | Nickel chloride trihydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | DLY | U | FD | 9 | w | 21 | d | JV | F | C | Lab | BIO | CHM | HMCT | BL | | 5.00 | N | 0.204 | N | 0.0186 | | 0.456 | 10 | 10 | 5 | 10 | 5 | 1 | 4 | 10 | 10 | 4 | 69 |
| 19 | 19522 | Pandey and Singh, 1999 | Nickel sulfate hexahydrate | 22.33 | Mouse (*Mus musculus*) | 3 | 0/3.57/7.14 | mg/kg bw/d | N | na | 5 per w | U | GV | 35 | d | NR | NR | JV | M | C | Lab | BIO | ENZ | LADH | TE | | 3.57 | Y | 0.02 | N | 0.00276 | | 0.797 | 10 | 8 | 5 | 10 | 10 | 1 | 4 | 10 | 10 | 4 | 72 |
| 20 | 19666 | Spears and Hatfield, 1985 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/30 | mg/kg diet | N | na | ADL | U | FD | 42 | d | NR | NR | JV | M | C | Lab | BIO | CHM | HMGL | BL | | 30 | Y | 0.253 | N | 0.02220 | | 2.63 | 10 | 10 | 5 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 70 |
| 21 | 19746 | Tandon and Mathur, 1986 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/3 | mg/kg bw/d | N | na | DLY | U | GV | 4 | w | NR | NR | JV | M | C | Lab | BIO | ENZ | MADH | KI | | 3 | Y | 0.15 | N | 0.01444 | | 3.00 | 10 | 8 | 10 | 10 | 10 | 1 | 4 | 10 | 10 | 4 | 77 |
| 22 | 19787 | Vyskocil et al, 1994 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/6.25 | mg/kg bw/d | N | na | ADL | U | DR | 6 | mo | 10 | w | JV | M | C | Lab | BIO | CHM | ALBM | UR | | 6.25 | Y | 0.5 | Y | 0.03120 | | 6.25 | 10 | 5 | 5 | 10 | 7 | 1 | 4 | 10 | 10 | 4 | 66 |
| 23 | 19496 | Novelli et al, 1998 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/2.97 | mg/org/d | N | na | ADL | U | DR | 2 | mo | 15 | w | JV | M | C | Lab | BIO | ENZ | AATT | SR | | 2.97 | Y | 0.2 | Y | 0.0238 | | 12.5 | 10 | 5 | 5 | 10 | 7 | 1 | 4 | 10 | 10 | 4 | 66 |
| 24 | 19792 | Waltschewa et al, 1972 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/25 | mg/kg bw/d | N | na | DLY | U | GV | 120 | d | 5 | mo | JV | M | C | Lab | BIO | ENZ | GENZ | TE | | 25 | Y | 0.12 | N | 0.012024 | | 25.0 | 10 | 8 | 10 | 10 | 10 | 1 | 4 | 10 | 10 | 4 | 77 |
| 25 | 61 | Dieter et al, 1988 | Nickel sulfate | 37.4 | Mouse (*Mus musculus*) | 4 | 0/115.7/285.7/395.7 | mg/kg bw/d | N | na | ADL | UX | DR | 180 | d | 6-8 | w | JV | F | C | Lab | BIO | ENZ | G6PD | BM | | 116 | Y | 0.03 | Y | 0.00347 | | 43.3 | 10 | 5 | 10 | 10 | 7 | 1 | 4 | 10 | 10 | 4 | 71 |
| 26 | 19416 | Mathur, 1987 | Nickel sulphate hexahydrate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/500 | mg/kg diet | N | na | ADL | U | FD | 3 | w | 3 | w | JV | M | C | Lab | BIO | ENZ | GOTR | LI | | 500 | N | 0.235 | N | 0.02089 | | 44.5 | 10 | 10 | 5 | 10 | 5 | 1 | 4 | 10 | 10 | 4 | 69 |
| 27 | 14485 | Weber and Reid, 1969 | Nickel acetate | 100 | Mouse (*Mus musculus*) | 3 | 0/4.143/6.143 | mg/org/d | N | na | ADL | U | FD | 4 | w | NR | NR | JV | B | C | Lab | BIO | ENZ | CCOX | LI | | 4.143 | Y | 0.0232 | Y | 0.004590 | | 179 | 10 | 10 | 5 | 5 | 7 | 1 | 4 | 10 | 10 | 4 | 66 |
| **Behavior** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 19664 | Spears et al, 1986 | Nickel chloride | 100 | Cattle (*Bos taurus*) | 2 | 0/5 | mg/kg diet | N | na | 2 per d | U | FD | 140 | d | 50 | d | JV | M | C | FieldA | BEH | FDB | FCNS | WO | 5 | | Y | 247.6 | Y | 5.00 | 0.101 | | 10 | 10 | 5 | 10 | 7 | 4 | 4 | 8 | 10 | 4 | 72 |
| 29 | 14477 | O'Dell et al, 1970 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 4 | 0/62.5/250/1000 | mg/kg diet | N | na | DLY | U | FD | 8 | w | 14 | w | JV | M | C | Lab | BEH | FDB | FCNS | WO | 250 | 1000 | Y | 180.8 | Y | 1.180 | 1.63 | 6.53 | 10 | 10 | 5 | 10 | 7 | 4 | 8 | 10 | 10 | 4 | 78 |
| 30 | 136 | Gershbein et al, 1983 | Nickelous chloride | 100 | Rat (*Rattus norvegicus*) | 2 | 0/75 | mg/kg diet | N | na | ADL | U | FD | 80 | d | 44 | d | JV | M | C | Lab | BEH | BEH | NMVM | WO | 75 | | Y | 0.4700 | N | 0.03693 | 5.89 | | 10 | 10 | 5 | 10 | 6 | 4 | 4 | 3 | 10 | 4 | 66 |
| 31 | 19787 | Vyskocil et al, 1994 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/6.25 | mg/kg bw/d | N | na | ADL | U | DR | 6 | mo | 10 | w | JV | M | C | Lab | BEH | FDB | WCON | WO | 6.25 | | Y | 0.5 | Y | 0.03120 | 6.25 | | 10 | 5 | 5 | 10 | 7 | 4 | 4 | 10 | 10 | 4 | 69 |
| 32 | 62 | Smith et al, 1993 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 4 | 0/1.33/6.8/31.63 | mg/kg bw/d | N | na | ADL | M | DR | 11 | w | 62 | d | LC | F | C | Lab | BEH | FDB | WCON | WO | 6.80 | 31.6 | Y | 0.2732 | Y | 0.03079 | 6.80 | 31.63 | 10 | 5 | 10 | 10 | 10 | 4 | 8 | 10 | 10 | 4 | 81 |
| 33 | 14479 | O'Dell et al, 1971 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 4 | 0/1.8/7.0/14.6 | mg/kg bw/d | N | na | DLY | UX | FD | 8 | w | 13-21 | w | JV | M | C | NR | BEH | FDB | FCNS | WO | 7.00 | 14.6 | Y | 183.8 | Y | 5.100 | 7.00 | 14.6 | 10 | 10 | 10 | 10 | 10 | 4 | 10 | 10 | 10 | 4 | 88 |
