Supplementary Non-Radiological Interim Acceptance Criteria for the Protection of Persons and the Environment

NWMO-TR-2017-05 June 2019

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Canada North Environmental Services

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ABSTRACT

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Abstract
The purpose of this report is to present interim acceptance criteria for a specific subset of elements based on the protection of persons and the environment to be used for the postclosure non-radiological release from a used fuel deep geological repository. These criteria were derived based on the available toxicity data and existing jurisdictional values compiled from a literature search. Effort was made to derive appropriate values for each media and element; however, there are some residual gaps and the criteria provided are associated with varying levels of uncertainty.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

1. INTRODUCTION

This document presents interim acceptance criteria for a specific subset of elements based on the protection of persons and the environment to be used for the postclosure non-radiological release from a used fuel deep geological repository. These criteria were derived based on the available toxicity data and existing jurisdictional values compiled from a literature search. Effort was made to derive appropriate values for each media and element; however, there are some residual gaps and the criteria provided are associated with varying levels of uncertainty.

2. SCOPE OF WORK

Medri (2015) completed a review of interim non-radiological acceptance criteria for the protection of persons and the environment due to potential non-radiological exposure to releases from a deep geological repository for used nuclear fuel. The document compiled criteria for surface water, groundwater, soil, sediment, and air for all relevant elements in a used fuel repository, based on Canadian Federal and Provincial guidelines supplemented as required by internationally developed guidelines. However, a specific subset of elements are missing from Medri (2015)'s compilation. Thus, the purpose of the current assessment is to develop criteria for the missing elements in various media through the review of available literature.

The fact that criteria in various environmental media were not found for some elements of interest in the previous report suggests a lack of available data. Therefore, multiple lines of evidence and approaches were considered in the current assessment in order to develop criteria for the missing elements.

2.1 ELEMENT IDENTIFICATION

The elements of interest associated with releases from a deep geological repository for CANDU used nuclear fuel which presently have insufficient criteria are identified in Table 2-1. Interim acceptance criteria specified in Medri (2015) are also provided in the table; media and elements requiring guideline derivation are indicated with shading.

Table 2-1: Summary of Interim Acceptance Criteria and Elements for Guideline Derivation

Element	Surface Water (µg/L)	Groundwater (µg/L)	Soil (µg/g)	Sediment (µg/g)	Air (µg/m^3)
Gold					
Bismuth			20		100
Bromine			10		20
Iodine	100		4		0.67
Indium					
Iridium					
Osmium					
Palladium					
Platinum					0.2
Rhodium					
Ruthenium					
Tellurium			250		10
Tungsten	30		400		67

Notes: Values from Medri (2015). Shading indicates guideline requiring development.

2.2 JURISDICTIONAL REVIEW

Medri (2015) completed a jurisdictional review for the elements of interest. The following additional jurisdictions were considered for acceptable criteria for the missing elements of interest:

- **Environment and Climate Change Canada (ECCC 2013):**
  Database of Environmental Quality Guidelines: a database of guidelines for chemicals in various media from multiple national and international jurisdictions was developed to facilitate screening and remediation processes for federal contaminated sites.
  - Surface water guideline for bromine

- **Texas Commission on Environmental Quality (TCEQ 2014):**
  Conducting Ecological Risk Assessments at Remediation Sites in Texas.
  - No additional guidelines

- **Texas Commission on Environmental Quality (TCEQ 2016):**
  Effects Screening Levels Used in the Review of Air Permitting Data. November.
  - Air quality guideline for gold, indium, osmium, palladium, rhodium, ruthenium

- **Savannah River National Laboratory (SRNL 2005):**
  Ecological Screening Values for Surface Water, Sediment, and Soil: provides a comprehensive listing of ecological screening values for surface water, sediment, and soil.
  - Sediment quality guideline for bromine

- **European Chemicals Agency (ECHA 2003):**
  Chemical Registration Dossiers: Probable No Effects Concentrations (PNECs) derived for the protection of the environment, as described in the risk assessment protocol.
    - Surface water quality guideline for bismuth, palladium, tellurium
    - Soil quality guideline for palladium
    - Sediment quality guideline for bismuth, iodine, palladium, tungsten

2.3 LITERATURE REVIEW METHODOLOGY AND SOURCES

In order to assess the toxicological properties of the missing elements of interest, the available toxicity data were compiled through a comprehensive literature search. A search was completed on February 10, 2017 using the ECOTOX database (U.S. EPA 2017) to identify aquatic and soil toxicity studies available in the literature. An additional search was completed on April 24, 2019 to identify any additional toxicity studies published since 2017. The TOXNET search engine was also used to search numerous databases on toxicology, hazardous chemicals, environmental health, and toxic releases including US EPA Integrated Risk Information System (IRIS), Hazardous Substances Data Bank (HSDB), and International Toxicity Estimates for Risk (ITER) to identify available human, aquatic, and soil toxicity studies as well as information regarding the environmental fate of the elements of interest. For elements lacking in data from these searches, a further literature search was conducted on March 15, 2017 and May 1, 2019. Science Direct and NCBI/PubMed were used to identify additional studies for the aquatic and terrestrial environment. Relevant references from toxicity studies were identified to populate the datasets for the elements of interest.

Several types of compounds were excluded from the toxicity datasets, including nanoparticles, amines or other ammonium containing compounds (such as ammonium tetrachloropalladate(II)), Ruthenium Red, and other organic compounds since the chemistry of these compounds are less likely to be the dominant species in soil, sediment, surface water or groundwater. The focus of this assessment is on the more environmentally relevant, soluble inorganic compounds and their associated salts (e.g., chlorides, sulphates and hydrates).

The World Health Organization (WHO) prepared Environmental Health Criteria documents for palladium (WHO 2002) and platinum (WHO 1991); these data were compiled herein. Since palladium and platinum are members of the Platinum Group Elements (PGE), they may act as surrogates for other members of the PGE such as osmium, ruthenium, rhodium, and iridium. Thus, literature references in papers relating to palladium and platinum were reviewed to determine if there were any relevant papers for other members of the PGE.

The studies identified through the literature review were scored and evaluated using evaluation forms (Appendix A.1 and A.2) and the applicable data were summarized (Appendix B.1 and B.2). Details on the data evaluation and scoring process are provided in the following section. Additional toxicity testing was completed by AquaTox Testing and Consulting (AquaTox) on behalf of NWMO to supplement the toxicity data available from the literature review and increase the confidence in the derived guidelines for rhodium and ruthenium. Tests were completed for chronic toxicity to the aquatic invertebrate species *Ceriodaphnia dubia* and *Hyalella azteca* and the fish species *Oncorhynchus mykiss* and *Pimephales promelas* (Appendix C.1), as well as terrestrial plants (alfalfa and barley) and earthworms (Appendix C.2).

2.4 DATA EVALUATION AND SCORING PROCEDURE

Figure 2-1 provides an overview of the data evaluation and scoring procedure selected for the current review. Any documents developed by the WHO were considered automatically acceptable, since environmental health criteria documents prepared by WHO through the International Programme on Chemical Safety are critical reviews completed with quality criteria consistent with this current review. Studies obtained from other sources, such as ECOTOX or Science Direct, were evaluated and scored for inclusion in the datasets for the elements of interest.

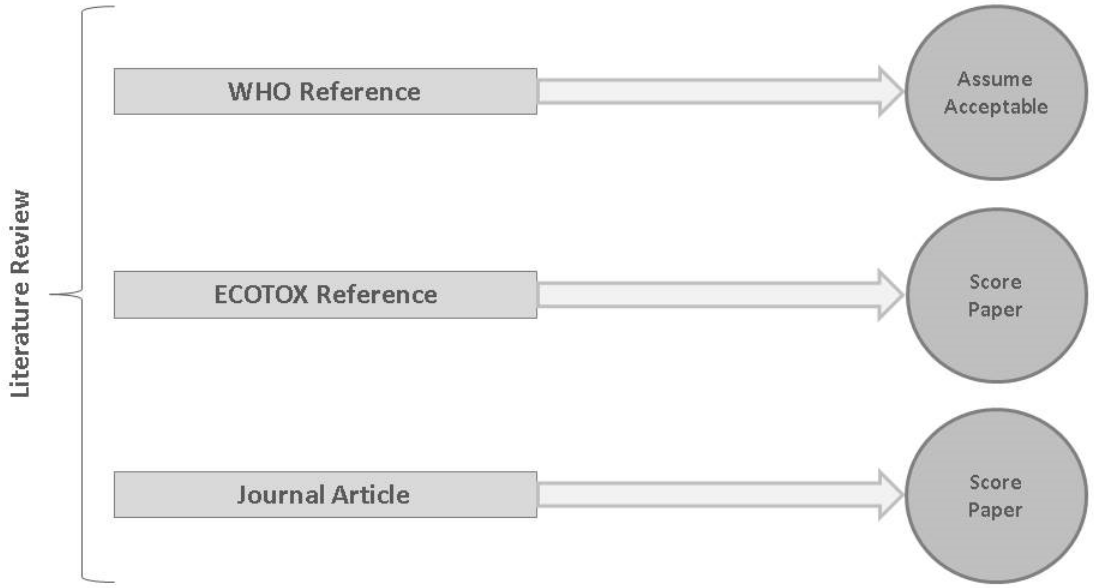

Figure 2-1: Overview of Data Evaluation Methodology

The following sections provide a detail on the data evaluation of the studies compiled for the aquatic and terrestrial toxicity datasets.

2.4.1 Aquatic Toxicity Studies

Studies obtained through ECOTOX (U.S. EPA) or other literature sources were evaluated and scored, as summarized in Appendix A.1. CCME (2007) provides guidance for the evaluation and categorization of the available aquatic toxicological data as primary, secondary or unacceptable based on suitability, usefulness, and reliability, with the allowance for special consideration on a case-by-case basis and the incorporation of scientific judgement. The following information from CCME (2007) was considered in the evaluation process:

- test conditions/design (e.g., flow-through, renewal, static, single species study, community study, mesocosm, etc.)
- test concentrations
- solubility limit of substance in relation of tested concentrations
- experimental design (i.e., analytical methodology, quality control/ quality assurance, controls, and number of replicates); and,
- description of statistics used in evaluating the data.

The datasets for the elements of interest for this study were not extensive. Therefore, the CCME (2007) guidance was generally followed with some accommodations and modifications made to the scoring approach to allow for the derivation of guidelines from the available data. This increases the uncertainty associated with the derived guidelines. Consistent with CCME (2007) guidance, a “primary” ranking was only assigned to studies with reported measured concentrations. All other studies were ranked “secondary” unless control results or reported endpoints were unacceptable (for example an LC100).

The 22 aquatic toxicity studies identified for the elements of interest in this study are provided in Appendix A.1. Only one study (Zimmerman et al. 2017) was given a primary ranking; this was a recent study that reported measured concentrations and completed the study under standard test procedures. Thirteen studies were given secondary ranking since they generally only reported nominal concentrations but provided appropriate controls and, in some cases, endpoints. One study (Harry and Aldrich 1983) was reported in U.S EPA ECOTOX; however, the paper could not be obtained. Given the general paucity of the datasets, this study was not excluded and was given an assumed secondary ranking. Three studies (Bengtsson and Tarkpea 1983, Jones 1939, and Vannini et al. 2011) were given an unacceptable ranking due to the fact that there were no measured data and no dose-response information. Four studies on platinum (Osterauer et al. 2009, 2010a, 2010b, 2011) were not considered for the dataset due to unacceptable endpoints; however, results from Osterauer et al. (2009) were included in the discussion for context for the guidelines.

The compiled aquatic dataset comprises toxicity data for fish, planktonic and benthic aquatic invertebrates, as well as aquatic plants. Overall, toxicity data for fish species were only identified for gold and platinum; no toxicity data for fish were available for other elements of interest in the compiled aquatic toxicity dataset. In addition, there were no chronic endpoints available for a number of the elements of interest in this review. This increases the uncertainty associated with the derived guidelines. Toxicity testing completed by Aquatox provided additional chronic endpoints for an invertebrate (*Ceriodaphnia dubia*) and fish (*Oncorhynchus mykiss* and *Pimephales promelas*) species for rhodium and ruthenium. These tests were given a “primary” ranking.

2.4.2 Terrestrial Toxicity Studies

Studies obtained for terrestrial toxicity through ECOTOX (U.S. EPA) or other literature sources were evaluated, scored, and summarized for consideration in the derivation of the Soil Quality Guidelines, as summarized in Appendix A.2. All terrestrial plant, animal, and soil invertebrate studies were considered, however, the majority of available data were toxicity studies completed on laboratory animals. Generally, CCME (2006) guidance for evaluation and categorization of laboratory toxicological data was followed. Consistent with CCME (2006) guidance, data were screened according to whether they were considered “acceptable” (selected) or “unacceptable” (consulted) for deriving soil quality guidelines.

The 14 terrestrial toxicity studies identified for the elements of interest in this study were scored and evaluated as shown in Appendix A.2. Five studies were given an “acceptable” ranking and were considered for the derivation of soil quality guidelines. The exposure pathways for these tests were either by oral ingestion or by external exposure to soil, and reported acceptable endpoints. Studies that administered the element intraperitoneally or intravenously were given an automatic scoring of “unacceptable”, since the CCME (2006) only uses the oral pathway for

the derivation of soil quality guidelines. The study completed by Schertzinger et al. (2017) was scored as “unacceptable”, since the data reported were not directly applicable, but used for additional context for the derived guidelines. A study (Speranza et al. 2010) associated with a 90-minute exposure duration for kiwi fruit pollen to water was designated as “unacceptable” since it is not relevant for deriving soil quality guidelines or for consideration of agricultural uses. Egorova et al. (2019) studied the phytotoxic effects of metals, including rhodium and palladium, on several terrestrial plant species, using aqueous solutions for the growth medium. This study was considered “unacceptable” for consideration of soil guidelines due to the growth medium and was not relevant for general consideration since the concentrations tested were designed for simulating an accidental spillage and were not environmentally relevant. Mello-Andrade et al. (2018) was also considered “unacceptable”, since it reported on the effects of a single dose of rhodium complex on mice.

Overall, the data in the 5 selected studies were related to laboratory rats and mice and there was a lack of toxicity data identified for non-laboratory animals in the compiled terrestrial toxicity dataset. Also, there were very few endpoints reported for vegetation and soil invertebrates. This increases the uncertainty associated with the derived guidelines in the current review. Toxicity testing completed by Aquatox provided additional chronic endpoints for vegetation and soil invertebrate for rhodium and ruthenium. These tests were given an “acceptable” ranking.

3. GUIDELINE APPROACH AND METHODOLOGY

The following sections outline the approach and methodology selected for the derivation of guidelines for the elements of interest. The first step involved a jurisdictional review. Guidelines available from the jurisdictional review were preferentially selected in favour of using literature studies for further guideline development. In the absence of a guideline from another jurisdiction, guidelines were derived from the literature search for available toxicity data. As data from the literature review were limited for the elements of interest in this study, the guideline derivation methodology was modified from standard protocols. Guidelines for other surrogate elements were considered for context in order to ensure that the derived guidelines were suitably protective, without being excessively conservative.

Elements in the same group (column) of the periodic table usually exhibit similar chemical behaviour, because they have the same number of outer electrons available to form chemical bonds (i.e. they form compounds in the same valence state) (IAEA 2009). Transition elements in the same period (row) of the periodic table also tend to be chemically similar to each another. A key use of surrogates is within the Platinum Group Elements (PGE) – platinum (Pt), palladium (Pd), rhodium (Rh), iridium (Ir), osmium (Os) and ruthenium (Ru) – which are chemically similar.

There are limitations to the use of surrogates (analogs) as generally similar chemistry does not necessarily imply similar metabolic characteristics in plants and animals, because of the high specificity of biochemical pathways.

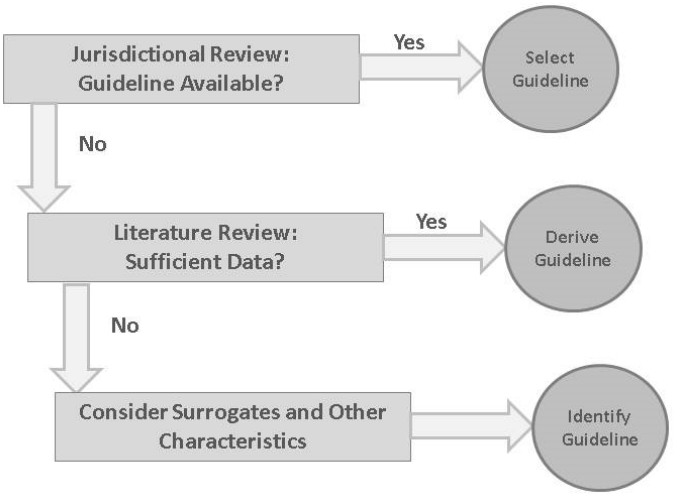

Figure 3-2: Overview of Approach and Methodology

3.1 SURFACE WATER QUALITY GUIDELINES

Criteria defined for surface water are intended to be protective of drinking water, aquatic life, agricultural water uses (irrigation and livestock), recreational water uses, and aesthetic features. The following sections describe the consideration of protection of aquatic life and agricultural protection in the selection of appropriate surface water quality guidelines (WQGs) for the elements of interest.

As discussed above, one consideration in the derivation of criteria for surface water is the protection of drinking water. Tungsten was the only element of interest in the current review with an available drinking water guideline; the lack of drinking water guidelines represents a data gap for the derived surface water quality guidelines. However, ecological effects on aquatic species are generally more restrictive than human health effects related to the consumption of water, and therefore the derived guidelines for the protection of aquatic life are expected to be protective of human health. In addition, surface water used for a drinking water source for human consumption is typically treated prior to consumption, this would further reduce and potential exposure to elements in the water.

3.1.1 Water Quality Guideline for the Protection of Aquatic Life

The CCME (2007) protocol for the derivation of Water Quality Guidelines (WQGs) for the protection of aquatic life provides an approach and methodology for developing guidelines that ensure that the introduction of toxic substances do not lead to the degradation of Canadian fresh and marine waters. This protocol was used as the guide for the development of WQGs for the protection of freshwater aquatic life for long-term exposures. Long-term exposure guidelines are designated to protect against all negative effects during indefinite exposures.

The derivation of WQGs for marine water was considered to be out of scope for the current study, since, as stated in Medri (2015), it is not anticipated that the repository will be sited near

saltwater. In any case, only two studies for the marine environment were found for the elements of interest for this study (Robinson et al. 1997, Bengtsson and Tarkpea 1983).

CCME (2007) provides three methods for aquatic protection guideline development – in order of decreasing robustness: Type A, Type B1, and Type B2. Type A guidelines are derived using a species sensitivity distribution (SSD) approach when there are adequate toxicity data to satisfactorily fit a SSD curve. Type B1 and B2 guidelines are derived for substances that either have inadequate or insufficient toxicity data for the SSD approach, but for which enough toxicity data from a minimum number of primary and/or secondary studies are available. There is currently no CCME guidance for the development of criteria if insufficient data are available to meet the minimum requirements for the derivation of a Type B2 guideline. Table 3-1 summarizes the minimum data requirements for each of the three guideline development approaches.

Table 3-1: Summary of Data Requirements for Development of CCME WQG

Group	Type A[a]	Type B1[b]	Type B2[b]	Comment
Fish	3 species	3 species	2 species	1 salmonid and 1 non-salmonid
Aquatic Invertebrates	3 species	3 species	2 species	1 planktonic crustacean
Aquatic Plants	1 species	1 species	0 species	Additional requirements if phyto-toxic
Amphibians	0 species	0 species	0 species	Highly desirable, but not necessary

Notes: From Table 1 of CCME (2007).
a – Type A WQG derived using a SSD approach when there are adequate toxicity data to satisfactorily fit a SSD curve
b – Lowest Endpoint Derivation Approach

There are further requirements on data quality for each of the guideline development approaches: Type A and Type B2 consider both primary and secondary data and Type B1 requires primary data (CCME 2007).

For a number of elements, there were no data for chronic toxicity to fish species from literature studies. Since CCME (2007) does not provide guidance for an approach with insufficient data, professional judgement was used along with consideration of surrogate elements to develop an approach for guideline derivation for this study. Thus for these elements, a long-term guideline was developed using the lowest endpoint Type B2 derivation approach. The CCME (2007) provide preferred acceptable endpoints for this approach which include, in the order of preference, EC/IC < 25%, LOEC, MATC, EC/IC < 50%, LC50. The most sensitive (lowest concentration) effects endpoint was selected as the critical study and used in the derivation of the guideline in this study. Following CCME (2007) guidance, the endpoint concentration from the critical study was divided by their recommended safety factor of 10 to derive the long-term exposure guideline.

In some cases, in addition to the lack of fish toxicity data, there were no available chronic aquatic toxicity data with which to derive a guideline following the modified Type B2 approach described above. This introduces considerable uncertainty to the guidelines derived using the modified Type B2 approach. The CCME (2007) protocol allows for consideration of endpoints from short-term exposure studies to be used as the critical study for the derivation of a long-term exposure guideline. In these cases, the lowest exposure concentration from the acute dataset was divided by the CCME default recommended safety factor of 100 for persistent, non-biodegradable substances to derive the long-term exposure guideline.

The guidelines derived by these methods were considered in the context of guidelines available for surrogates to select an appropriate guideline value that represents the available toxicity data, but also considers the various uncertainties introduced by the derivation method while ensuring the protection of aquatic life. The specifics of the guideline derivation for the elements for this study are provided in Section 4.1.2.

The additional species testing completed for rhodium and ruthenium by Aquatox (Appendix C.1) was selected based on satisfying the minimum criteria for the derivation of a Type B2 guideline per the CCME (2007) protocol. Therefore, one salmonid (*Oncorhynchus mykiss*) and non-salmonid (*Pimephales promelas*) fish species were identified, as well as one planktonic crustacean (*Ceriodaphnia dubia*) and one epibenthic amphipod (*Hyalella azteca*). Test methods satisfying the CCME (2007) protocol for chronic duration were also selected.

3.1.2 Water Quality Guideline for the Protection of Agricultural Uses

The CCME (1999a) protocol for the derivation of WQGs for the protection of agricultural water uses (irrigation and livestock water) provides an approach and methodology for developing guidelines to protect crops from adverse effects and damage due to contaminants in irrigation water. To derive a WQG for irrigation water, the CCME (1999a) protocol requires certain minimum toxicological data set requirements, which include toxicity data for cereals, tame hays, pastures, and other crops. For a WQG for livestock water, the minimum toxicological data set requirements outlined in the protocol include toxicity data for livestock and domestic poultry species. There were no available data in the compiled datasets to meet these minimum data requirements for the derivation of WQG for the protection of agricultural uses. This is identified as a data gap and introduces uncertainty in the derived WQGs for the elements of interest in the current study.

3.2 SOIL QUALITY GUIDELINES

Criteria defined for soil are intended to be protective of ecological receptors and human health based on various land uses (agricultural, residential/parkland, commercial, and industrial). Soil Quality Guideline (SQG) values were derived following the CCME (2006) protocol. As described in Section 2.3, this involved an extensive literature search of published data regarding the toxicity of the elements of interest to soil-dependent biota (soil invertebrates and terrestrial plants) and terrestrial animals (mammals and birds), followed by review and classification of the data. The derivation of the SQG for each land use category (agricultural, residential/parkland, commercial, industrial) is complex and requires the evaluation of multiple exposure pathways.

The overall SQG for each land use is equal to the lowest of the applicable pathway-specific guideline values for both environmental protection and human health. In order to set an overall

environmental SQG for each land use, values for the soil contact (SQG_{SC}), soil and food ingestion (SQG_{I}), and offsite migration (SQG_{OM-E}) need to be derived. SQG_{SC} are derived for all land uses, while SQG_{I} only apply for agricultural and residential/parkland (in the absence of element biomagnification information) land uses and SQG_{OM-E} apply for commercial and industrial land uses. SQG_{HH} were not quantitatively derived due to a lack of appropriate human health toxicity data; however, consideration was given to potential effects on human health through the consideration of surrogate benchmark.

Evaluation of nutrient and energy cycling (SQG_{NEC}) was not completed since insufficient data were available from the literature search to evaluate the guideline check regarding potential effects of the elements of interest on soil nutrient and energy cycling. Therefore, this component of the SQG is not considered for the guideline derivation and is recognized as a data gap. The groundwater components of the SQG for freshwater life (SQG_{FL}), agricultural irrigation uses (SQG_{IR}), and agricultural livestock watering (SQG_{LW}) are not applicable to metal compounds and are therefore not derived.

As discussed in Section 2.4.2, there was overall a lack of toxicity data identified for non-laboratory animals in the compiled terrestrial toxicity dataset. In addition, most of the available data were for laboratory rats and mice and there were very few endpoints reported for vegetation and soil invertebrates. It should be noted that the CCME (2006) protocol acknowledges that it is preferable to establish a guideline based on incomplete data (i.e., a provisional value) than to not establish a value at all; therefore, where possible, applicable guidelines were derived; however, the minimum data requirements outlined in CCME (2006) were never satisfied for soil and food ingestion. The modified approaches for the various components of the SQG are outlined in the following sections.

The guidelines derived by these methods were considered in the context of guidelines available for surrogates to select an appropriate guideline value that represents the available toxicity data, but considers the various uncertainties introduced by the derivation method while ensuring protection of the environment and human health. The specifics of the guideline derivation for this approach are provided in Section 4.2.1.

3.2.1 Soil Quality Guideline for Soil Contact (SQG_{SC})

The Soil Quality Guideline for soil contact (SGC_{SC}) protects soil-dependent organisms such as soil invertebrates and plants. The CCME (2006) derives a Threshold Effects Concentration (TEC) for agricultural or residential/parkland land use categories and an Effects Concentration – Low (ECL) for commercial and industrial land use categories. The CCME (2006) protocol provides three approaches to derive the TEC and ECL as discussed below.

The Weight of Evidence Method is the preferred approach and requires at least ten data points from three studies, including a minimum of two soil invertebrate data points and two crop/plant data points. The Lowest Observed Effect Concentration (LOEC) Method and Median Effects Method both require endpoints from at least three studies, including at least one plant and one soil invertebrate study. Per the CCME (2006) protocol, if minimum data requirements cannot be met, a guideline value for soil cannot be derived.

For most elements of interest in this study, the minimum data requirements to derive a soil contact SQG_{SC} were not met by the available terrestrial toxicity database. Acknowledging this deficiency, a modified approach for the development of the guideline using the Median Effects

Method was undertaken. The lowest median effect concentration was selected from the available data for toxic effects on plants and soil invertebrates and an uncertainty factor was applied to derive a TEC. The uncertainty factor was selected, based on consideration of the available data (number of studies, various taxon represented), duration of the test (short-term vs. long-term), the endpoint selected, and whether the CCME minimum requirements for deriving a guideline were met. Per the CCME (2006) protocol, an ECL (commercial and industrial land use) cannot be calculated using the Median Effects Method.

The additional species testing completed for rhodium and ruthenium by Aquatox (Appendix C.2) was selected based on satisfying the minimum criteria for the Lowest Observed Effect Concentration Method per the CCME (2006) protocol. Therefore, two plant species (*Medicago sativa*, *Hordeum vulgare*) and one soil invertebrate species (*Eisenia andrei*) were tested. Test methods satisfying the CCME (2006) protocol for chronic duration were also selected. The IC25 endpoints from the Aquatox studies were determined to be reasonable substitutes for LOEC values. Following the LOEC Method, the TEC for agricultural and parkland use was derived by selecting the lowest IC25 and applying an uncertainty factor of 3 (based on using minimum number of studies and assuming IC25 is equivalent to a LOEC). The ECL for commercial and industrial land use was derived, also following the LOEC Method, by calculating the geometric mean of the IC25 endpoints.

3.2.2 Soil Quality Guideline for Soil and Food Ingestion (SQG_I)

The derivation of a SQG for primary consumers (SQG_{1C}) requires a minimum of three studies, including at least two oral mammalian studies (one of which must be a livestock species or grazing herbivore with a high ingestion rate to body weight ratio) and one oral avian study. A maximum of one laboratory rodent study may be included in the dataset if needed to fulfill the data requirements. Similar data requirements exist for deriving SQGs for secondary (SQG_{2C}) and tertiary (SGQ_{3C}) consumers, with a focus on predatory mammals and birds as opposed to herbivores.

Per the CCME (2006) protocol, the final SQG_I is the lowest of the values calculated for the primary, secondary and tertiary consumers, and, if minimum data requirements cannot be met, a guideline value for soil and food ingestion cannot be derived. Recognizing that the minimum data requirements were not met by the available terrestrial toxicity database for the elements of interest, a modified approach was developed to allow for the derivation of guidelines considering the available data.

The lowest effects dose was identified from the available oral laboratory rodent studies. An uncertainty factor of 500 was selected to account for the numerous uncertainties associated with the modified approach, including the CCME recommended factor of 5, an additional factor of 10 to account for intra-species variation and extrapolation to field conditions, and another factor of 10 because the CCME minimum requirements for guideline derivation were not met. The lowest effects dose was used with the uncertainty factor to derive a daily threshold effects dose (DTED). A meadow vole (*Microtus pennsylvanicus*), with the characteristics presented in Table 3-2, was identified as an appropriate primary consumer surrogate for the laboratory rodent and the calculated DTED was used to represent the $DTED_{1C}$.