| 34 | 19514 | Oosting et al, 1991 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 3 | 0/49.5/104.9 | mg/kg diet | N | na | ADL | M | FD | 28 | d | 31 | d | JV | M | C | Lab | BEH | FDB | FCNS | WO | 105 | | N | 0.217 | Y | 0.0161 | 7.78 | | 10 | 10 | 10 | 10 | 6 | 4 | 4 | 10 | 10 | 4 | 78 |
| 35 | 19514 | Oosting et al, 1991 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 2 | 0/100 | mg/kg diet | N | na | ADL | M | FD | 28 | d | 31 | d | JV | M | C | Lab | BEH | FDB | FCNS | WO | 100 | | N | 0.217 | Y | 0.0178 | 8.20 | | 10 | 10 | 10 | 10 | 6 | 4 | 4 | 10 | 10 | 4 | 78 |
| 36 | 19460 | Nation et al, 1985 | Nickel Chloride | 100 | Rat (*Rattus norvegicus*) | 3 | 0/10/20 | mg/kg bw/d | N | na | DLY | U | FD | 14 | d | 80 | d | JV | M | C | Lab | BEH | BEH | ACTP | WO | 10.0 | 20.0 | Y | 0.1833 | N | 0.0170 | 10.0 | 20.0 | 10 | 10 | 5 | 10 | 10 | 4 | 10 | 10 | 10 | 4 | 83 |
| 37 | 36694 | Alexander et al, 1978 | Nickel chloride hexahydrate | 100 | Meadow vole (*Microtus pennsylvanicus*) | 4 | 0/21/187/1968 | mg/kg diet | N | na | ADL | M | FD | 49 | d | 14 | d | JV | NR | C | Lab | BEH | FDB | FCNS | WO | 187 | 1968 | Y | 0.035 | Y | 0.0055 | 29.4 | 309 | 10 | 10 | 10 | 10 | 7 | 4 | 6 | 10 | 10 | 4 | 81 |
| 38 | 61 | Dieter et al, 1988 | Nickel sulfate | 37.4 | Mouse (*Mus musculus*) | 4 | 0/115.7/285.7/395.7 | mg/kg bw/d | N | na | ADL | UX | DR | 180 | d | 6-8 | w | JV | F | C | Lab | BEH | FDB | WCON | WO | 116 | 286 | Y | 0.03 | Y | 0.00347 | 43.3 | 107 | 10 | 5 | 10 | 10 | 7 | 4 | 10 | 10 | 10 | 4 | 80 |
| 39 | 14485 | Weber and Reid, 1969 | Nickel acetate | 100 | Mouse (*Mus musculus*) | 3 | 0/4.143/6.143 | mg/org/d | N | na | ADL | U | FD | 4 | w | NR | NR | JV | M | C | Lab | BEH | FDB | FCNS | WO | 4.143 | 6.143 | Y | 0.0232 | Y | 0.004590 | 179 | 265 | 10 | 10 | 5 | 5 | 7 | 4 | 10 | 10 | 10 | 4 | 75 |
| 40 | 36331 | Cempel and Janicka, 2002 | Nickel chloride hexahydrate | 100 | Rat (Rattus norvegicus) | 3 | 0/7.9/29.0 | mg/org/d | N | na | ADL | U | DR | 90 | d | NR | NR | JV | M | C | Lab | BEH | FDB | WCON | WO | | 7.9 | Y | 0.21 | Y | 0.0000263 | | 37.6 | 10 | 5 | 5 | 10 | 7 | 4 | 4 | 10 | 10 | 4 | 69 |
| **Physiology** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 41 | 19729 | Szakmary et al, 1995 | Nickelous chloride | 45.29 | Rat (*Rattus norvegicus*) | 2 | 0/3 | mg/kg bw/d | N | na | DLY | U | GV | 8 | d | NR | NR | GE | F | C | Lab | PHY | PHY | BLPR | HE | 3 | | Y | 0.263 | N | 0.02292 | 1.36 | | 10 | 8 | 10 | 10 | 10 | 4 | 4 | 10 | 10 | 4 | 80 |
| 42 | 14479 | O'Dell et al, 1971 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 4 | 0/1.8/7.0/14.6 | mg/kg bw/d | N | na | DLY | UX | FD | 8 | w | 13 | w | JV | M | C | NR | PHY | PHY | EXCR | UR | 1.80 | 7.00 | Y | 198 | Y | 5.800 | 1.80 | 7.00 | 10 | 10 | 10 | 10 | 10 | 4 | 8 | 10 | 10 | 4 | 86 |
| 43 | 19507 | Obone et al, 1999 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/44.7/111.75/223.5 | mg/L | N | na | ADL | U | DR | 13 | w | NR | NR | JV | M | C | Lab | PHY | PHY | EXCR | UR | 44.7 | 112 | Y | 0.55 | N | 0.0578 | 4.70 | 11.7 | 10 | 5 | 5 | 10 | 6 | 4 | 10 | 10 | 10 | 4 | 74 |
| 44 | 14477 | O'Dell et al, 1970 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 4 | 0/62.5/250/1000 | mg/kg diet | N | na | DLY | U | FD | 8 | w | 14 | w | JV | M | C | Lab | PHY | PHY | DIFD | WO | 1000 | | Y | 180.08 | Y | 1.180 | 6.55 | | 10 | 10 | 5 | 10 | 7 | 4 | 4 | 10 | 10 | 4 | 74 |
| 45 | 14476 | ODell et al, 1970 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 3 | 0/365/1835 | mg/org/d | N | na | 1 per d | U | FD | 6 | w | NR | NR | LC | F | C | NR | PHY | PHY | GPHY | MK | 1835 | | N | 272 | Y | 7.350 | 6.75 | | 10 | 10 | 5 | 10 | 6 | 4 | 4 | 10 | 10 | 4 | 73 |
| **Pathology** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 46 | 19098 | Chatterjee et al, 1979 | Nickel sulfate hexahydrate | 22.33 | Rat (*Rattus norvegicus*) | 2 | 0/1.5 | mg/kg bw/d | N | na | NR | U | FD | 21 | d | NR | NR | JV | M | C | Lab | PTH | ORW | SMIX | LI | 1.50 | | Y | 0.0755 | N | 0.008215 | 0.335 | | 10 | 10 | 5 | 10 | 10 | 4 | 4 | 10 | 10 | 4 | 77 |
| 47 | 19478 | Nielsen, 1980 | Nickel chloride trihydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | DLY | U | FD | 10 | w | NR | NR | JV | F | C | Lab | PTH | ORW | SMIX | LI | 5.00 | 50.0 | N | 0.204 | N | 0.0186 | 0.456 | 4.56 | 10 | 10 | 5 | 10 | 5 | 4 | 8 | 10 | 10 | 4 | 76 |
| 48 | 14477 | O'Dell et al, 1970 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 4 | 0/62.5/250/1000 | mg/kg diet | N | na | DLY | U | FD | 8 | w | 14 | w | JV | M | C | Lab | PTH | ORW | ORWT | LU | 250 | 1000 | Y | 180.08 | Y | 1.180 | 1.64 | 6.55 | 10 | 10 | 5 | 10 | 7 | 4 | 8 | 10 | 10 | 4 | 78 |