Table 3-2: Summary of Meadow Vole Characteristics

Characteristic	Value	Comment
Body weight	0.0349 kg	Government of Canada (2012)
Food ingestion rate – ww basis	0.012 kg ww/d	Calculated based on 0.33 kg wet food/kg wet BW/day, Government of Canada (2012)
Food ingestion rate – dw basis	0.003 kg dw/d	Calculated from food ingestion rate – ww basis, using an assumed moisture content of 70%
Incidental soil ingestion rate	2.4% of dry food ingestion rate	Government of Canada (2012)
Soil ingestion rate	0.0001 kg dw/d	Calculated from food ingestion rate – dw basis and incidental soil ingestion rate

Notes: From FCSAP Guidance, Module 3 (Government of Canada 2012).

The bioavailability factor (BF) of a soil-absorbed element was assumed to be one and the soil-to-plant bioconcentration factor (BCF) was obtained from literature (Baes et al. 1984) on an element-specific basis.

The calculation of the SQG_{1C} followed Equation (3-1), which was based on CCME (2006) protocol, Equation 11:

$$SQG_{1C} = \frac{0.75 \times DTED_{1C} \times BW_{1C}}{(SIR_{1C} \times BF) + (FIR_{1C} \times BCF)} \quad (3\text{-}1)$$

Where:

SQG_{1C} = soil quality guideline derived for primary consumers (mg/kg dw)
$DTED_{1C}$ = assumed derived daily threshold effects dose for primary consumers (mg/kg bw/d), element specific
BW_{1C} = body weight of primary consumer (kg), see Table 3-2
SIR_{1C} = soil ingestion rate of primary consumer (kg dw/d), see Table 3-2
BF = bioavailability factor (-), assumed 1
FIR_{1C} = food ingestion rate of primary consumer (kg dw/d), see Table 3-2
BCF = soil-to-plant bioconcentration factor (-), based on element-specific literature data

Given the numerous uncertainties already inherent in the modified approach and the further uncertainties introduced with the transport of elements through the food chain, SQG for secondary and tertiary consumers were not calculated.

3.2.3 Soil Quality Guideline for Offsite Migration (SQG_{OM-E})

The movement of soil from industrial and commercial sites to adjacent more sensitive land uses is considered in the offsite migration check by the CCME (2006) to ensure that wind and water erosion of contaminated material from an industrial site does not cause unacceptable concentrations on adjacent properties. It is calculated as shown in Equation (3-2), based on Equation 3 of the CCME (2006, Appendix G) protocol:

$$SQG_{OM-E} = 14.3 \times SQG - 13.3 \times BSC \quad (3\text{-}2)$$

Where:

SQG_{OM-E} = Soil quality guideline check for offsite migration (mg/kg dw)
SQG = Element-specific calculated SQG (mg/kg dw)
BSC = Background concentration of element in the receiving soil (mg/kg), assumed 0

For this study, the SQG used in the calculation of offsite migration was based on the lowest of the derived SQG_{SC} and SQG_{1C}, as available.

3.2.4 Soil Quality Guideline for Human Health

The CCME (2006) protocol includes consideration of the protection of human health in the development of SQG. The derivation of human health SQGs includes assessing the toxicological hazard or risk from a chemical; determining estimated daily intake (EDI) of the chemical from "background" exposure; and the integration of exposure and toxicity information to set SQGs. The protocol relies on information established by Health Canada for the guideline derivation. There is an allowance for toxicity reference values developed by other agencies, such as U.S. EPA IRIS and WHO; however, the appropriate toxicity information is not available for the elements of interest in this review. Therefore, consideration of the protection of human health was addressed through an evaluation of the human health portion of the SQG from surrogate elements.

3.3 GROUNDWATER QUALITY GUIDELINES

Criteria defined for groundwater are intended to be protective of drinking water, agricultural water uses (irrigation and livestock), and surface water bodies from groundwater baseflow. Consideration was given to developing groundwater quality guidelines following the CCME protocol (CCME 2015a); however, CCME has clarified that the protocol only applies to organic substances, due to the high level of uncertainty and variability in the fate and transport of inorganic substances in groundwater, including highly variable soil-water partitioning and contaminant transport rates which are dependent on soil chemistry. Thus this approach could not be used in this study.

In the derivation of soil and groundwater standards (MOE 2011a), the Ontario Ministry of the Environment and Climate Change (MOECC) account for dilution within the surface water in a mixing zone when deriving a value for protection of aquatic life. No dilution within the groundwater aquifer is considered which assumes that the contamination could be up to the edge of the surface water body. The acceptability of specific uses of mixing zones is captured in Policy 5 of the Blue Book (MOEE 1994). MOECC acknowledge that dilution will occur when groundwater discharges to surface water and selected a conservative, order of magnitude dilution factor of 10 to account for this (MOE 2011a). The application of a dilution factor of 10 adopted by the MOECC, was adopted for the derivation of groundwater guidelines based on protection of aquatic life in this document.

In the derivation of guidelines for potable groundwater conditions, both the MOECC and CCME consider available drinking water guidelines and default to the lower of the aquatic toxicity and drinking water guideline. Tungsten was the only element of interest in the current review with an available drinking water guideline; the lack of drinking water guidelines represents a significant

data gap for the derived groundwater quality guidelines. To address this data gap, the groundwater quality guidelines derived for elements with unknown human toxicity or suspected human toxicity were assumed to be equal to the derived surface water quality guideline for the protection of aquatic life, with no applied dilution factor. Although this does not account for potential human health effects, as discussed earlier, ecological effects on aquatic species are generally more restrictive than human health effects related to the consumption of water. Therefore, the derived groundwater quality guidelines for these elements are expected to also be protective of human health, in the absence of other data. For elements known to be non-toxic to humans, the applied dilution factor of 10 was considered to be a reasonable approach for the derivation of groundwater quality guidelines protective of human health.

3.4 SEDIMENT QUALITY GUIDELINES

The CCME (1995) provides a protocol for developing sediment quality guidelines based on either the National Status and Trends Program (NSTP) or spiked-sediment toxicity test (SSTT). The NSTP approach relies on a range of data sources and uses a weight-of-evidence approach to establish associations between concentrations of chemicals in sediments and adverse biological effects. The SSTT uses information on the responses of test organisms to specific sediment associated chemicals under controlled laboratory conditions. The CCME has set freshwater sediment quality guidelines using these approaches.

European Chemicals Agency (ECHA 2003) supports setting sediment protection levels ($PNEC_{sed}$) based on long-term toxicity test data for benthic organisms. However, to compensate for a lack of appropriate toxicity data the equilibrium partitioning method was proposed as a screening approach. This method uses the $PNEC_{water}$ for aquatic organisms and the sediment/water partitioning coefficient. Results from this screening can be used as a trigger for determining whether whole-sediment tests with benthic organisms should be conducted. In the partitioning method, it is assumed that sediment-dwelling organisms and water column organisms are equally sensitive, that the concentration of the substance in sediment, interstitial water and benthic organisms are at equilibrium and that generic partition coefficients can be applied.

The approach used by ECHA, which considers the sediment/water partitioning coefficient (Kd) applied to the water quality guideline, was adopted for the derivation of sediment quality guidelines in this document. When a sediment/water partitioning coefficient was not available from the ERICA database (Brown et al. 2008), soil/water partitioning coefficients from Baes et al. (1984) were used. Consideration of surrogates and radiotoxicity were also used in the determination of appropriate sediment quality guidelines.

3.5 AIR QUALITY GUIDELINES

Criteria defined for air are intended to be protective of human health, the environment, and nuisance effects (like odour). The development of appropriate guidelines for air considered the procedure outlined in the MOECC (2011b) document *Ontario Air Standards for Uranium and Uranium Compounds* and included a review of available toxicological benchmarks and existing air standards. Existing air standards were located for most of the elements of interest. No available toxicological benchmarks were available for the remaining elements; therefore, consideration of surrogates and radiotoxicity were used in the determination of appropriate air quality guidelines.

4. DERIVATION OF ENVIRONMENTAL QUALITY GUIDELINES

4.1 SURFACE WATER QUALITY GUIDELINES

Table 4-1 summarizes the available surface water quality guidelines (WQG) from Medri (2015) and identifies the elements which require further investigation for the development of WQGs. As seen from the table, WQGs are only available for iodine and tungsten.

Table 4-1: Summary of WQGs – Initial Stage

Element	WQG (µg/L)
Gold	
Bismuth	
Bromine	
Iodine	100
Indium	
Iridium	
Osmium	
Palladium	
Platinum	
Rhodium	
Ruthenium	
Tellurium	
Tungsten	30

Notes: Values from Medri (2015). Shading indicates WQG derived in the following sections.

4.1.1 Jurisdictional Review

The first step for the derivation of WQGs for the elements identified in Table 4-1 was the completion of a jurisdictional review (Section 2.2). The jurisdictional review identified guidelines for five elements (bismuth, bromine, indium, palladium and tellurium) derived for the protection of aquatic life. These guidelines are summarized in Table 4-2.

Table 4-2: Summary of WQGs – Jurisdictional Review

Element	WQG (µg/L)	Remarks
Gold		
Bismuth	140	PNEC freshwater derived with an assessment factor of 1000 applied to 137 mg/L 4-d LC50 for fish (ECHA)
Bromine	2	UK Environment Agency (2011), lowest chronic value for aquatic life, NOEC or 5th percentile of SSD (depending on data availability) with appropriate uncertainty factor (ECCC, 2013)
Iodine	100	Medri (2015)
Indium	40.6	PNEC freshwater derived from a sensitivity distribution (ECHA)
Iridium Osmium		
Palladium	0.027	PNEC freshwater derived with an assessment factor of 50 applied to a chronic value of 1.3 µg/L based on an algal NOEC (ECHA)
Platinum Rhodium Ruthenium		
Tellurium	5.8	PNEC freshwater derived with an assessment factor of 1000 to an acute value of 5,790 µg/L based on an EC50 (mobility) for *Daphnia magna* (ECHA)
Tungsten	30	Medri (2015)

Notes: PNEC – Probable No Effect Concentration from ECHA dossiers, represents a concentration below which adverse effects in the environment are not expected to occur.
Shading indicates WQG derived in the following sections.

The WQG for bromine is based on non-statutory Environmental Quality Standards (EQSs) from the UK Environment Agency (2011). The guideline of 2 µg/L is based on freshwater annual average concentration; an additional maximum acceptable concentration for freshwater (5 µg/L) is available. However, the annual average standard value is considered to be consistent with the chronic levels of protection outlined in Medri (2015).

The PNEC derived for palladium by ECHA is based on the most toxic palladium compound diamminedichloropalladium which is an industrial catalyst and thus unlikely to be

environmentally relevant. Therefore, aquatic toxicity data compiled for other palladium compounds (Appendix B.1) were used for the derivation of a WQG for palladium.

The available aquatic toxicity data for the remaining elements (indicated with shading in Table 4-2) were compiled and evaluated for further derivation of water quality guidelines as discussed in the following section.

4.1.2 Toxicity Review – Aquatic Data

The elements gold, iridium, osmium, palladium, platinum, rhodium, and ruthenium were identified as requiring WQG derivation. The available aquatic toxicity data were compiled as described in Section 2.3, and the data were evaluated and scored as described in Section 2.4. The approach provided by CCME (2007) and described in Section 3.1.1 was followed to derive the guidelines protective of aquatic life. The results of the WQG derivation are provided in the following sections.

4.1.2.1 Gold

A total of eight studies on aquatic species, conducted between 1939 and 2005, were available for gold and its compounds (auric chloride and tetrachloroaurate). There were four chronic studies with reported EC16, EC50, LC50, LC100, and LOEC endpoints for mortality, growth, reproduction, and metabolism. These studies were reviewed and evaluated (Appendix A.1), and two studies received an acceptable (secondary) scoring and were considered in the guideline derivation, while one study (Jones 1939) was considered unacceptable due to a LC100 endpoint. One study (Robinson et al. 1997) was completed in the marine environment for a diatom and was not considered further for the guideline derivation.

The compiled dataset for gold aquatic toxicity data is provided in Appendix B.1. The acceptable chronic data comprises three aquatic invertebrate endpoints (EC16, EC50, LC50) and 1 aquatic plant endpoint (EC50). Table 4-3 summarizes the available chronic aquatic toxicity data for gold for consideration with guideline derivation data requirements.

Table 4-3: Summary of Chronic Aquatic Toxicity Data – Gold

Group	Requirements	Remarks
Fish	3 (Type A, B1) 2 (Type B2)	None
Aquatic Invertebrates	3 (Type A, B1) 2 (Type B2)	*Daphnia magna*
Aquatic Plants	1 (Type A, B1) 0 (Type B2)	*Scenedesmus acutiformis*

Notes: Other data requirements, such as salmonid and non-salmonid species and planktonic crustaceans, are not included in the table.

The data requirements for the derivation of a long-term exposure guideline for freshwater are not satisfied for any of the guideline derivation methods. However, the Type B2 approach was

used to derive a guideline with consideration of the available data for gold. The 21-d EC16 for reproduction in *Daphnia magna* (Biesinger and Christensen 1972) was identified as the lowest chronic value (60 µg/L) and a safety factor of 10 was applied to derive a long-term guideline of 6 µg/L for gold.

Due to the paucity of data for aquatic toxicity for gold, other surrogate guidelines were considered. Copper and silver were identified as potential surrogates for gold based on their location in the periodic table. Table 4-4 provides a summary of the available WQG from CCME (2017).

Table 4-4: Summary of Available Surrogate WQG – Gold

Element	WQG (µg/L)	Remarks
Copper	2 - 4	Varies based on hardness
Silver	0.25	Toxic mode of action – effects on fish gill

Notes: CCME WQG for the protection of aquatic life.

The WQG for copper is similar to the derived WQG for gold. Silver toxicity to aquatic species is known to occur through the accidental uptake across the gill in fish, which ultimately leads to death (CCME 2015b); however, the lowest available chronic toxicity value is for growth effects in *Oncorhynchus mykiss* (rainbow trout). Hadrup et al. (2015) conducted a review of elemental gold toxicity and found it to be of relatively low acute toxicity. Further study was identified to better assess whether gold ions released from the surface of elemental gold induce toxicity in the same way that has been demonstrated for silver.

Although there were no available chronic toxicity studies for effects on fish from gold, 6 acute LC50 endpoints were available for three fish species: *Thymallus arcticus*, *Oncorhynchus mykiss,* and *Oncorhynchus kisutch*. The concentrations associated with these 96-hr LC50s ranged from 9,100 µg/L to 33,500 µg/L. These values are significantly higher than the 96-hr LC50s for silver, which range from 1.5 µg/L to 34.4 µg/L (CCME 2015b). Therefore, it is considered unlikely that gold exhibits a similar toxic effect on fish species at the low concentrations demonstrated by silver. Although chronic toxicity data for fish species are not available for gold, the derived WQG of 6 µg/L is considered reasonable. It is also well below toxic effects associated with acute exposure for fish.

4.1.2.2 Iridium

A total of two studies on aquatic species, conducted between 1994 and 2005, were available for iridium and its compounds (iridium chloride). The studies were considered acute tests and reported LC50, LOEC, and NOEC endpoints for mortality and growth effects. These studies were reviewed and evaluated (Appendix A.1) and received an acceptable (secondary) scoring. One study (Farago and Parsons 1994) was classified as secondary because NOEC and LOEC endpoints were inferred from the narrative description of the test results and the concentrations tested. The LOEC was assigned to the concentration at which effects were observed, while the NOEC was assigned the highest concentration that did not result in measurable effects.

As no chronic toxicity were available for iridium, the acute exposure data were considered for the derivation of the long-term guideline. The compiled dataset for iridium aquatic toxicity data is provided in Appendix B.1. The acceptable data comprises two aquatic invertebrate endpoints (LC50) for *Hyalella azteca* and two aquatic plant endpoints (NOEC, LOEC) for *Eichhornia crassipes*. The 7-d LC50 for *Hyalella azteca* (Borgmann et al. 2005) was identified as the lowest-effects acute value (>1,000 µg/L) and a safety factor of 100 was applied to derive a long-term guideline of 10 µg/L for iridium.

Iridium belongs to the Platinum Group Elements (PGE) and little is known of its toxicological characteristics (Nordberg et al. 2014). Other members of the PGE include platinum, osmium, ruthenium, rhodium, and palladium. Rhodium was identified as potential surrogate for iridium based on its location in the periodic table and also being a member of the PGE. Although there was a the lack of chronic aquatic toxicity data for iridium and only two acute studies from which to derive a guideline, the derived guideline of 10 µg/L is consistent with the more robust guideline derived for rhodium (see Section 4.1.2.6) and therefore the guideline of 10 µg/L is selected for iridium.

4.1.2.3 Osmium

A total of five studies on aquatic species, conducted between 1983 and 2009, were available for osmium and its compounds (osmium oxide, osmium sodium chloride). The studies were considered acute tests and reported EC50, LC50, LOEC, and NOEC endpoints for mortality, immobilization, and growth effects. These studies were reviewed and evaluated (Appendix A.1), and four studies received an acceptable (secondary) scoring, while one study (Bengtsson and Tarkpea 1983) was considered unacceptable due to lack of measured data and failure of the statistical test for osmium. One study (Farago and Parsons 1994) was classified as secondary because NOEC and LOEC endpoints were inferred from the narrative description of the test results and the concentrations tested. The LOEC was assigned to the concentration at which effects were observed, while the NOEC was assigned the highest concentration that did not result in measurable effects.

As no chronic toxicity were available for osmium, the acute exposure data were considered for the derivation of the long-term guideline. The compiled dataset for osmium aquatic toxicity data is provided in Appendix B.1. The acceptable data comprises seven aquatic invertebrate (*Hyalella azteca*, *Tubifex tubifex*, and *Cypris subglobosa*) endpoints (EC50, LC50) and two aquatic plant endpoints (NOEC, LOEC) for *Eichhornia crassipes*. The 96-hr EC50 for *Tubifex tubifex* immobilization (Khangarot 1991) was identified as the lowest-effects acute value (6.7 µg/L) and a safety factor of 100 was applied to derive a long-term guideline of 0.067 µg/L for osmium.

Osmium also belongs to the Platinum Group Elements (PGE); other members of the PGE include platinum, iridium, ruthenium, rhodium, and palladium. Although there was a lack of chronic aquatic toxicity data for osmium, the derived guideline of 0.067 µg/L was selected for osmium, since it was based on element-specific toxicity data.

4.1.2.4 Palladium

A total of five studies on aquatic species, conducted between 1994 and 2017, were available for palladium and its compounds (palladium chloride and palladium dichloride). The studies were

considered acute tests and reported EC20, EC50, LC50, LOEC, and NOEC endpoints for mortality, immobilization, and growth effects. These studies were reviewed and evaluated (Appendix A.1), and received an acceptable (primary and secondary) scoring. One study (Farago and Parsons 1994) was classified as secondary because NOEC and LOEC endpoints were inferred from the narrative description of the test results and the concentrations tested. The LOEC was assigned to the concentration at which effects were observed, while the NOEC was assigned the highest concentration that did not result in measurable effects.

As no chronic toxicity were available for palladium, the acute exposure data were considered for the derivation of the long-term guideline. The compiled dataset for palladium aquatic toxicity data is provided in Appendix B.1. The acceptable data comprises 13 aquatic invertebrate (*Daphnia magna*, *Hyalella azteca*, *Tubifex tubifex*, and *Cypris subglobosa*) endpoints (EC20, EC50, LC50) and two aquatic plant endpoints (NOEC, LOEC) for *Eichhornia crassipes*. The 48-hr EC20 for *Daphnia magna* immobilization (Zimmerman et al. 2017) from exposure to palladium dichloride was identified as the lowest-effects acute value (6.8 µg/L) and a safety factor of 100 was applied to derive a long-term guideline of 0.068 µg/L for palladium.

A comparison of this derived long-term guideline for more environmentally relevant palladium compounds to the ECHA PNEC of 0.027 µg/L for the most toxic palladium compound diamminedichloropalladium indicates that the derived WQG of 0.068 µg/L is reasonably protective even though it is based on acute studies without the consideration of fish toxicity. In a chronic aquatic toxicity study of the terrestrial nematode *Caenorhabditis elegans,* Schertzinger et al. (2017) could not determine an exact EC50 for reproduction but the endpoint ranged between 10 and 100 µg/L. In an aquatic study conducted by Vannini et al. (2011), algal growth was significantly diminished at 250 µg/L and completely blocked at 500 µg/L after a 72 hour exposure. These values are well above the derived WQG for palladium.

4.1.2.5 Platinum

A total of eight studies on aquatic species, conducted between 1972 and 2017, were available for platinum and its compounds (platinum chloride). There was 1 chronic study with reported EC16, EC50, and LC50 endpoints for mortality and reproduction. This study (Biesinger and Christensen 1972) was reviewed and evaluated (Appendix A.1) and received an acceptable (secondary) scoring.

The compiled dataset for platinum aquatic toxicity data is provided in Appendix B.1. The acceptable chronic study included three aquatic invertebrate endpoints (EC16, EC50, and LC50). Table 4-5 summarizes the available chronic aquatic toxicity data for platinum for consideration with guideline derivation data requirements.

Table 4-5: Summary of Chronic Aquatic Toxicity Data – Platinum

Group	Requirements	Remarks
Fish	3 (Type A, B1) 2 (Type B2)	None
Aquatic Invertebrates	3 (Type A, B1) 2 (Type B2)	*Daphnia magna*
Aquatic Plants	1 (Type A, B1) 0 (Type B2)	None

Notes: Other data requirements, such as salmonid and non-salmonid species and planktonic crustaceans, are not included in the table.

The data requirements for the derivation of a long-term exposure guideline for freshwater are not satisfied for any of the guideline derivation methods. However, the Type B2 approach was used to derive a guideline with consideration of the available data for platinum. The 21-d EC16 for reproduction in *Daphnia magna* (Biesinger and Christensen 1972) was identified as the lowest chronic value (14 µg/L) and a safety factor of 10 was applied to derive a long-term guideline of 1.4 µg/L for platinum.

The CCME (2007) protocol allows for consideration of lowest-effects concentrations from short-term exposure studies if the long-term exposure guideline is not considered to be sufficiently protective. This approach was considered for platinum due to the limited chronic toxicity data. There were seven acute studies that were reviewed and evaluated (Appendix A.1) and received an acceptable (primary and secondary) scoring. The acceptable data comprises 15 aquatic invertebrate endpoints, three fish endpoints, and two aquatic plant endpoints. The 96-hr EC50 for *Tubifex tubifex* immobilization (Khangarot 1991) was identified as the lowest-effects acute value (61 µg/L) and a safety factor of 100 was applied to derive a long-term guideline of 0.61 µg/L for platinum.

Platinum belongs to the Platinum Group Elements (PGE), therefore consideration of the existing guideline for palladium was given. The palladium guideline is based on a lowest chronic toxicity value of 1.3 µg/L for an algal species. A 14-d NOEC endpoint of 500 µg/L for platinum for the aquatic plant *Eichhornia crassipes* was available; this value is considerably above the lowest chronic value used for palladium. Furthermore, in a study of chronic aquatic toxicity for the terrestrial nematode *Caenorhabditis elegans,* Schertzinger et al. (2017) identified that palladium is more toxic than platinum. The dataset for platinum includes a chronic aquatic invertebrate study, an acute fish study, and a number of aquatic invertebrate and aquatic plants for acute exposure and was determined to be sufficient. Therefore, the lower of the derived values for platinum (0.61 µg/L, based on acute studies) was selected for the WQG.

One study (Osterauer et al. 2009) completed on zebrafish (*Danio rerio*) and Ramshorn snail (*Marisa cornuarietis*) was considered for inclusion in the dataset. It was deemed to not provide acceptable endpoints for the platinum dataset, however the results for effects on embryonic development are considered as additional context for the derived WQG for platinum. Hatching success of the two species was affected at platinum concentrations of 36 and 73 µg/L. For other observed endpoints, including mortality, no influence of platinum could be determined up to concentrations of 73 µg/L. In a chronic aquatic toxicity study of the terrestrial nematode

Caenorhabditis elegans, Schertzinger et al. (2017) found an EC50 for reproduction of 497 µg/L. The results from these additional studies are well above the derived WQG of 0.61 µg/L for platinum.

4.1.2.6 Rhodium

A total of three studies on aquatic species, conducted between 1994 and 2017, were available for rhodium and its compounds (rhodium chloride). The studies were considered acute tests and reported EC20, EC50, LC50, LOEC, and NOEC endpoints for mortality, immobilization, and growth effects. These studies were reviewed and evaluated (Appendix A.1), and received an acceptable (primary and secondary) scoring. One study (Farago and Parsons 1994) was classified as secondary because NOEC and LOEC endpoints were inferred from the narrative description of the test results and the concentrations tested. The LOEC was assigned to the concentration at which effects were observed, while the NOEC was assigned the highest concentration that did not result in measurable effects.

Chronic toxicity data were available for rhodium from the AquaTox testing (Appendix C.1) and these data were used for the derivation of a long-term guideline, since chronic data were preferred. The compiled dataset for rhodium aquatic toxicity data is provided in Appendix B.1. The acceptable chronic data included IC/EC25 for two aquatic invertebrate species and two fish species. Table 4-6 summarizes the available chronic aquatic toxicity data for rhodium for consideration with guideline derivation data requirements.

Table 4-6: Summary of Chronic Aquatic Toxicity Data – Rhodium

Group	Requirements	Remarks
Fish	3 (Type A, B1) 2 (Type B2)	*Pimephales promelas, Oncorhynchus mykiss*
Aquatic Invertebrates	3 (Type A, B1) 2 (Type B2)	*Ceriodaphnia dubia, Hyalella azteca*
Aquatic Plants	1 (Type A, B1) 0 (Type B2)	None

Notes: Other data requirements, such as salmonid and non-salmonid species and planktonic crustaceans, are not included in the table.

The data requirements for the derivation of a long-term exposure guideline for freshwater are satisfied for the Type B2 approach, including consideration of salmonid/non-salmonid species and planktonic crustaceans. Endpoints for all species were identified as >100 µg/L and this was selected as the lowest chronic value (100 µg/L) and a safety factor of 10 was applied to derive a long-term guideline of 10 µg/L for rhodium.

Schertzinger et al (2017) completed chronic aquatic toxicity testing on the terrestrial nematode *Caenorhabditis elegans*. The study found that rhodium showed no inhibition at any endpoint studied (reproduction, fertility, and growth) between concentrations of 100 to 10,000 µg/L. The derived guideline of 10 µg/L is therefore protective of this nematode in the aquatic environment. The guideline derived for rhodium from chronic data is considered to be appropriate and

remains conservative since endpoints were reported as “>” concentrations and conservatively assumed to be equal to the concentrations.

4.1.2.7 Ruthenium

Two acute studies completed for ruthenium aquatic species were available. One study conducted in 2005 reported LC50 endpoints for mortality in the aquatic invertebrate *Hyalella azteca*. The other study was conducted in 2018 on effects from ruthenium complexes on zebrafish embryos. Chronic toxicity data were available for ruthenium from the AquaTox testing (Appendix C.1) and these data were used for the derivation of a long-term guideline, since chronic data were preferred. The compiled dataset for ruthenium aquatic toxicity data is provided in Appendix B.1. The acceptable chronic data included IC/EC25 for two aquatic invertebrate species and two fish species. Table 4-7 summarizes the available chronic aquatic toxicity data for ruthenium for consideration with guideline derivation data requirements.

Table 4-7: Summary of Chronic Aquatic Toxicity Data – Ruthenium

Group	Requirements	Remarks
Fish	3 (Type A, B1) 2 (Type B2)	*Pimephales promelas, Oncorhynchus mykiss*
Aquatic Invertebrates	3 (Type A, B1) 2 (Type B2)	*Ceriodaphnia dubia, Hyalella azteca*
Aquatic Plants	1 (Type A, B1) 0 (Type B2)	None

Notes: Other data requirements, such as salmonid and non-salmonid species and planktonic crustaceans, are not included in the table.

The data requirements for the derivation of a long-term exposure guideline for freshwater are satisfied for the Type B2 approach, including consideration of salmonid/non-salmonid species and planktonic crustaceans. Endpoints for all species were identified as >100 µg/L and this was selected as the lowest chronic value (100 µg/L) and a safety factor of 10 was applied to derive a long-term guideline of 10 µg/L for ruthenium.

The guideline of 10 µg/L derived for ruthenium is considered to be appropriate and remains conservative since endpoints were reported as “>” concentrations and conservatively assumed to be equal to the concentrations.

4.1.3 Summary

Table 4-8 provides a summary of the WQGs for the elements of interest in the current literature review.