| 49 | 14474 | Ambrose et al, 1976 | Nickel sulfate hexahydrate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/100/1000/2500 | mg/kg diet | N | na | ADL | U | FD | 24 | mo | 28 | d | JV | B | C | Lab | PTH | ORW | SMIX | HE | 100 | 1000 | Y | 0.409 | N | 0.0329 | 8.06 | 80.6 | 10 | 10 | 5 | 10 | 6 | 4 | 8 | 10 | 10 | 4 | 77 |
| 50 | 14474 | Ambrose et al, 1976 | Nickel sulfate hexahydrate | 100 | Dog (*Canis familiaris*) | 4 | 0/100/1000/2500 | mg/kg diet | N | na | 1 per d | U | FD | 24 | mo | 6 | mo | JV | B | C | Lab | PTH | ORW | SMIX | KI | 1000 | 2500 | N | 10.8 | N | 0.4858 | 45.0 | 112 | 10 | 10 | 5 | 10 | 5 | 4 | 10 | 10 | 10 | 4 | 78 |
| 51 | 1858 | Schroeder and Mitchener, 1975 | Nickelous acetate | 100 | Mouse (*Mus musculus*) | 2 | 0/5 | mg/L | N | na | NR | U | DR | 520 | d | 19-20 | d | JV | M | C | Lab | PTH | HIS | EDMA | WO | | 5.00 | Y | 0.029 | N | 0.004091 | | 0.705 | 10 | 5 | 5 | 10 | 6 | 4 | 4 | 10 | 10 | 4 | 68 |
| 52 | 19521 | Pandey et al, 1999 | Nickel sulfate | 37.94 | Mouse (*Mus musculus*) | 3 | 0/3.57/7.14 | mg/kg bw/d | N | na | 5 per w | U | GV | 35 | d | NR | NR | JV | M | C | Lab | PTH | ORW | ORWT | PG | | 3.57 | Y | 0.025 | N | 0.00331 | | 1.35 | 10 | 8 | 10 | 10 | 10 | 4 | 4 | 10 | 10 | 4 | 80 |
| 53 | 19293 | Kakela et al, 1999 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/30/100 | mg/L | N | na | ADL | U | DR | 62 | d | 3.5-9 | mo | GE | F | C | Lab | PTH | ORW | SMIX | LI | | 30.0 | Y | 0.257 | N | 0.02915 | | 3.40 | 10 | 5 | 5 | 10 | 6 | 4 | 4 | 10 | 10 | 4 | 68 |
| 54 | 19507 | Obone et al, 1999 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/44.7/111.75/223.5 | mg/L | N | na | ADL | U | DR | 13 | w | NR | NR | JV | M | C | Lab | PTH | ORW | ORWT | HE | | 44.7 | Y | 0.55 | N | 0.0578 | | 4.70 | 10 | 5 | 5 | 10 | 6 | 4 | 4 | 10 | 10 | 4 | 68 |

| Ref | | | Exposure | | | | | | | | | | | | | | | | | | | Effects | | | | | Conversion to mg/kg bw/day | | | | | Result | | Data Evaluation Score | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Result # | Ref N. | Reference | Chemical Form | MW% | Test Species | # 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 |
| 55 | 14484 | Schroeder et al, 1974 | Nickel | 100 | Rat (*Rattus norvegicus*) | 2 | 0/5.44 | mg/kg bw/d | N | na | DLY | M | DR | 1217 | d | 30 | d | JV | B | C | Lab | PTH | HIS | GHIS | HE | | 5.44 | Y | 0.397 | Y | 0.027290 | | 5.44 | 10 | 5 | 10 | 4 | 10 | 4 | 4 | 10 | 10 | 4 | 71 |
| 56 | 19787 | Vyskocil et al, 1994 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/6.25 | mg/kg bw/d | N | na | ADL | U | DR | 6 | mo | 10 | w | JV | M | C | Lab | PTH | ORW | SMIX | KI | | 6.25 | Y | 0.5 | Y | 0.03120 | | 6.25 | 10 | 5 | 5 | 10 | 7 | 4 | 4 | 10 | 10 | 4 | 69 |
| 57 | 61 | Dieter et al, 1988 | Nickel sulfate | 37.4 | Mouse (*Mus musculus*) | 4 | 0/115.7/285.7/395.7 | mg/kg bw/d | N | na | ADL | UX | DR | 180 | d | 6-8 | w | JV | F | C | Lab | PTH | ORW | ORWT | LI | | 116 | Y | 0.03 | Y | 0.00347 | | 43.3 | 10 | 5 | 10 | 10 | 7 | 4 | 4 | 10 | 10 | 4 | 74 |
| 58 | 113 | Seidenberg et al, 1986 | Nickelous chloride | 45.29 | Mouse (*Mus musculus*) | 2 | 0/200 | mg/kg/bw/d | N | na | DLY | U | GV | 4 | d | NR | NR | GE | F | C | Lab | PTH | GRS | BDWT | WO | | 200 | Y | 0.0392 | N | 0.00479 | | 90.6 | 10 | 8 | 10 | 10 | 10 | 4 | 4 | 10 | 10 | 4 | 80 |
| **Reproduction** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 59 | 19293 | Kakela et al, 1999 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/10/30/100 | mg/L | N | na | ADL | U | DR | 28 | d | 3.5-9 | mo | SM | M | C | Lab | REP | REP | GIDX | WO | 10.0 | 30.0 | Y | 0.3379 | N | 0.03729 | 1.10 | 3.31 | 10 | 5 | 5 | 10 | 6 | 10 | 10 | 10 | 10 | 4 | 80 |
| 60 | 36722 | Pandey and Srivastava, 2000 | Nickel sulfate | 37.93 | Mouse (*Mus musculus*) | 4 | 0/3.57/7.14/14.29 | mg/kg bw/d | N | na | 5 per w | U | OR | 35 | d | NR | mo | JV | M | C | Lab | REP | REP | SPCL | SM | 7.14 | 14.29 | Y | 0.025 | N | 0.00331 | 1.35 | 2.71 | 10 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4 | 92 |
| 61 | 36722 | Pandey and Srivastava, 2000 | Nickelous chloride | 45.29 | Mouse (*Mus musculus*) | 4 | 0/3.57/7.14/14.29 | mg/kg bw/d | N | na | 5 per w | U | OR | 35 | d | NR | NR | JV | M | C | Lab | REP | REP | SPCL | SM | 3.57 | 7.14 | Y | 0.025 | N | 0.00331 | 1.70 | 3.40 | 10 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4 | 92 |
| 62 | 14480 | Phatak and Patwardhan, 1950 | Nickel carbonate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/.25/.5/1 | mg/g diet | N | na | ADL | U | FD | 4 | mo | 4 | w | GE | F | C | Lab | REP | REP | PRWT | WO | 1.00 | | Y | 0.115 | Y | 0.001070 | 9.30 | | 10 | 10 | 5 | 10 | 7 | 10 | 4 | 1 | 10 | 4 | 71 |
| 63 | 1260 | Chernoff and Kavlock, 1982 | Nickel chloride | 45.29 | Mouse (*Mus musculus*) | 2 | 0/100 | mg/kg bw/d | N | na | DLY | U | GV | 5 | d | 60 | d | GE | F | C | Lab | REP | REP | PROG | WO | 100 | | N | 0.0225 | N | 0.00304 | 45.3 | | 10 | 8 | 10 | 10 | 10 | 10 | 4 | 10 | 10 | 4 | 86 |
| 64 | 19064 | Berman and Rehnberg, 1983 | Nickel chloride | 100 | Mouse (*Mus musculus*) | 3 | 0/85.3/170.7 | mg/kg bw/d | N | na | ADL | U | DR | 15 | d | NR | NR | GE | F | C | Lab | REP | REP | PRFM | WO | 85.3 | 170.7 | Y | 0.0297 | Y | 5.387 | 85.3 | 171 | 10 | 5 | 5 | 10 | 7 | 10 | 10 | 10 | 10 | 4 | 81 |
| 65 | 113 | Seidenberg et al, 1986 | Nickelous chloride | 45.29 | Mouse (*Mus musculus*) | 2 | 0/200 | mg/kg/bw/d | N | na | DLY | U | GV | 4 | d | NR | NR | GE | F | C | Lab | REP | REP | PRWT | WO | 200 | | Y | 0.0392 | N | 0.00479 | 90.6 | | 10 | 8 | 10 | 10 | 10 | 10 | 4 | 6 | 10 | 4 | 82 |
| 66 | 14474 | Ambrose et al, 1976 | Nickel sulfate hexahydrate | 100 | Dog (*Canis familiaris*) | 4 | 0/100/1000/2500 | mg/kg diet | N | na | 1 per d | U | FD | 24 | mo | 6 | mo | JV | B | C | Lab | REP | REP | TEWT | TE | 2500 | | N | 10.8 | N | 0.4858 | 112 | | 10 | 10 | 5 | 10 | 5 | 10 | 4 | 6 | 10 | 4 | 74 |
| 67 | 14474 | Ambrose et al, 1976 | Nickel sulfate hexahydrate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/250/500/1000 | mg/kg diet | N | na | DLY | U | FD | 118 | d | 28 | d | GE | F | C | Lab | REP | REP | PRWT | WO | 500 | 1000 | N | 0.000156 | N | 0.0001 | 164 | 327 | 10 | 10 | 5 | 10 | 5 | 10 | 10 | 10 | 10 | 4 | 84 |
| 68 | 14474 | Ambrose et al, 1976 | Nickel sulfate hexahydrate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/100/1000/2500 | mg/kg diet | N | na | ADL | U | FD | 2 | yr | 28 | d | JV | M | C | Lab | REP | REP | TEWT | TE | 2500 | | Y | 0.367 | N | 0.0301 | 205 | | 10 | 10 | 5 | 10 | 6 | 10 | 4 | 1 | 10 | 4 | 70 |
| 69 | 66 | Schroeder and Mitchener, 1971 | Nickel | 100 | Rat (*Rattus norvegicus*) | 2 | 0/5 | mg/L | N | na | ADL | U | DR | 9 | mo | 21 | d | GE | F | C | Lab | REP | REP | DEYO | WO | | 5.00 | N | 0.344 | N | 0.03789 | | 0.551 | 10 | 5 | 5 | 4 | 5 | 10 | 4 | 10 | 10 | 4 | 67 |
| 70 | 19522 | Pandey and Singh, 1999 | Nickel sulfate hexahydrate | 22.33 | Mouse (*Mus musculus*) | 3 | 0/3.57/7.14 | mg/kg bw/d | N | na | 5 per w | U | GV | 35 | d | NR | NR | JV | M | C | Lab | REP | REP | SPCV | SM | | 3.57 | Y | 0.02 | N | 0.00276 | | 0.797 | 10 | 8 | 5 | 10 | 10 | 10 | 4 | 10 | 10 | 4 | 81 |
| 71 | 62 | Smith et al, 1993 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 4 | 0/1.33/6.8/31.63 | mg/kg bw/d | N | na | ADL | M | DR | 23 | w | 62 | d | LC | F | C | Lab | REP | REP | DEYO | WO | | 1.33 | Y | 0.2689 | Y | 0.02479 | | 1.33 | 10 | 5 | 10 | 10 | 10 | 10 | 4 | 10 | 10 | 4 | 83 |
| 72 | 19521 | Pandey et al, 1999 | Nickel sulfate | 37.94 | Mouse (*Mus musculus*) | 3 | 0/3.57/7.14 | mg/kg bw/d | N | na | 5 per w | U | GV | 35 | d | NR | NR | JV | M | C | Lab | REP | REP | TEWT | TE | | 3.57 | Y | 0.025 | N | 0.00331 | | 1.35 | 10 | 8 | 10 | 10 | 10 | 10 | 4 | 10 | 10 | 4 | 86 |
| 73 | 19520 | Pandey et al, 1999 | Nickel sulfate hexahydrate | 22.33 | Mouse (*Mus musculus*) | 2 | 0/7.14 | mg/kg bw/d | N | na | 5 per w | U | GV | 35 | d | NR | NR | AD | M | V | Lab | REP | REP | RSUC | WO | | 7.14 | Y | 0.02 | N | 0.00276 | | 1.59 | 10 | 8 | 10 | 10 | 10 | 10 | 4 | 10 | 10 | 4 | 86 |
| 74 | 19507 | Obone et al, 1999 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/44.7/111.75/223.5 | mg/L | N | na | ADL | U | DR | 13 | w | NR | NR | JV | M | C | Lab | REP | REP | TEWT | TE | | 44.7 | Y | 0.55 | N | 0.0578 | | 4.70 | 10 | 5 | 5 | 10 | 6 | 10 | 4 | 10 | 10 | 4 | 74 |
| 75 | 19792 | Waltschewa et al, 1972 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/25 | mg/kg bw/d | N | na | DLY | U | GV | 120 | d | 5 | mo | JV | M | C | Lab | REP | REP | SPCL | SM | | 25 | Y | 0.12 | N | 0.012024 | | 25.0 | 10 | 8 | 10 | 10 | 10 | 10 | 4 | 10 | 10 | 4 | 86 |
| **Growth** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 76 | 19764 | Uthus and Poellot, 1997 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/1 | ug/g diet | N | na | DLY | U | FD | 57 | d | NR | NR | JV | M | C | Lab | GRO | GRO | BDWT | WO | 1 | | Y | 0.315 | N | 0.0265808 | 0.0844 | | 10 | 10 | 5 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 77 |
| 77 | 19664 | Spears et al, 1986 | Nickel chloride | 100 | Cattle (*Bos taurus*) | 2 | 0/5 | mg/kg diet | N | na | 2 per d | U | FD | 140 | d | 50 | d | JV | M | C | FieldA | GRO | GRO | BDWT | WO | 5 | | Y | 247.6 | Y | 5.00 | 0.101 | | 10 | 10 | 5 | 10 | 7 | 8 | 4 | 10 | 10 | 4 | 78 |