Table 4-8: Summary of WQGs

Element	WQG (µg/L)	Remarks
Gold	6	Derived Type B2 Guideline
Bismuth	140	ECHA PNEC
Bromine	2	UK Environment Agency (2011)
Iodine	100	Medri (2015)
Indium	41	ECHA PNEC
Iridium	10	Derived Type B2 Guideline
Osmium	0.067	Derived Type B2 Guideline
Palladium	0.068	Derived Type B2 Guideline with consideration of ECHA PNEC
Platinum	0.61	Derived Type B2 Guideline
Rhodium	10	Derived Type B2 Guideline
Ruthenium	10	Derived Type B2 Guideline
Tellurium	5.8	ECHA PNEC
Tungsten	30	Medri (2015)

Notes: PNEC – Probable No Effect Concentration from ECHA dossiers, represents a concentration below which adverse effects in the environment are not expected to occur.

4.2 SOIL QUALITY GUIDELINES

Table 4-9 summarizes the available soil quality guidelines (SQGs) from Medri (2015) and identifies the elements which require further investigation for the development of SQGs. The available terrestrial toxicity data for the remaining elements (indicated with shading in Table 4-9) were compiled and evaluated for further derivation of soil quality guidelines.

Table 4-9: Summary of SQGs – Initial Stage

Element	SQG (µg/g)
Gold	
Bismuth	20
Bromine	10
Iodine	4
Indium	
Iridium	
Osmium	
Palladium	
Platinum	
Rhodium	
Ruthenium	
Tellurium	250
Tungsten	400

Notes: Values from Medri (2015). Shading indicates guideline derived in the following sections.

4.2.1 Toxicity Review – Terrestrial Data

The elements gold, indium, iridium, osmium, palladium, platinum, rhodium, and ruthenium were identified as requiring SQG derivation. The available terrestrial toxicity data were compiled as described in Section 2.3, and the data were evaluated and scored as described in Section 2.4. The approach provided by CCME (2006) and described in Section 3.2 was followed. The results of the SQG derivation are provided in the following sections.

4.2.1.1 Gold

One study on a soil invertebrate species, conducted in 2014, was available for gold and its compounds (Gold (III) chloride hydrate). Three endpoints received an acceptable scoring and were selected for deriving the soil quality guideline.

The compiled dataset for gold terrestrial toxicity data is provided in Appendix B.2 and includes an EC10 and an EC50 for reproductive effects, as well as an LC50 in oligochaetes. Table 4-11 summarizes the available terrestrial toxicity data for indium for consideration with guideline derivation data requirements.

Table 4-10: Summary of Selected Terrestrial Toxicity Data – Gold

Pathway	Requirements	Remarks
Soil Contact (SQG_{SC})	3 endpoints, including 1 Plant and 1 Soil Invertebrate	3 endpoints, all soil invertebrate
Soil and Food Ingestion (SQG_{1C})	2 Mammalian, 1 Avian	No data

Notes: Other data requirements, such as livestock species, are not included in the table. Soil contact (SQG_{SC}) requirements are shown for the LOEC and Median Effects Methods only.

The data requirements for the derivation of a SQG for direct contact and soil and food ingestion are not satisfied. Nevertheless, a guideline for direct contact was derived with consideration of the available data for gold. The procedure outlined in Section 3.2.1 was followed for the calculation of a SQG_{sc}. The EC50 of 35.5 µg/g soil for exposure to *Enchytraeus buchholzi* was selected as the median effective concentration. A multiplicative uncertainty factor of 375 was applied to the modified approach as follows: 5 to account for the CCME minimum requirements not being met; 5 to account for the lowest datum being an EC50, 5 to account for the study being short-term, 3 to account for the minimum number of studies not being reached and only one taxon represented; resulting in a total uncertainty factor of 375. The application of this factor resulted in a SQG_{SC} of 0.1 µg/g soil for gold. The offsite migration check was completed by multiplying the lowest SQG by 14.3 (Section 3.2.3). Table 4-11 summarizes the derived guidelines for gold based on the available terrestrial toxicity.

Table 4-11: Summary of Derived Environmental SQG – Gold

Guideline (µg/g)	Land Use			
	Agricultural	Res/Parkland	Commercial	Industrial
Soil Contact (SQG_{SC})	0.1	0.1	-	-
Soil and Food Ingestion (SQG_{1C})	ND	ND	ND	ND
Nutrient and Energy Cycling (SQG_{NEC})	NC[a]	NC[a]	NC[a]	NC[a]
Groundwater – Freshwater Life (SQG_{FL})	NC[b]	NC[b]	NC[b]	NC[b]
Groundwater – Agricultural, Irrigation (SQG_{IR})	NC[b]	-	-	-
Groundwater – Agricultural, Livestock (SQG_{LW})	NC[b]	-	-	-
Off-site migration check (SQG_{OM-E})	-	-	1.4	1.4
SQG_E	0.1			

Notes: ND – no data; NC – not calculated.
a – Data are insufficient/inadequate to calculate the nutrient and energy cycling check.
b – Applies to organic compounds and not calculated for metal contaminants.

Due to the paucity of data for terrestrial toxicity for gold, other surrogate guidelines were considered. Silver was identified as potential surrogate for gold based on its location in the

periodic table. Table 4-12 provides a summary of the available SQG from CCME (2017). The silver guideline was derived in 1991 and the basis of the guideline is not available.

Table 4-12: Summary of Available Surrogate SQG – Gold

Element	SQG_E (µg/g)	SQG_{HH} (µg/g)	Remarks
Silver	20	20	SQG, basis unknown

Notes: CCME SQG for the protection of environmental and human health.

The EC10 of 24.3 µg/g for reproductive effects in soil invertebrates for gold is similar to the silver CCME SQG of 20 µg/g, however, data are lacking on potential effects on plants and wildlife, therefore, the value of 0.1 µg/g is selected. The derived soil guideline is above the average gold concentration in the upper soil layer of approximately 0.004 µg/g (Nordberg et al. 2014) and thus is determined to be a reasonable SQG.

Due to a lack of appropriate human health toxicity information, the derived guideline does not consider human health effects. Levels of human exposure to gold from air, food, and water are very low. Measurable exposure can be caused by dental alloys, however, this type of exposure apparently has little toxicological significance (Nordberg et al. 2014). A positive correlation has been observed between gold allergy and the presence of dental gold. Based on this information, the SQG of 0.1 µg/g based on ecological endpoints is considered to be likely protective of human health.

4.2.1.2 Indium

ECHA dossiers derived a PNEC of 7.3 µg/g dw soil which represents a concentration below which adverse effects in the environment are not expected to occur. ECHA derived the PNEC using an assessment factor of 10; supporting information suggested the PNEC was derived for soil contact for soil microorganisms from a long-term EC10. In the selection of the PNEC for indium, ECHA also considered toxicity data available for terrestrial arthropods and plants. Toxicity to soil microorganisms was the limiting consideration.

One study on terrestrial species, conducted in 1996, was available for indium and its compounds (indium phosphide). Two endpoints received an acceptable scoring and were selected for deriving the soil quality guideline.

The compiled dataset for indium terrestrial toxicity data is provided in Appendix B.2, and include a NOEC and LOEC for blood chemistry effects in laboratory ICR mice.

Table 4-13 summarizes the available terrestrial toxicity data for indium for consideration with guideline derivation data requirements.

Table 4-13: Summary of Selected Terrestrial Toxicity Data – Indium

Pathway	Requirements	Remarks
Soil Contact (SQG_{SC})	3 endpoints, including 1 Plant and 1 Soil Invertebrate	None
Soil and Food Ingestion (SQG_{1C})	2 Mammalian, 1 Avian	Laboratory Rodent

Notes: Other data requirements, such as livestock species, are not included in the table. Soil contact (SQG_{SC}) requirements are shown for the LOEC and Median Effects Methods only.

The data requirements for the derivation of a SQG for direct contact and soil and food ingestion are not satisfied. Nevertheless, a guideline for soil and food ingestion was derived with consideration of the available data for indium. The procedure outlined in Section 3.2.2 was followed for the calculation of a SQG_I. The LOEC of 3938 µg/g bw for one-time oral exposure to a laboratory mouse was selected as the lowest effects dose. An uncertainty factor of 500 was applied to account for the various uncertainties related to the selected modified approach. This resulted in a $DTED_{1C}$ of 7.9 µg/g bw/d. Following the CCME (2006) protocol, and consideration of the soil and food ingestion rates for a meadow vole (*Microtus pennsylvanicus*) and a soil-to-plant BCF of 0.004 from Baes et al. (1984), a SQG_{1C} of 2100 µg/g was derived for indium. The offsite migration check was completed by multiplying the lowest SQG by 14.3 (Section 3.2.3). Table 4-14 summarizes the derived guidelines for indium based on the available terrestrial toxicity.

Table 4-14: Summary of Derived Environmental SQG – Indium

Guideline (µg/g)	Land Use			
	Agricultural	Res/Parkland	Commercial	Industrial
Soil Contact (SQG_{SC})	7.3[a]	7.3[a]	7.3[a]	7.3[a]
Soil and Food Ingestion (SQG_{1C})	2,100	2,100	-	-
Nutrient and Energy Cycling (SQG_{NEC}	NC[b]	NC[b]	NC[b]	NC[b]
Groundwater – Freshwater Life (SQG_{FL})	NC[c]	NC[c]	NC[c]	NC[c]
Groundwater – Agricultural, Irrigation (SQG_{IR})	NC[c]	-	-	-
Groundwater – Agricultural, Livestock (SQG_{LW})	NC[bc]	-	-	-
Off-site migration check (SQG_{OM-E})	-	-	30,000	30,000
SQG_E	7.3			

Notes: ND – no data; NC – not calculated.
a – PNEC for Indium derived by ECHA.
b – Data are insufficient/inadequate to calculate the nutrient and energy cycling check.
c – Applies to organic compounds and not calculated for metal contaminants.

The derived guideline of 7.3 µg/g for indium is based on the ECHA PNEC for soil contact. Consideration of the available mammalian data for indium indicates that the selected guideline is protective of mammals coming into contact with and ingesting soils.

Indium is present at very low concentrations in background soils of 0.011 µg/g (Nordberg et al., 2014). With consideration of the uncertainties (only one toxicity test result for a laboratory rodent) in the derived guidelines for indium, the derived guideline of 7.3 µg/g is considered to be appropriate.

Due to a lack of appropriate human health toxicity information, the derived guideline does not consider human health effects. Indium is considered to be a nonessential element. Indium compounds are poorly absorbed when ingested. The International Agency for Research on Cancer (IARC, 2006) has determined that indium phosphide, used in the microelectronics industry, is a probable human carcinogen. Exposure to indium, indium arsenide and indium chloride has been shown to produce a number of effects on gene-expression patterns. The marked inhibitory effects of indium on protein synthesis may play a role in altering the activities of DNA repair enzymes and the expression of proteins involved in regulating apoptosis (IARC 2006). This reinforces that a conservative approach, as used above, should be adopted for the derivation of the indium guideline.

4.2.1.3 Iridium

No terrestrial toxicity data were available to derive soil quality guidelines for iridium. With an average concentration of 0.05 ng/g (5×10^{-5} µg/g), iridium is one of the least abundant elements in the Earth's crust.

Iridium belongs to the Platinum Group Elements (PGE); other members of the PGE include platinum, osmium, rhodium, ruthenium, and palladium. Rhodium was identified as potential surrogate for iridium based on its location in the periodic table and also being a member of the PGE. A guideline for rhodium was derived based on available terrestrial toxicity data, as described in Section 4.2.1.7. Therefore, due to the absence of terrestrial toxicity data for iridium, the guideline of 2.2µg/g dw soil for agricultural and park land use for rhodium is adopted for iridium.

Due to a lack of appropriate human health toxicity information, the derived guideline does not consider human health effects. Current data relating to environmental iridium concentrations in air, soil, roadside dust, water, and foods indicate quite low levels that are not thought to pose a serious threat to human health (Nordberg et al. 2014). Based on this information, the SQG based on ecological endpoints is considered to be likely protective of human health.

4.2.1.4 Osmium

No terrestrial toxicity data were available to derive soil quality guidelines for osmium. Osmium belongs to the Platinum Group Elements (PGE); other members of the PGE include iridium, platinum, rhodium, ruthenium, and palladium. Ruthenium was identified as potential surrogate for osmium based on its location in the periodic table and also being a member of the PGE. A guideline for ruthenium was derived based on available terrestrial toxicity data, as described in

Section 4.2.1.8. Therefore, due to the absence of terrestrial toxicity data for osmium, the guideline 1 µg/g dw soil for agricultural and park land use for ruthenium is adopted for osmium.

4.2.1.5 Palladium

ECHA dossiers derived a PNEC of 0.012 µg/g dw soil which represents a concentration below which adverse effects in the environment are not expected to occur. ECHA derived the PNEC using the equilibrium partitioning extrapolation method; supporting information suggested the PNEC was derived for soil contact for soil microorganisms. The PNEC derived for palladium by ECHA is based on the most toxic palladium compound diamminedichloropalladium which is an industrial catalyst and is unlikely to be environmentally relevant.

The literature review identified three studies on terrestrial species for palladium and its compounds (palladium chloride, palladium sulfate and palladium oxide). Seven endpoints received an acceptable scoring and were selected for deriving the soil quality guideline.

The compiled dataset for palladium terrestrial toxicity data is provided in Appendix B.2, and include a LD10, LD50, and LD90 for mortality in mice and rat species. Table 4-19 summarizes the available terrestrial toxicity data for palladium for consideration with guideline derivation data requirements.

Table 4-15: Summary of Selected Terrestrial Toxicity Data – Palladium

Pathway	Requirements	Remarks
Soil Contact (SQG_{SC})	3 endpoints, including 1 Plant and 1 Soil Invertebrate	None available
Soil and Food Ingestion (SQG_{1C})	2 Mammalian, 1 Avian	7 Mammalian (laboratory rodent)

Notes: Other data requirements, such as livestock species, are not included in the table. Soil contact (SQG_{SC}) requirements are shown for the LOEC and Median Effects Methods only.

The data requirements for the derivation of a SQG for direct contact and soil and food ingestion are not satisfied. Nevertheless, a guideline for soil and food ingestion was derived with consideration of the available data for palladium. The procedure outlined in Section 3.2.2 was followed for the calculation of a SQG_I. The LD10 of 166 µg/g bw/d for 14-d oral exposure to laboratory rat was selected as the lowest effects dose. An uncertainty factor of 500 was applied to account for the various uncertainties related to the selected modified approach. This resulted in a $DTED_{1C}$ of 0.33 µg/g bw/d. With consideration of the soil and food ingestion rates for a meadow vole (*Microtus pennsylvanicus*) and a soil-to-plant BCF of 0.15 from Baes et al. (1984), a SQG_{1C} of 14 µg/g was derived for palladium. The offsite migration check was completed by multiplying the lowest SQG by 14.3 (Section 3.2.3). Table 4-20 summarizes the derived guidelines for palladium based on the available terrestrial toxicity.