| 78 | 19098 | Chatterjee et al, 1979 | Nickel sulfate hexahydrate | 22.33 | Rat (*Rattus norvegicus*) | 2 | 0/1.5 | mg/kg bw/d | N | na | NR | U | FD | 21 | d | NR | NR | JV | M | C | Lab | GRO | GRO | BDWT | WO | 1.50 | | Y | 0.0755 | N | 0.008215 | 0.335 | | 10 | 10 | 5 | 10 | 10 | 8 | 4 | 10 | 10 | 4 | 81 |
| 79 | 19671 | Spears et al, 1984 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/25 | mg/kg diet | N | na | ADL | U | FD | 49 | d | 1 | d | JV | NR | C | Lab | GRO | GRO | BDWT | WO | 25 | | Y | 8.501 | N | 0.39901 | 1.17 | | 10 | 10 | 5 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 77 |
| 80 | 62 | Smith et al, 1993 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 4 | 0/1.33/6.8/31.63 | mg/kg bw/d | N | na | ADL | M | DR | 15 | w | 62 | d | LC | F | C | Lab | GRO | GRO | BDWT | WO | 1.33 | 6.80 | Y | 0.3707 | Y | 0.02921 | 1.33 | 6.80 | 10 | 5 | 10 | 10 | 10 | 8 | 8 | 10 | 10 | 4 | 85 |
| 81 | 19729 | Szakmary et al, 1995 | Nickelous chloride | 45.29 | Rat (*Rattus norvegicus*) | 2 | 0/3 | mg/kg bw/d | N | na | DLY | U | GV | 8 | d | NR | NR | GE | F | C | Lab | GRO | GRO | BDWT | WO | 3 | | Y | 0.263 | N | 0.02292 | 1.36 | | 10 | 8 | 10 | 10 | 10 | 8 | 4 | 10 | 10 | 4 | 84 |
| 82 | 19666 | Spears and Hatfield, 1985 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/15/225 | mg/kg diet | N | na | ADL | U | FD | 21 | d | NR | NR | JV | M | C | Lab | GRO | GRO | BDWT | WO | 15 | 225 | Y | 0.137 | N | 0.01341 | 1.47 | 22.0 | 10 | 10 | 5 | 10 | 6 | 8 | 6 | 10 | 10 | 4 | 79 |
| 83 | 14477 | O'Dell et al, 1970 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 4 | 0/62.5/250/1000 | mg/kg diet | N | na | DLY | U | FD | 8 | w | 14 | w | JV | M | C | Lab | GRO | GRO | BDWT | WO | 250 | 1000 | Y | 180.08 | Y | 1.180 | 1.64 | 6.55 | 10 | 10 | 5 | 10 | 7 | 8 | 8 | 10 | 10 | 4 | 82 |
| 84 | 19109 | Cikrt et al, 1992 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/1.18 | mg/org/d | N | na | ADL | U | DR | 90 | d | NR | NR | JV | F | C | Lab | GRO | GRO | BDWT | WO | 1.18 | | Y | 0.3978 | N | 0.04319 | 2.97 | | 10 | 5 | 5 | 10 | 7 | 8 | 4 | 10 | 10 | 4 | 73 |
| 85 | 19479 | Nielsen, 1980 | Nickel chloride trihydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | DLY | U | FD | 10 | w | NR | NR | JV | F | C | Lab | GRO | GRO | BDWT | WO | 50 | | N | 0.204 | N | 0.0186 | 4.56 | | 10 | 10 | 5 | 10 | 5 | 8 | 4 | 1 | 10 | 4 | 67 |
| 86 | 19461 | Nielsen et al, 1979 | Nickel chloride trihydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | DLY | U | FD | 9 | w | 21 | d | JV | F | C | Lab | GRO | GRO | BDWT | WO | 50.00 | | N | 0.204 | N | 0.0186 | 4.56 | | 10 | 10 | 5 | 10 | 5 | 8 | 4 | 1 | 10 | 4 | 67 |
| 87 | 14484 | Schroeder et al, 1974 | Nickel | 100 | Rat (*Rattus norvegicus*) | 2 | 0/5.44 | mg/kg bw/d | N | na | DLY | M | DR | 1217 | d | 30 | d | JV | B | C | Lab | GRO | GRO | BDWT | WO | 5.44 | | Y | 0.397 | Y | 0.02779 | 5.44 | | 10 | 5 | 10 | 4 | 10 | 8 | 4 | 10 | 10 | 4 | 75 |
| 88 | 136 | Gershbein et al 1983 | Nickelous chloride | 100 | Rat (*Rattus norvegicus*) | 2 | 0/75 | mg/kg diet | N | na | ADL | U | FD | 80 | d | 44 | d | JV | M | C | Lab | GRO | GRO | BDWT | WO | 75 | | Y | 0.4700 | N | 0.03693 | 5.89 | | 10 | 10 | 5 | 10 | 6 | 8 | 4 | 1 | 10 | 4 | 68 |
| 89 | 14476 | ODell et al, 1970 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 3 | 0/365/1835 | mg/org/d | N | na | 1 per d | U | FD | 6 | w | NR | NR | LC | F | C | NR | GRO | GRO | BDWT | WO | 1835 | | N | 272 | Y | 7.350 | 6.75 | | 10 | 10 | 5 | 10 | 6 | 8 | 4 | 1 | 10 | 4 | 68 |
| 90 | 14479 | O'Dell et al, 1971 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 4 | 0/1.8/7.0/14.6 | mg/kg bw/d | N | na | DLY | UX | FD | 8 | w | 13-21 | w | JV | M | C | NR | GRO | GRO | BDWT | WO | 7.00 | 14.6 | Y | 183.8 | Y | 5.100 | 7.00 | 14.6 | 10 | 10 | 10 | 10 | 10 | 8 | 10 | 10 | 10 | 4 | 92 |
| 91 | 19514 | Oosting et al, 1991 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 3 | 0/49.5/104.9 | mg/kg diet | N | na | ADL | M | FD | 28 | d | 31 | d | JV | M | C | Lab | GRO | GRO | BDWT | WO | 105 | | N | 0.217 | Y | 0.0161 | 7.78 | | 10 | 10 | 10 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 82 |
| 92 | 14474 | Ambrose et al, 1976 | Nickel sulfate hexahydrate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/100/1000/2500 | mg/kg diet | N | na | ADL | U | FD | 6 | w | 28 | d | JV | B | C | Lab | GRO | GRO | BDWT | WO | 100 | 1000 | Y | 0.205 | N | 0.0187 | 9.11 | 91.1 | 10 | 10 | 5 | 10 | 6 | 8 | 8 | 10 | 10 | 4 | 81 |
| 93 | 14480 | Phatak and Patwardhan, 1950 | Nickel carbonate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/.25/.5/1 | mg/g diet | N | na | ADL | U | FD | 8 | w | 4 | w | JV | B | C | Lab | GRO | GRO | BDWT | WO | 1.00 | | Y | 0.115 | Y | 0.001070 | 9.30 | | 10 | 10 | 5 | 10 | 7 | 8 | 4 | 1 | 10 | 4 | 69 |