Table 4-16: Summary of Derived Environmental SQG – Palladium

Guideline (µg/g)	Land Use			
	Agricultural	Res/Parkland	Commercial	Industrial
Soil Contact (SQG_{SC})	0.012[a]	0.012[a]	0.012[a]	0.012[a]
Soil and Food Ingestion (SQG_{1C})	14	14	-	-
Nutrient and Energy Cycling (SQG_{NEC})	NC[b]	NC[b]	NC[b]	NC[b]
Groundwater – Freshwater Life (SQG_{FL})	NC[c]	NC[c]	NC[c]	NC[c]
Groundwater – Agricultural, Irrigation (SQG_{IR})	NC[c]	-	-	-
Groundwater – Agricultural, Livestock (SQG_{LW})	NC[c]	-	-	-
Off-site migration check (SQG_{OM-E})	-	-	0.17	0.17
SQG_E	0.012			

Notes: ND – no data; NC – not calculated.
a – PNEC for Palladium derived by ECHA.
b – Data are insufficient/inadequate to calculate the nutrient and energy cycling check.
c – Applies to organic compounds and not calculated for metal contaminants.

The derived guideline of 0.012 µg/g for palladium is based on the ECHA PNEC for soil contact. As noted previously, the PNEC is based on the most toxic palladium compound which is unlikely to be environmentally relevant; however, it is the only value available for soil contact. Consideration of the available mammalian data for palladium indicates that the selected guideline is protective of mammals coming into contact with and ingesting soils.

The derived guideline is above background concentrations in soil. Palladium concentrations are increasing in the general environment because of its increased use in automobile catalysts (Nordberg et al. 2014). The palladium concentration in an area around a platinum group metal mine in Sudbury, Ontario was determined to be 0.002 to 0.0045 µg/g and thus the derived guideline of 0.012 µg/g is considered to be appropriate.

Due to a lack of appropriate human health toxicity information the derived guideline does not consider human health effects. Environmental levels of palladium in water, soil, and ambient air are not high, and environmental exposure and intake from food are not significant. The oral toxicity of palladium is believed to be low, although it does depend on the water solubility of the palladium compounds. Skin or mucosal contact with palladium-containing jewelry and dental alloys appears to be an important route of exposure. Palladium is associated with contact allergic reactions. No data are available on its carcinogenicity, reproductive toxicity, or other effects in humans (Nordberg et al. 2014). Based on this information, the SQG of 0.012 µg/g based on ecological endpoints is considered to likely be protective of human health.

4.2.1.6 Platinum

Two studies on terrestrial species, conducted in 1976 and 1984, were available for platinum and its compounds (platinum chloride, platinum oxide, platinum sulphate, and platinum tetrachloride). Ten endpoints received an acceptable scoring and were selected for deriving the soil quality guideline.

The compiled dataset for platinum terrestrial toxicity data is provided in Appendix B.2, and include LD10, LD50, and LD90 for mortality in Sprague-Dawley rats. Table 4-17 summarizes the available terrestrial toxicity data for platinum for consideration with guideline derivation data requirements.

Table 4-17: Summary of Selected Terrestrial Toxicity Data – Platinum

Pathway	Requirements	Remarks
Soil Contact (SQG_{SC})	3 endpoints, including 1 Plant and 1 Soil Invertebrate	None
Soil and Food Ingestion (SQG_{1C})	2 Mammalian, 1 Avian	Laboratory Rodent

Notes: Other data requirements, such as livestock species, are not included in the table. Soil contact (SQG_{SC}) requirements are shown for the LOEC and Median Effects Methods only.

The data requirements for the derivation of a SQG for direct contact and soil and food ingestion are not satisfied. Nevertheless, a guideline for soil and food ingestion was derived with consideration of the available data for platinum. The procedure outlined in Section 3.2.2 was followed for the calculation of a SQG_I. The lowest LD10 of 60 µg/g bw/d for 14-d oral exposure to laboratory rat was selected as the lowest effects dose. An uncertainty factor of 500 was applied to account for the various uncertainties related to the selected modified approach. This resulted in a $DTED_{1C}$ of 0.12 µg/g bw/d. With consideration of the soil and food ingestion rates for a meadow vole (*Microtus pennsylvanicus*) and a soil-to-plant BCF of 0.095 from Baes et al. (1984), a SQG_{1C} of 7.6 µg/g was derived for platinum. The offsite migration check was completed by multiplying the lowest SQG by 14.3 (Section 3.2.3). Table 4-18 summarizes the derived guidelines for platinum based on the available terrestrial toxicity.

There is no soil contact value available for platinum; however since it belongs to the Platinum Group Elements (PGE) and palladium is a potential surrogate due to its location in the periodic table, the existing guideline for palladium for soil contact was used as a surrogate and is included in Table 4-18.

Table 4-18: Summary of Derived Environmental SQG – Platinum

Guideline (µg/g)	Land Use			
	Agricultural	**Res/Parkland**	**Commercial**	**Industrial**
Soil Contact (SQG_{SC})	0.012[a]	0.012[a]	0.012[a]	0.012[a]
Soil and Food Ingestion (SQG_{1C})	7.6	7.6	-	-
Nutrient and Energy Cycling (SQG_{NEC})	NC[b]	NC[b]	NC[b]	NC[b]
Groundwater – Freshwater Life (SQG_{FL})	NC[c]	NC[c]	NC[c]	NC[c]
Groundwater – Agricultural, Irrigation (SQG_{IR})	NC[c]	-	-	-
Groundwater – Agricultural, Livestock (SQG_{LW})	NC[c]	-	-	-
Off-site migration check (SQG_{OM-E})	-	-	0.17	0.17
SQG_E	0.012			

Notes: ND – no data; NC – not calculated.
a – PNEC for Palladium derived by ECHA
b – Data are insufficient/inadequate to calculate the nutrient and energy cycling check.
c – Applies to organic compounds and not calculated for metal contaminants.

The palladium guideline of 0.012 µg/g dw soil is adopted for platinum. A consideration of the available mammalian data for platinum indicates that the selected guideline is protective of mammals coming into contact with and ingesting soils containing platinum. The derived guideline is also above the background concentration in soil, which is approximately 0.0027 µg/g (Nordberg et al. 2014).

Due to a lack of appropriate human health toxicity information the derived guideline does not consider human health effects. The main health effect of platinum compounds is sensitization. Platinum salt sensitivity is manifested as conjunctivitis, rhinitis, and asthma. No health effects from environmental exposure to platinum have been reported (Nordberg et al. 2014). Based on this information, the SQG of 0.012 µg/g based on ecological endpoints is considered to be protective of human health.

4.2.1.7 Rhodium

One study on terrestrial species, conducted in 2014, was available for rhodium and its compounds (rhodium chloride). Four endpoints received an acceptable scoring and were selected for deriving the soil quality guideline. Additional terrestrial toxicity testing for plants and soil invertebrates was completed by Aquatox (Appendix C.2) for rhodium and these data were considered in the derivation of the soil quality guideline.

The compiled dataset for rhodium terrestrial toxicity data is provided in Appendix B.2, and include LOAEC and NOAECs for renal function in Wistar rats. Table 4-19 summarizes the available terrestrial toxicity data for rhodium for consideration with guideline derivation data requirements.

Table 4-19: Summary of Selected Terrestrial Toxicity Data – Rhodium

Pathway	Requirements	Remarks
Soil Contact (SQG_{SC})	3 endpoints, including 1 Plant and 1 Soil Invertebrate	2 Plant, 1 Soil Invertebrate
Soil and Food Ingestion (SQG_{1C})	2 Mammalian, 1 Avian	Laboratory Rodent

Notes: Other data requirements, such as livestock species, are not included in the table. Soil contact (SQG_{SC}) requirements are shown for the LOEC and Median Effects Methods only.

The data requirements for the derivation of a SQG for direct contact are satisfied, and therefore, as described in Section 3.2.1, a SQG_{SC} based on a TEC for agricultural and park land use and an ECL for commercial and industrial land use was derived for rhodium. The lowest IC25 of 6.6 µg/g for reproductive effects on the earthworm *Eisenia andrei* was selected as a reasonable substitute for a LOEC and a TEC of 2.2 µg/g was derived with the application of a factor of 3 (based on using minimum number of studies and assuming IC25 is equivalent to a LOEC). The ECL of 7.9 µg/g was derived as the geometric mean of the IC25 endpoints for the two plant species (*Medicago sativa*, *Hordeum vulgare*) and one soil invertebrate species (*Eisenia andrei*).

From Table 4-19, the soil and food ingestion requirements are not satisfied. Nevertheless, a guideline for soil and food ingestion was derived with consideration of the available data for rhodium. The procedure outlined in Section 3.2.2 was followed for the calculation of a SQG_I. The lowest LOAEC of 0.1 mg/L for 14-d oral exposure to laboratory rat was selected as the lowest effects dose. The LOAEC represents the concentration in drinking water provided *ad libitum*; this was converted to a daily dose of rhodium using an assumed water ingestion rate of 0.046 L/day from Sample et al. (1996) and a body weight of 0.265 kg (Iavicoli et al. 2014), which resulted in a value of 0.02 µg/g bw/d. An uncertainty factor of 500 was applied to account for the various uncertainties related to the selected modified approach. This resulted in a $DTED_{1C}$ of 0.00003 µg/g bw/d. With consideration of the soil and food ingestion rates for a meadow vole (*Microtus pennsylvanicus*) and a soil-to-plant BCF of 0.15 from Baes et al. (1984), a SQG_{1C} of 0.002 µg/g was derived for rhodium. The offsite migration check was completed by multiplying the lowest SQG by 14.3 (Section 3.2.3). Table 4-20 summarizes the derived guidelines for rhodium based on the available terrestrial toxicity.

Table 4-20: Summary of Derived Environmental SQG – Rhodium

Guideline (µg/g)	Land Use			
	Agricultural	Res/Parkland	Commercial	Industrial
Soil Contact (SQG_{SC})	2.2	2.2	7.9	7.9
Soil and Food Ingestion (SQG_{1C})	-[a]	-[a]	-	-
Nutrient and Energy Cycling (SQG_{NEC})	NC[b]	NC[b]	NC[b]	NC[b]
Groundwater – Freshwater Life (SQG_{FL})	NC[c]	NC[c]	NC[c]	NC[c]
Groundwater – Agricultural, Irrigation (SQG_{IR})	NC[c]	-	-	-
Groundwater – Agricultural, Livestock (SQG_{LW})	NC[c]	-	-	-
Off-site migration check (SQG_{OM-E})	-	-	112	112
SQG_E	2.2	2.2	7.9	7.9

Notes: ND – no data; NC – not calculated.
a – The SQG_{1C} derived from terrestrial toxicity data for rhodium of 0.002 µg/g was based on an endpoint for renal effects, which is not a preferred endpoint for the derivation of guidelines and resulted in a value similar to background levels. It was therefore excluded from consideration of the SQG_E.
b – Data are insufficient/inadequate to calculate the nutrient and energy cycling check.
c – Applies to organic compounds and not calculated for metal contaminants.

Background levels of rhodium in soil are in the range of 0.0003 to 0.001 µg/g (Nordberg et al. 2014). It is noted that road dust can contribute to measured levels in soil due to the use of catalytic converters in vehicles. Although the SQG_{1C} derived from terrestrial toxicity data for rhodium is below the SQG_{SC} for agricultural and park land use, the endpoint used to derive the SQG_{1C} is based on renal effects, which is not a preferred endpoint for the derivation of guidelines. The use of this endpoint results in a value similar to background levels. Therefore, the derived SQG_{SC} based on laboratory toxicity data for rhodium is selected for the SQG_E.

Due to a lack of appropriate information the derived guideline does not consider human health effects. Occupational allergic contact dermatitis, contact urticarial and asthma have been confirmed in subjects working in the jewelry trade and exposed to rhodium; however, no reactions were detected in non-occupationally exposed subjects, suggesting that the risk of developing hypersensitivity correlates with the intensity of the exposure (Nordberg et al. 2014). Rhodium in its metallic form is relatively inert but there is some limited data that demonstrate the cytotoxic and genotoxic effects of rhodium on cellular systems and the induction of immunological alterations in animals (Nordberg et al. 2014).

4.2.1.8 Ruthenium

One study on terrestrial species, conducted in 1976, was available for ruthenium and its compounds (ruthenium chloride). Three endpoints received an acceptable scoring and were selected for deriving the soil quality guideline. Additional terrestrial toxicity testing for plants and

soil invertebrates was completed by Aquatox (Appendix C.2) for ruthenium and these data were considered in the derivation of the soil quality guideline.

The compiled dataset for ruthenium terrestrial toxicity data is provided in Appendix B.2, and include a LD10, LD50, and LD90 for mortality in Sprague-Dawley rats. Table 4-21 summarizes the available terrestrial toxicity data for ruthenium for consideration with guideline derivation data requirements.

Table 4-21: Summary of Selected Terrestrial Toxicity Data – Ruthenium

Pathway	Requirements	Remarks
Soil Contact (SQG_{SC})	3 endpoints, including 1 Plant and 1 Soil Invertebrate	2 Plant, 1 Soil Invertebrate
Soil and Food Ingestion (SQG_{1C})	2 Mammalian, 1 Avian	Laboratory Rodent

Notes: Other data requirements, such as livestock species, are not included in the table. Soil contact (SQG_{SC}) requirements are shown for the LOEC and Median Effects Methods only.

The data requirements for the derivation of a SQG for direct contact are satisfied, and therefore, as described in Section 3.2.1, a SQG_{SC} based on a TEC for agricultural and park land use and an ECL for commercial and industrial land use was derived for ruthenium. The lowest IC25 of 3.1 µg/g for reproductive effects on the earthworm *Eisenia andrei* was selected as a reasonable substitute for a LOEC and a TEC of 1.0 µg/g was derived with the application of a factor of 3 (based on using minimum number of studies and assuming IC25 is equivalent to a LOEC). The ECL of 6.8 µg/g was derived as the geometric mean of the IC25 endpoints for the two plant species (*Medicago sativa*, *Hordeum vulgare*) and one soil invertebrate species (*Eisenia andrei*).

From Table 4-19, the soil and food ingestion requirements are not satisfied. Nevertheless, a guideline for soil and food ingestion was derived with consideration of the available data for ruthenium. The procedure outlined in Section 3.2.2 was followed for the calculation of a SQG_I. The LD10 of 180 µg/g bw/d for 14-d oral exposure to laboratory rat was selected as the lowest effects dose. An uncertainty factor of 500 was applied to account for the various uncertainties related to the selected modified approach. This resulted in a $DTED_{1C}$ of 0.36 µg/g bw/d. With consideration of the soil and food ingestion rates for a meadow vole (*Microtus pennsylvanicus*) and a soil-to-plant BCF of 0.075 from Baes et al. (1984), a SQG_{1C} of 28 µg/g was derived for ruthenium. The offsite migration check was completed by multiplying the lowest SQG by 14.3 (Section 3.2.3). Table 4-22 summarizes the derived guidelines for ruthenium based on the available terrestrial toxicity.

Table 4-22: Summary of Derived Environmental SQG – Ruthenium

Guideline (µg/g)	Land Use			
	Agricultural	**Res/Parkland**	**Commercial**	**Industrial**
Soil Contact (SQG_{SC})	1.0	1.0	6.8	6.8
Soil and Food Ingestion (SQG_{1C})	28	28	-	-
Nutrient and Energy Cycling (SQG_{NEC})	NC[a]	NC[a]	NC[a]	NC[a]
Groundwater – Freshwater Life (SQG_{FL})	NC[b]	NC[b]	NC[b]	NC[b]
Groundwater – Agricultural, Irrigation (SQG_{IR})	NC[b]	-	-	-
Groundwater – Agricultural, Livestock (SQG_{LW})	NC[b]	-	-	-
Off-site migration check (SQG_{OM-E})	-	-	97	97
SQG_E	1	1	6.8	6.8

Notes: ND – no data; NC – not calculated.
a – Data are insufficient/inadequate to calculate the nutrient and energy cycling check.
b – Applies to organic compounds and not calculated for metal contaminants.

The guideline of 1 µg/g dw soil for agricultural and park land use is adopted for ruthenium; consideration of the available mammalian data for ruthenium indicates that the selected guideline is protective of mammals coming into contact with and ingesting soils.

Due to a lack of appropriate human health toxicity information the derived guideline does not consider human health effects. Relatively little is known about the biokinetics of ruthenium (IARC 2009); however the limited data available suggest that it is poorly absorbed from the gut and is rapidly eliminated from the body (Nordberg et al. 2014). Based on this information, the SQG of 1 µg/g based on ecological endpoints is considered to likely be protective of human health.

4.2.2 Summary

Table 4-23 provides a summary of the SQGs for the elements of interest in the current literature review.

Table 4-23: Summary of SQGs

Element	SQG (µg/g)	Remarks
Gold	0.1	Based on SQG_{SC} (derived)
Bismuth	20	Medri (2015)
Bromine	10	Medri (2015)
Iodine	4	Medri (2015)
Indium	7.3	Based on SQG_{SC} (ECHA PNEC)
Iridium	2.2	Based on Rhodium SQG
Osmium	1	Based on Ruthenium SQG
Palladium	0.012	Based on SQG_{SC} (ECHA PNEC)
Platinum	0.012	Based on Palladium SQG
Rhodium	2.2	Based on SQG_{SC} (derived)
Ruthenium	1	Based on SQG_{SC} (derived)
Tellurium	250	Medri (2015)
Tungsten	400	Medri (2015)

Notes: PNEC – Probable No Effect Concentration from ECHA dossiers, represents a concentration below which adverse effects in the environment are not expected to occur.

4.3 GROUNDWATER QUALITY GUIDELINES

No groundwater quality guidelines (GQGs) were identified in Medri (2015) for the elements of interest. Therefore, GQGs are derived for all elements considered in the current review. A jurisdictional review did not identify any additional GQGs for the elements of interest. Therefore, GQGs based on protection of aquatic life were derived using the approach described in Section 3.3, as summarized in Table 4-24. As described in Section 3.3, in order to address the data gap due to the lack of drinking water guidelines for human health, for elements with unknown human toxicity or suspected toxicity, the surface water guidelines were adopted as GQGs; otherwise, a factor of 10 was applied to the surface water guideline for the protection of aquatic life to account for dilution when the groundwater discharges to surface water. Although the lack of drinking water guidelines remains a data gap for the derived GQGs, the values are expected to remain protective of human health, since ecological effects on aquatic species are generally more restrictive than human health effects related to the consumption of water.

Table 4-24: Summary of GQGs

Element	WQG (µg/L)	GQG (µg/L)	Rationale
Gold	6	60	Applied dilution factor of 10; considered non-toxic for humans
Bismuth	140	1,400	Applied dilution factor of 10; considered non-toxic for humans
Bromine	2	20	Applied dilution factor of 10; considered non-toxic for humans
Iodine	100	100	Assumed equal to WQG
Indium	41	41	Assumed equal to WQG
Iridium	10	100	Applied dilution factor of 10; considered non-toxic for humans
Osmium	0.067	0.067	Assumed equal to WQG
Palladium	0.068	0.68	Applied dilution factor of 10; considered non-toxic for humans
Platinum	0.61	6.1	Applied dilution factor of 10; considered non-toxic for humans
Rhodium	10	10	Assumed equal to WQG
Ruthenium	10	100	Applied dilution factor of 10; considered non-toxic for humans
Tellurium	5.8	5.8	Assumed equal to WQG
Tungsten	30	16	Default U.S. EPA (2016) screening level value for tapwater

Notes: GQG derived using MOE (2011a) approach and applying a factor of 10 to the WQG, as outlined in Section 3.3

For gold, bismuth, bromine, iridium, palladium, platinum, and ruthenium, a dilution factor of 10 was applied to the WQG for the protection of aquatic life, since these elements are not considered to be a concern for human health. Gold is used in dental alloys, however, this type of exposure apparently has little toxicological significance (Nordberg et al. 2014); therefore, gold is considered to be non-toxic for humans. Although high levels of exposure to bismuth can have toxic effects in humans, most exposures occur through the therapeutic use of bismuth compounds (Nordberg et al. 2014). Therefore, bismuth is considered to not be a concern for human health in this context. WHO (2010) considers the bromine anion, bromide, to have a low degree of toxicity and derived drinking water concentrations based on acceptable daily intake levels that are unlikely to be encountered in drinking water supplies (concentrations of 2 mg/L and higher). Therefore, the derived GQG would be protective of human health for drinking water. Current data relating to environmental iridium concentrations in air, soil, roadside dust, water, and foods indicates that quite low levels that are not thought to pose a serious threat to human health (Nordberg et al. 2014). The oral toxicity of palladium is believed to be low, although it does depend on the water solubility of the palladium compounds (Nordberg et al. 2014). The main health effect of platinum compounds is sensitization. Platinum salt sensitivity is manifested as conjunctivitis, rhinitis, and asthma. No health effects from environmental exposure to platinum have been reported (Nordberg et al. 2014). Relatively little is known about

the biokinetics of ruthenium (IARC 2009); however the limited data available suggest that it is poorly absorbed from the gut and is rapidly eliminated from the body (Nordberg et al. 2014).

For indium, the WQG from Medri (2015) was adopted as the GQG, since the basis of the WQG was not known (possibly human health or other considerations.

For indium, osmium, rhodium, and tellurium, with consideration of human toxicity data, or the lack thereof, the WQG for the protection of aquatic life was selected as the GQG, with no consideration of further dilution in the environment. The International Agency for Research on Cancer (IARC 2006) has determined that indium phosphide, used in the microelectronics industry, is a probable human carcinogen. Exposure to indium, indium arsenide and indium chloride has been shown to produce a number of effects on gene-expression patterns. The marked inhibitory effects of indium on protein synthesis may play a role in altering the activities of DNA repair enzymes and the expression of proteins involved in regulating apoptosis (IARC 2006). Metallic osmium is known to be innocuous (McLaughlin et al. 1946), however the compound osmium tetroxide (which forms on exposure to air) is highly toxic to humans. Rhodium in its metallic form is relatively inert but there is some limited data that demonstrates the cytotoxic and genotoxic effects of rhodium on cellular systems and the induction of immunological alterations in animals (Nordberg et al. 2014). Although tellurium has not been reported to be a human or animal carcinogen and there have been no reports of workers dying from exposure to tellurium or tellurium compounds, accidental deaths have occurred following exposure to sodium tellurite (Nordberg et al. 2014).

For tungsten, the GQG selected is based on the protection of drinking water, since the U.S. EPA (2016) screening level value for tapwater was more restrictive than the aquatic life component.

4.4 SEDIMENT QUALITY GUIDELINES

No sediment quality guidelines (SedQGs) were identified in Medri (2015) for the elements of interest. Therefore, SedQGs are derived for all elements considered in the current review.

4.4.1 Jurisdictional Review

The first step for the derivation of SedQGs for the elements identified in Table 2-1 was the completion of a jurisdictional review (Section 2.2). The jurisdictional review identified guidelines for six elements (bismuth, bromine, indium, iodine, palladium, and tungsten) derived for sediment. These guidelines are summarized in Table 4-25.

Table 4-25: Summary of SedQGs – Jurisdictional Review

Element	SedQG (µg/g)	Remarks
Gold		
Bismuth	65,000	PNEC freshwater derived with a partition coefficient (ECHA)
Bromine	20	RIVM (2000) target level of soil/sediment (SRNL, 2005)
Iodine	4	PNEC freshwater derived with equilibrium partitioning method (ECHA)
Indium	5,050	PNEC freshwater derived with equilibrium partitioning method (ECHA)
Iridium		
Osmium		
Palladium	0.27	PNEC freshwater derived with an assessment factor of 100 (ECHA)
Platinum		
Rhodium		
Ruthenium		
Tellurium		
Tungsten	960	PNEC freshwater derived with equilibrium partitioning method and assessment factor of 10 (ECHA)

Notes: PNEC – Probable No Effect Concentration from ECHA dossiers, represents a concentration below which adverse effects in the environment are not expected to occur. Shading indicates SedQG derived in the following sections.

The sediment quality guideline listed for bromine is a target value from the Dutch Ministry of the Environment (RIVM 2000); RIVM has set the same benchmarks for sediment and soil and should therefore be used with caution. Medri (2015) identified a soil quality guideline for bromine of 10 µg/g. The RIVM value selected for the SedQG for bromine of 20 µg/g is reasonable considering the lack of other available information.

The PNEC derived for palladium by ECHA is based on the most toxic palladium compound diamminedichloropalladium which is an industrial catalyst and thus unlikely to be environmentally relevant. Therefore, a SedQG was also derived for palladium using the Kd approach below.

SedQG were derived as discussed in the following section for the remaining elements of interest.

4.4.2 Sediment Quality Guideline Derivation

In the absence of any sediment-related toxicity data for the elements of interest, SedQG were derived using the approach described in Section 3.4. Sediment/water partitioning coefficients (Kds) for the elements of interest were taken from the ERICA database (Brown et al. 2008) where available and are summarized in Table 4-26; when a sediment/water Kd was not available from the ERICA database, soil/water partitioning coefficients from Baes et al. (1984) were used.

SedQGs were calculated as shown in Table 4-26 using the identified WQG (µg/L) and applying the partition coefficient (L/g) to derive a SedQG (µg/g). Consideration was also given to potential surrogates and radiotoxicity.

Table 4-26: Derivation of SedQGs

Element	WQG (µg/L)	Kd (L/g)	SedQG (µg/g)
Gold	6	25[a]	150
Bismuth	140	-[b]	65,000
Bromine	2	-[b]	20
Iodine	100	-[b]	4
Indium	41	-[b]	5,050
Iridium	10	266	2,700
Osmium	0.067	450[a]	30
Palladium	0.068	60[a]	4.1
Platinum	0.61	90[a]	55
Rhodium	10	60[a]	600
Ruthenium	10	39	390
Tellurium	5.8	5.3	31
Tungsten	30	-[b]	960

Notes: SedQG derived using the approach used by ECHA , as outlined in Section 3.4
a –in the absence of available sediment/water partitioning coefficient, soil/water partitioning coefficients from Baes et al. (1984) were used
b – not applicable, SedQG available from jurisdictional review.

4.4.3 Summary

Table 4-27 provides a summary of the SedQGs for the elements of interest in the current literature review.

Table 4-27: Summary of SedQGs

Element	SedQG (µg/g)	Remarks
Gold	150	Calculated using literature Kd (soil)
Bismuth	65,000	PNEC freshwater derived with a partition coefficient
Bromine	20	RIVM (2000) target level of soil/sediment
Iodine	4	PNEC freshwater derived with equilibrium partitioning method
Indium	5,050	PNEC freshwater derived with equilibrium partitioning method
Iridium	2,700	Calculated using literature Kd
Osmium	30	Calculated using literature Kd (soil)
Palladium	4.1	Calculated using literature Kd (soil)
Platinum	55	Calculated using literature Kd (soil)
Rhodium	600	Calculated using literature Kd (soil)
Ruthenium	390	Calculated using literature Kd
Tellurium	31	Calculated using literature Kd
Tungsten	960	PNEC freshwater derived with equilibrium partitioning method and assessment factor of 10

Notes: PNEC – Probable No Effect Concentration from ECHA dossiers, represents a concentration below which adverse effects in the environment are not expected to occur.

4.5 AIR QUALITY GUIDELINES

Table 4-28 summarizes the available air quality guidelines (AQGs) from Medri (2015) and identifies the elements which require further investigation for the development of AQGs in this study.

Table 4-28: Summary of AQGs – Initial Stage

Element	AQG (µg/m^3)
Gold	
Bismuth	100
Bromine	20
Iodine	0.67
Indium	
Iridium	
Osmium	
Palladium	
Platinum	0.2
Rhodium	
Ruthenium	
Tellurium	10
Tungsten	67

Notes: Values from Medri (2015). Shading indicates guideline derived in the following sections.

4.5.1 Jurisdictional Review

The first step for the derivation of AQGs for the elements identified in Table 4-28 was the completion of a jurisdictional review (Section 2.2). The jurisdictional review identified six additional guidelines (gold, indium, osmium, palladium, rhodium, and ruthenium), as summarized in Table 4-29.

Table 4-29: Summary of AQGs – Jurisdictional Review

Element	AQG (µg/m^3)	Remarks
Gold	2.5	TCEQ (2016), interim long-term ESL for health
Bismuth	100	Medri (2015)
Bromine	20	Medri (2015)
Iodine	0.67	Medri (2015)
Indium	0.1	TCEQ (2016), interim long-term ESL for health
Iridium		
Osmium	0.002	TCEQ (2016), interim long-term ESL for health
Palladium	5	TCEQ (2016), interim long-term ESL for health
Platinum	0.2	Medri (2015)
Rhodium	0.1	TCEQ (2016), interim long-term ESL for health
Ruthenium	3	TCEQ (2016), interim long-term ESL for health
Tellurium	10	Medri (2015)
Tungsten	67	Medri (2015)

Notes: ESL – Effects Screening Level from TCEQ (2016), represents a concentration below which adverse effects in the environment are not expected to occur. Shading indicates AQG derived in the following sections.