| 94 | 63 | Whanger, 1973 | Nickel acetate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/100/500/1000 | mg/kg diet | N | na | DLY | U | FD | 6 | w | 35 | d | JV | NR | C | Lab | GRO | GRO | BDWT | WO | 100 | 500 | Y | 0.163 | N | 0.01547 | 9.49 | 47.4 | 10 | 10 | 5 | 5 | 6 | 8 | 8 | 10 | 10 | 4 | 76 |
| 95 | 19293 | Kakela et al, 1999 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/30/100 | mg/L | N | na | ADL | U | DR | 62 | d | 3.5-9 | mo | GE | F | C | Lab | GRO | GRO | BDWT | WO | 100 | | Y | 0.2357 | N | 0.02696 | 11.4 | | 10 | 5 | 5 | 10 | 6 | 8 | 4 | 8 | 10 | 4 | 70 |
| 96 | 19507 | Obone et al, 1999 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/44.7/111.75/223.5 | mg/L | N | na | ADL | U | DR | 13 | w | NR | NR | JV | M | C | Lab | GRO | GRO | BDWT | WO | 112 | 224 | Y | 0.575 | N | 0.0602 | 11.7 | 23.4 | 10 | 5 | 5 | 10 | 6 | 8 | 10 | 10 | 10 | 4 | 78 |
| 97 | 36694 | Alexander et al, 1978 | Nickel chloride hexahydrate | 100 | Meadow vole (*Microtus pennsylvanicus*) | 3 | 0/18/100 | mg/kg diet | N | na | ADL | U | FD | 45 | d | 14 | d | JV | NR | C | Lab | GRO | GRO | BDWT | WO | 100 | | Y | 0.0349 | N | 0.0043567 | 12.5 | | 10 | 10 | 5 | 10 | 6 | 8 | 4 | 1 | 10 | 4 | 68 |
| 98 | 19460 | Nation et al, 1985 | Nickel Chloride | 100 | Rat (*Rattus norvegicus*) | 3 | 0/10/20 | mg/kg bw/d | N | na | DLY | U | FD | 14 | d | 80 | d | JV | M | C | Lab | GRO | GRO | BDWT | WO | 20.0 | | Y | 0.1867 | N | 0.0173 | 20.0 | | 10 | 10 | 5 | 10 | 10 | 8 | 4 | 1 | 10 | 4 | 72 |
| 99 | 36694 | Alexander et al, 1978 | Nickel chloride hexahydrate | 100 | Meadow vole (*Microtus pennsylvanicus*) | 4 | 0/21/187/1968 | mg/kg diet | N | na | ADL | M | FD | 49 | d | 14 | d | JV | NR | C | Lab | GRO | GRO | BDWT | WO | 187 | 1968 | Y | 0.035 | Y | 0.0055 | 29.4 | 309 | 10 | 10 | 10 | 10 | 7 | 8 | 6 | 10 | 10 | 4 | 85 |
| 100 | 14474 | Ambrose et al, 1976 | Nickel sulfate hexahydrate | 100 | Dog (*Canis familiaris*) | 4 | 0/100/1000/2500 | mg/kg diet | N | na | 1 per d | U | FD | 65 | w | 6 | mo | JV | B | C | Lab | GRO | GRO | BDWT | WO | 1000 | 2500 | N | 10.8 | N | 0.4858 | 45.0 | 112 | 10 | 10 | 5 | 10 | 5 | 8 | 10 | 10 | 10 | 4 | 82 |
| 101 | 1260 | Chernoff and Kavlock, 1982 | Nickel chloride | 45.29 | Mouse (*Mus musculus*) | 2 | 0/100 | mg/kg bw/d | N | na | DLY | U | GV | 5 | d | 60 | d | GE | F | C | Lab | GRO | GRO | BDWT | WO | 100 | | N | 0.0225 | N | 0.00001 | 45.3 | | 10 | 8 | 10 | 10 | 10 | 8 | 4 | 1 | 10 | 4 | 82 |
| 102 | 19064 | Berman and Rehnberg, 1983 | Nickel chloride | 100 | Mouse (*Mus musculus*) | 3 | 0/85.3/170.7 | mg/kg bw/d | N | na | ADL | U | DR | 15 | d | NR | NR | GE | F | C | Lab | GRO | GRO | BDWT | WO | 85.3 | 170.7 | Y | 0.0297 | Y | 5.387 | 85.3 | 171 | 10 | 5 | 5 | 10 | 7 | 8 | 10 | 10 | 10 | 4 | 79 |
| 103 | 61 | Dieter et al, 1988 | Nickel sulfate | 37.4 | Mouse (*Mus musculus*) | 4 | 0/115.7/285.7/395.7 | mg/kg bw/d | N | na | ADL | UX | DR | 180 | d | 6-8 | w | JV | F | C | Lab | GRO | GRO | BDWT | WO | 286 | 396 | Y | 0.028 | Y | 0.0016 | 107 | 148 | 10 | 5 | 10 | 10 | 7 | 8 | 10 | 10 | 10 | 4 | 84 |
| 104 | 19666 | Spears and Hatfield, 1985 | Nickel chloride hexahydrate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/30 | mg/kg diet | N | na | ADL | U | FD | 21 | d | NR | NR | JV | M | C | Lab | GRO | GRO | BDWT | WO | | 30 | Y | 0.175 | N | 0.01640 | | 2.81 | 10 | 10 | 5 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 77 |
| 105 | 19514 | Oosting et al, 1991 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 2 | 0/100 | mg/kg diet | N | na | ADL | M | FD | 28 | d | 31 | d | JV | M | C | Lab | GRO | GRO | BDWT | WO | | 100 | N | 0.217 | Y | 0.0178 | | 8.20 | 10 | 10 | 10 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 82 |
| 106 | 19111 | Clary, 1975 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 2 | 0/225 | mg/L | N | na | ADL | U | DR | 4 | mo | NR | NR | JV | M | C | Lab | GRO | GRO | BDWT | WO | | 225 | Y | 0.356 | N | 0.03908 | | 24.7 | 10 | 5 | 5 | 10 | 6 | 8 | 4 | 10 | 10 | 4 | 72 |
| 107 | 14485 | Weber and Reid, 1969 | Nickel acetate | 100 | Mouse (*Mus musculus*) | 3 | 0/4.143/6.143 | mg/org/d | N | na | ADL | U | FD | 4 | w | NR | NR | JV | F | C | Lab | GRO | GRO | BDWT | WO | | 4.143 | Y | 0.0199 | Y | 0.003780 | | 208 | 10 | 10 | 5 | 5 | 7 | 8 | 4 | 10 | 10 | 4 | 73 |
| **Survival** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 108 | 19521 | Pandey et al, 1999 | Nickel sulfate | 37.94 | Mouse (*Mus musculus*) | 3 | 0/3.57/7.14 | mg/kg bw/d | N | na | 5 per w | U | GV | 35 | d | NR | NR | JV | M | C | Lab | MOR | MOR | MORT | WO | 7.14 | | Y | 0.025 | N | 0.00331 | 2.71 | | 10 | 8 | 10 | 10 | 10 | 9 | 4 | 10 | 10 | 4 | 85 |
| 109 | 19483 | Nielsen et al 1982 | Nickel chloride trihydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | ADL | U | FD | 11 | w | NR | NR | JV | F | C | Lab | MOR | MOR | MORT | WO | 50.0 | | N | 0.204 | N | 0.0186 | 4.56 | | 10 | 10 | 5 | 10 | 5 | 9 | 4 | 10 | 10 | 4 | 77 |

| Ref | | | Exposure | | | | | | | | | | | | | | | | | | | Effects | | | | | Conversion to mg/kg bw/day | | | | | Result | | Data Evaluation Score | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Result # | Ref N. | Reference | Chemical Form | MW% | Test Species | # 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 |
| 110 | 36722 | Pandey and Srivastava, 2000 | Nickel sulfate | 37.93 | Mouse (*Mus musculus*) | 4 | 0/3.57/7.14/14.29 | mg/kg bw/d | N | na | 5 per w | U | OR | 35 | d | NR | NR | JV | M | C | Lab | MOR | MOR | MORT | WO | 14.29 | | Y | 0.025 | N | 0.00331 | 5.42 | | 10 | 8 | 10 | 10 | 10 | 9 | 4 | 10 | 10 | 4 | 85 |
| 111 | 36722 | Pandey and Srivastava, 2000 | Nickelous chloride | 45.29 | Mouse (*Mus musculus*) | 4 | 0/3.57/7.14/14.29 | mg/kg bw/d | N | na | 5 per w | U | OR | 35 | d | NR | NR | JV | M | C | Lab | MOR | MOR | MORT | WO | 14.29 | | Y | 0.025 | N | 0.00331 | 6.47 | | 10 | 8 | 10 | 10 | 10 | 9 | 4 | 10 | 10 | 4 | 85 |
| 112 | 36694 | Alexander et al, 1978 | Nickel chloride hexahydrate | 100 | Meadow vole (*Microtus pennsylvanicus*) | 4 | 0/21/187/1968 | mg/kg diet | N | na | ADL | M | FD | 14 | d | 14 | d | JV | NR | C | Lab | MOR | MOR | MORT | WO | 187 | 1968 | Y | 0.035 | Y | 0.0055 | 29.4 | 309 | 10 | 10 | 10 | 10 | 7 | 9 | 6 | 10 | 10 | 4 | 86 |
| 113 | 1260 | Chernoff and Kavlock, 1982 | Nickel chloride | 45.29 | Mouse (*Mus musculus*) | 2 | 0/100 | mg/kg bw/d | N | na | DLY | U | GV | 5 | d | 60 | d | GE | F | C | Lab | MOR | MOR | MORT | WO | 100 | | N | 0.0225 | N | 0.00304 | 45.3 | | 10 | 8 | 10 | 10 | 10 | 9 | 4 | 1 | 10 | 4 | 76 |
| 114 | 113 | Seidenberg et al, 1986 | Nickelous chloride | 45.29 | Mouse (*Mus musculus*) | 2 | 0/200 | mg/kg/bw/d | N | na | DLY | U | GV | 4 | d | NR | NR | GE | F | C | Lab | MOR | MOR | MORT | WO | 200 | | Y | 0.0392 | N | 0.00479 | 90.6 | | 10 | 8 | 10 | 10 | 10 | 9 | 4 | 10 | 10 | 4 | 85 |
| 115 | 14474 | Ambrose et al, 1976 | Nickel sulfate hexahydrate | 100 | Dog (*Canis familiaris*) | 4 | 0/100/1000/2500 | mg/kg diet | N | na | 1 per d | U | FD | 24 | mo | 6 | mo | JV | B | C | Lab | MOR | MOR | MORT | WO | 2500 | | N | 10.8 | N | 0.4858 | 112 | | 10 | 10 | 5 | 10 | 5 | 9 | 4 | 10 | 10 | 4 | 77 |
| 116 | 36331 | Cempel and Janicka, 2002 | Nickel chloride hexahydrate | 100 | Rat (Rattus norvegicus) | 3 | 0/7.9/29.0 | mg/org/d | N | na | ADL | U | DR | 90 | d | NR | NR | JV | M | C | Lab | MOR | MOR | MORT | WO | 29 | | Y | 0.21 | Y | 0.0000242 | 138 | | 10 | 5 | 5 | 10 | 7 | 9 | 4 | 10 | 10 | 4 | 74 |
| 117 | 14474 | Ambrose et al, 1976 | Nickel sulfate hexahydrate | 100 | Rat (*Rattus norvegicus*) | 4 | 0/100/1000/2500 | mg/kg diet | N | na | ADL | U | FD | 24 | mo | 28 | d | JV | B | C | Lab | MOR | MOR | MORT | WO | 2500 | | Y | 0.367 | N | 0.0301 | 205 | | 10 | 10 | 5 | 10 | 6 | 9 | 4 | 10 | 10 | 4 | 78 |
| 118 | 14447 | Schroeder et al, 1964 | Divalent Nickel | 100 | Mouse (*Mus musculus*) | 2 | 0/5 | mg/L | N | na | DLY | U | DR | 16 | mo | 21 | d | JV | B | C | Lab | MOR | MOR | SURV | WO | | 5.00 | N | 0.0375 | Y | 0.0047 | | 0.62 | 10 | 5 | 5 | 10 | 6 | 9 | 4 | 10 | 10 | 4 | 73 |
| 119 | 1858 | Schroeder and Mitchener, 1975 | Nickelous acetate | 100 | Mouse (*Mus musculus*) | 2 | 0/5 | mg/L | N | na | NR | U | DR | 520 | d | 19-20 | d | AD | F | C | Lab | MOR | MOR | LFSP | WO | | 5.00 | Y | 0.025 | N | 0.003579 | | 0.716 | 10 | 5 | 5 | 5 | 6 | 9 | 4 | 10 | 10 | 4 | 68 |
| **Data Not Used to Derive TRV** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 120 | 19787 | Vyskocil et al, 1994 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/6.25 | mg/kg bw/d | N | na | ADL | U | DR | 6 | mo | 10 | w | JV | M | C | Lab | GRO | GRO | BDWT | WO | 6.25 | | Y | 0.5 | Y | 0.03120 | 6.25 | | 10 | 5 | 5 | 10 | 7 | 8 | 4 | 1 | 10 | 4 | 64 |
| 121 | 1858 | Schroeder and Mitchener, 1975 | Nickelous acetate | 100 | Mouse (*Mus musculus*) | 2 | 0/5 | mg/L | N | na | NR | U | DR | 520 | d | 19-20 | d | JV | F | C | Lab | GRO | GRO | BDWT | WO | 5.00 | | Y | 0.0428 | N | 0.005807 | 0.678 | | 10 | 5 | 5 | 5 | 6 | 8 | 4 | 6 | 10 | 4 | 63 |
| 122 | 19461 | Nielsen et al, 1979 | Nickel chloride trihydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | DLY | U | FD | 9 | w | 21 | d | JV | F | C | Lab | PTH | ORW | SMIX | LI | 50.0 | | N | 0.204 | N | 0.0186 | 4.56 | | 10 | 10 | 5 | 10 | 5 | 4 | 4 | 1 | 10 | 4 | 63 |
| 123 | 19483 | Nielsen et al 1982 | Nickel chloride trihydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | ADL | U | FD | 11 | w | NR | NR | JV | F | C | Lab | BIO | CHM | LIPD | PL | 50.0 | | N | 0.204 | N | 0.0186 | 4.56 | | 10 | 10 | 5 | 10 | 5 | 1 | 4 | 1 | 10 | 4 | 60 |
| 124 | 19479 | Nielsen, 1980 | Nickel chloride trihydrate | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | DLY | U | FD | 10 | w | NR | NR | JV | F | C | Lab | BIO | CHM | HMCT | BL | 50 | | N | 0.204 | N | 0.0186 | 4.56 | | 10 | 10 | 5 | 10 | 5 | 1 | 4 | 1 | 10 | 4 | 60 |
| 125 | 15690 | Nielsen et al, 1980 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 3 | 0/5/50 | ug/g diet | N | na | DLY | U | FD | 10 | w | NR | NR | JV | F | C | Lab | BIO | CHM | HMGL | BL | 50.00 | | N | 0.2024 | N | 0.018478 | 4.56 | | 10 | 10 | 5 | 10 | 5 | 1 | 4 | 1 | 10 | 4 | 60 |
| 126 | 136 | Gershbein et al, 1983 | Nickelous chloride | 100 | Rat (*Rattus norvegicus*) | 2 | 0/75 | mg/kg diet | N | na | ADL | U | FD | 80 | d | 44 | d | JV | M | C | Lab | PTH | HIS | GHIS | MT | 75 | | Y | 0.4700 | N | 0.03693 | 5.89 | | 10 | 10 | 5 | 10 | 6 | 4 | 4 | 1 | 10 | 4 | 64 |
| 127 | 14476 | ODell et al, 1970 | Nickelous carbonate | 100 | Cattle (*Bos taurus*) | 3 | 0/365/1835 | mg/org/d | N | na | 1 per d | U | FD | 6 | w | NR | NR | LC | F | C | NR | BEH | FDB | FCNS | WO | 1835 | | N | 272 | Y | 7.300 | 6.75 | | 10 | 10 | 5 | 10 | 6 | 4 | 4 | 1 | 10 | 4 | 64 |
| 128 | 36732 | Tomokuni and Ichiba, 1990 | Nickel nitrate hexahydrate | 100 | Mouse (*Mus musculus*) | 2 | 0/57 | mg/L | N | na | ADL | U | DR | 12 | d | NR | NR | JV | M | C | Lab | BIO | ENZ | ALAD | BL | 57 | | Y | 0.045 | N | 0.00607 | 7.69 | | 10 | 5 | 5 | 10 | 6 | 1 | 4 | 1 | 10 | 4 | 56 |
| 129 | 19496 | Novelli et al, 1998 | Nickel sulfate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/2.97 | mg/org/d | N | na | ADL | U | DR | 2 | mo | 15 | w | JV | M | C | Lab | BEH | FDB | WCON | WO | 2.97 | | Y | 0.2 | Y | 0.0238 | 12.5 | | 10 | 5 | 5 | 10 | 7 | 4 | 4 | 3 | 10 | 4 | 62 |
| 130 | 14481 | Phatak and Patwardhan, 1952 | Nickel | 100 | Rat (*Rattus norvegicus*) | 2 | 0/250 | mg/kg diet | N | na | DLY | U | FD | 60 | w | 5 | w | JV | B | C | Lab | GRO | GRO | BDWT | WO | 250 | | Y | 0.25 | N | 0.021982 | 22.0 | | 10 | 10 | 5 | 4 | 6 | 8 | 4 | 1 | 10 | 4 | 62 |
| 131 | 659 | Eakin et al, 1980 | Nickel acetate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/500 | mg/kg diet | N | na | ADL | U | FD | 16 | w | NR | NR | JV | F | C | Lab | GRO | GRO | BDWT | WO | 500 | | Y | 0.325 | N | 0.02727 | 42.0 | | 10 | 10 | 5 | 5 | 6 | 8 | 4 | 1 | 10 | 4 | 63 |
| 132 | 659 | Eakin et al, 1980 | Nickel acetate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/500 | mg/kg diet | N | na | ADL | U | FD | 16 | w | NR | NR | JV | M | C | Lab | PHY | PHY | BLPR | WO | 500 | | Y | 0.325 | N | 0.02727 | 42.0 | | 10 | 10 | 5 | 5 | 6 | 4 | 4 | 1 | 10 | 4 | 59 |
| 133 | 659 | Eakin et al, 1980 | Nickel acetate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/500 | mg/kg diet | N | na | ADL | U | FD | 16 | w | NR | NR | JV | M | C | Lab | BIO | CHM | GBCM | PL | 500 | | Y | 0.325 | N | 0.02727 | 42.0 | | 10 | 10 | 5 | 5 | 6 | 1 | 4 | 1 | 10 | 4 | 56 |
| 134 | 14485 | Weber and Reid, 1969 | Nickel acetate | 100 | Mouse (*Mus musculus*) | 3 | 0/4.143/6.143 | mg/org/d | N | na | ADL | U | FD | 4 | w | NR | NR | JV | B | C | Lab | PHY | PHY | DIFD | FC | 6.143 | | Y | 0.0184 | Y | 0.003730 | 334 | | 10 | 10 | 5 | 5 | 7 | 4 | 4 | 1 | 10 | 4 | 60 |
| 135 | 15506 | Schroeder, 1968 | Nickelous acetate | 100 | Rat (*Rattus norvegicus*) | 2 | 0/3.764 | mg/kg bw/d | N | na | ADL | U | DR | 306 | d | 21-23 | d | JV | F | C | Lab | BIO | CHM | CHOL | SR | | 3.76 | N | 0.51 | N | 0.054007 | | 3.76 | 10 | 5 | 5 | 5 | 10 | 1 | 4 | 10 | 10 | 4 | 64 |
| 136 | 19500 | Novelli et al, 1994 | Nickel monosulfide | 100 | Rat (*Rattus norvegicus*) | 2 | 0/21.2 | mg/kg bw/d | N | na | ADL | U | DR | 7 | d | 15 | mo | AD | M | C | Lab | BIO | ENZ | ALPH | SR | | 200 | N | 0.5 | N | 0.0531 | | 21.2 | 10 | 5 | 5 | 10 | 5 | 1 | 4 | 10 | 3 | 4 | 57 |
| 137 | 19111 | Clary, 1975 | Nickel chloride | 100 | Rat (*Rattus norvegicus*) | 2 | 0/225 | mg/L | N | na | ADL | U | DR | 4 | mo | NR | NR | JV | M | C | Lab | BIO | CHM | CHOL | SR | | 225 | Y | 0.356 | N | 0.03908 | | 24.7 | 10 | 5 | 5 | 10 | 6 | 1 | 4 | 10 | 10 | 4 | 65 |

All abbreviations and definitions are used in coding stuides are available from Attachment 4-3 of the Eco-SSL guidance (U.S. EPA 2003).

Duplicate values for NOAELs and LOAELs for the same reference represent results from different experimental designs.