TCEQ (2016) provided Effects Screening Levels (ESLs) for a number of elements of interest, as indicated in Table 4-29. The ESLs are based on health effects data, potential nuisance odours, and effects on vegetation; however, they are screening levels and not ambient air standards. Therefore, if an air concentration exceeds the screening level, a more detailed review should be conducted. If the screening level is not exceeded, then adverse health and welfare effects are not expected. The ESLs presented in Table 4-29 are long-term values and apply to an annual averaging period.

The Ontario MOECC (2019) has published a 24-hr ambient air quality criteria for palladium of 10 µg/m^3 based on health effects. This value is provided for consideration, however the ESL from TCEQ (2016) is selected for the guideline, since the ESL represents an annual averaging period.

The review of toxicity data for the remaining elements of interest to this study are provided in the following section.

4.5.2 Toxicity Review

Toxicity data related to potential chemical effects from exposure to iridium were not found. Therefore, the following sections provide a qualitative discussion for the derivation of appropriate AQGs for this element.

4.5.2.1 Iridium

Iridium belongs to the Platinum Group Elements (PGE) and little is known of its toxicological characteristics (Nordberg et al. 2014). Current data relating to environmental iridium concentrations in air, soil, roadside dust, water, and foods indicate quite low levels that are not thought to pose a serious threat to human health. Authorities such as the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the German Research Foundation (Deutsche Forschungsgemeinshaft) have not established threshold values for iridium in air (Nordberg et al. 2014). In contrast with other PGE, which have shown an increasing trend in airborne concentrations, iridium concentrations in air over the past few decades have remained relatively stable (Nordberg et al. 2014). Measured iridium concentrations in air have been reported as high as 3.73 pg/m^3 (or 3.73 x 10^{-6} µg/m^3).

Considering the lack of information related to potential negative effects from exposure to iridium in air, the established guideline for rhodium was identified as potential surrogate for iridium based on its location in the periodic table and also being a member of the PGE. This guideline is several orders of magnitude above measured concentrations in the environment, as reported in Nordberg et al. (2014).

4.5.3 Summary

Table 4-30 provides a summary of the AQGs for the elements of interest in the current literature review.

Table 4-30: Summary of AQGs

Element	AQG (µg/m^3)	Remarks
Gold	2.5	TCEQ (2016), interim long-term ESL for health
Bismuth	100	Medri (2015)
Bromine	20	Medri (2015)
Iodine	0.67	Medri (2015)
Indium	0.1	TCEQ (2016), interim long-term ESL for health
Iridium	0.1	Adopted AQG for surrogate (rhodium)
Osmium	0.002	TCEQ (2016), interim long-term ESL for health
Palladium	5	TCEQ (2016), interim long-term ESL for health
Platinum	0.2	Medri (2015)
Rhodium	0.1	TCEQ (2016), interim long-term ESL for health
Ruthenium	3	TCEQ (2016), interim long-term ESL for health
Tellurium	10	Medri (2015)
Tungsten	67	Medri (2015)

Notes: ESL – Effects Screening Level from TCEQ (2016), represents a concentration below which adverse effects in the environment are not expected to occur.

5. DISCUSSION

Table 5-1 provides a summary of the various aspects considered for the derived criteria for each environmental media. As shown in the table, human health data were limited with the exception of air. Additionally, data were limited to consider potential effects on agricultural and drinking water uses. Thus, the criteria were generally derived based on ecological endpoints. In Table 5-1, an overall level of uncertainty was assigned to the criteria developed for each media; this designation was assigned based on professional judgement and primarily reflects the lack of information on human health and the relevance of this pathway for a particular guideline. Drinking water guidelines, a component of the derivation for both surface water and groundwater, were not available for the elements of interest; this is considered a more significant data gap for groundwater ("high" level of uncertainty) than surface water ("medium" level of uncertainty) for the reasons discussed in Section 3.1. Human health data were not available for consideration in the derivation of soil criteria. Qualitative information available regarding possible human health effects for exposure to the elements of interest were considered in the context of the soil guideline derivations; therefore, this data gap was considered to result in a "medium" level of uncertainty for the derived guidelines. For sediment guidelines, the sediment exposure pathway is typically not significant for human exposures; the derived guidelines were based on ecological data, which is considered more relevant for sediment guidelines. Therefore, the lack of human health effects was considered to result in a "medium" level of uncertainty for the derived sediment guidelines. Finally, air quality guidelines were based largely on jurisdictional values that considered potential negative effects on human health; this was considered to result in a "low" level of uncertainty for the air guidelines.

Table 5-1: Aspects Considered for Derived Criteria

Media	Surface Water[a]			Groundwater			Soil		Sediment			Air		
Element	**Drinking Water**	**Aquatic Life**	**Agricultural Uses**	**Drinking Water**	**Agricultural Uses**	**Surface Water**	**Ecological Health**	**Human Health**	**Aquatic Life**	**Human Health**	**Environment**	**Human Health**	**Environment**	**Nuisance (odour)**
Gold	X	√	X	X	X	√	√	X	√	X	√	√	√	√
Bismuth	X	√	X	X	X	√		b	√	X	√		b	
Bromine	X	√	X	X	X	√		b	X	X	√		b	
Iodine		b		X	X	√		b	√	X	√		b	
Indium	X	√	X	X	X	√	√	X	√	X	√	√	√	√
Iridium	X	√	X	X	X	√	√	X	√	X	√	√	X	X
Osmium	X	√	X	X	X	√	√	X	√	X	√	√	√	√
Palladium	X	√	X	X	X	√	√	X	√	X	√	√	√	√
Platinum	X	√	X	X	X	√	√	X	√	X	√		b	
Rhodium	X	√	X	X	X	√	√	X	√	X	√	√	√	√
Ruthenium	X	√	X	X	X	√	√	X	√	X	√	√	√	√
Tellurium	X	√	X	X	X	√		b	√	X	√		b	
Tungsten		b		√	X	√		b	√	X	√		b	
Level of Uncertainty[c]	Medium			High			Medium		Medium			Low		

Notes: X – not considered; √ –considered.
a – recreational and aesthetic uses are not appropriate for the elements of interest.
b – value from Medri (2015).
c – overall level of uncertainty was assigned to the criteria developed for each media; this designation was assigned based on professional judgement and primarily reflects the lack of information on human health and the relevance of this pathway for a particular guideline. See text for additional detail.

Table 5-2 provides an accounting of the various data gaps and uncertainties involved in the derivation of the guidelines for each element in the current review. In Table 5-2, an overall level of uncertainty was assigned to the criteria developed for each media; this designation was assigned based on professional judgement and consideration of the data gaps included in the derived guidelines. Typically, guidelines that were based on jurisdictional values or considered some element-specific data were considered to have a lower level of uncertainty than guidelines that were based entirely on surrogate assumptions or methods using default (non-element specific) parameters. It is not possible to discern at this time how the derived guidelines would change with additional element-specific toxicity data; however the uncertainty in the derived values will be less when more relevant data become available.

Table 5-2: Summary of Data Gaps and Limitations

Guideline	Uncertainty/ Data Gap	Level of Uncertainty	Element
Water Quality	Use of ECHA PNEC	Low	Bismuth, Tellurium, Indium
	Use of UK EA lowest chronic value	Low	Bromine
	Use of Limited Dataset with consideration of ECHA PNEC	Low	Palladium
	Derived Type B2 guideline	Low	Rhodium, Ruthenium
	Use of Limited Dataset with consideration of acute and chronic data	Low	Platinum
	Use of Limited Dataset – no chronic toxicity data	Medium	Gold, Iridium
	Use of Limited Dataset – no fish data or chronic toxicity data	High	Osmium
Groundwater Quality	Use of U.S. EPA screening level for tapwater	Low	Tungsten
	Use of Default Factor of 10	High	Gold, Bismuth, Bromine, Iridium, Palladium, Platinum, Ruthenium
	Use of WQG	High	Iodine, Indium, Osmium, Rhodium, Tellurium
Soil Quality	Use of ECHA PNEC	Low	Indium, Palladium
	Derived SQG_E	Low	Rhodium, Ruthenium
	Use of Limited Dataset – no ingestion pathway data	Medium	Gold
	Use of Surrogate	High	Iridium, Osmium, Platinum
Sediment Quality	Use of ECHA PNEC	Low	Bismuth, Indium, Iodine, Tungsten
	Use of RIVM	Medium	Bromine
	Use of Literature Kd	Medium	Iridium, Tellurium, Ruthenium
	Use of Literature Kd (soil)	High	Gold, Osmium, Palladium, Platinum, Rhodium
Air Quality	Use of TCEQ	Low	Gold, Indium, Osmium, Palladium, Rhodium, Ruthenium
	Use of Surrogate	High	Iridium

6. CONCLUSIONS

The derived interim acceptance criteria for the elements of interest are provided in Table 6-1. These criteria were derived based on the existing jurisdictional values and the available toxicity data compiled from a literature search. Effort was made to derive appropriate values for each media and element but there are some residual gaps and the values are associated with varying levels of uncertainty (see Section 5).

Table 6-1: Summary of Interim Acceptance Criteria

Element	Surface Water (µg/L)	Groundwater (µg/L)	Soil (µg/g)	Sediment (µg/g)	Air (µg/m^3)
Gold	6	60	0.1	150	2.5
Bismuth	140	1,400	20	65,000	100
Bromine	2	20	10	20	20
Iodine	100	100	4	4	0.67
Indium	41	41	7.3	5,050	0.1
Iridium	10	100	2.2	2,700	0.002
Osmium	0.067	0.067	1	30	0.1
Palladium	0.068	0.68	0.012	4.1	5
Platinum	0.61	6.1	0.012	55	0.2
Rhodium	10	10	2.2	600	0.1
Ruthenium	10	100	1	390	3
Tellurium	5.8	5.8	250	31	10
Tungsten	30	16	400	960	67

Notes: Shading indicates guideline derived in the current review. Unshaded values from Medri (2015).

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ACRONYMS

AQG	Air Quality Guideline
BCF	Soil-to-Plant Bioconcentration Factor
BF	Bioavailability Factor
BW	Body Weight
CCME	Canadian Council of Ministers of the Environment
DTED	Daily Threshold Effects Dose
ECx	Effects Concentration – x %
ECCC	Environment and Climate Change Canada
ECHA	European Chemicals Agency
ECL	Effects Concentration – Low
EDI	Estimated Daily Intake
ESL	Effects Screening Level
FCSAP	Federal Contaminated Sites Action Plan
FIR	Food Ingestion Rate
GQG	Groundwater Quality Guideline
HSDB	Hazardous Substances Data Bank
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
ICx	Inhibition Concentration – x %
IRIS	Integrated Risk Information System
ITER	International Toxicity Estimates for Risk
Kd	Sediment/Water Partitioning Coefficient
LCx	Lethal Concentration – x %
LOAEC	Lowest Observable Adverse Effects Concentration
LOEC	Lowest Observable Effects Concentration
MATC	Maximum Acceptable Toxicant Concentration
MOE	Ontario Ministry of the Environment
MOECC	Ontario Ministry of the Environment and Climate Change
NC	Not Calculated
ND	No Data
NIOSH	National Institute for Occupational Safety and Health
NOAEC	No Observable Adverse Effects Concentration
NOEC	No Observable Effects Concentration
NSTP	National Status and Trends Program
NWMO	Nuclear Waste Management Organization
OSHA	Occupational Safety and Health Administration
PGE	Platinum Group Elements
PNEC	Probable No Effects Concentration
RIVM	Dutch Ministry of the Environment
SedQG	Sediment Quality Guideline
SIR	Soil Ingestion Rate
SQG	Soil Quality Guideline
SQG_E	Soil Quality Guideline for Environment
SQG_{FL}	Soil Quality Guideline for Freshwater Life
SQG_{HH}	Soil Quality Guideline for Human Health
SQG_I	Soil Quality Guideline for Soil and Food Ingestion
SQG_{IF}	Soil Quality Guideline for Agricultural Irrigation Uses
SQG_{LW}	Soil Quality Guideline for Agricultural Livestock Watering

SQG_{NEC}	Soil Quality Guideline for Nutrient and Energy Cycling
SQG_{OM-E}	Soil Quality Guideline for Offsite Migration
SQG_{SC}	Soil Quality Guideline for Soil Contact
SQG_{1C}	Soil Quality Guideline for Primary Consumers
SQG_{2C}	Soil Quality Guideline for Secondary Consumers
SQG_{3C}	Soil Quality Guideline for Tertiary Consumers
SRNL	Savannah River National Laboratory
SSD	Species Sensitivity Distribution
SST	Spiked-Sediment Toxicity Test
TCEQ	Texas Commission on Environmental Quality
TEC	Threshold Effects Concentration
U.S. EPA	United States Environmental Protection Agency
WHO	World Health Organization
WQG	Water Quality Guideline

APPENDIX A.1: AQUATIC TOXICITY STUDY EVALUATION FORMS

Ref: Bengtsson,B.E., and M. Tarkpea, 1983. The Acute Aquatic Toxicity of Some Substances Carried by Ships. Mar. Pollut. Bull, 14(6): 213-214.

Medium: Saltwater

Substance CAS RN: Osmium tetroxide

Purity/formulated product: NR

Score: 3

Acceptability: Unacceptable

Justification: very little information provided and statistical test failed for osmium, units assumed based on AQUIRE, no measured data

Test Organisms: Nitocra spinipes

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	0	No information provided	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	0	Details on testing procedures have been published previously by Linden et al. (1979), from which some data are included in the present report, for the sake of completeness.	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	0	No information provided	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	0	No information provided	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	Acute (96-hr)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	0	No information provided	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	This was due to fast chemical reaction in the water (osmium tetroxide), resulting in a poor correlation between dose and response. The subsequent probit analysis did not result in acceptable 96 h LC50 values (too high)~2 values), but based on repeated tests, the possible range was estimated.	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	LC50 with 95% confidence limits	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	0	No information provided	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	3		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 10/03/2017

Other notes:

Ref: Biesinger,K.E., and G.M. Christensen, 1972. Effects of Various Metals on Survival, Growth, Reproduction and Metabolism of Daphnia magna. J. Fish. Res. Board Can., 29(12): 1691-1700.

Medium: Freshwater

Substance CAS RN: Gold Au (III); Platinum Pt(IV)

Purity/formulated product: Reagant grade

Score: 15

Acceptability: Acceptable (secondary)

Justification: Old study but robust methodology; nominal concentrations

Test Organisms: Daphnia magna (water flea)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	2	considered physicochemical properties and solubility	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	Standard test method not cited, but detailed design provided, 5 to 12 concentrations tested	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	assume nominal	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Control measures applied, results not reported	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	3-week (chronic)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	reagent grade used	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	2	LC50 and EC16 (reproductive impariment)	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Litchfield and Wilcoxon and 95% CI reported for LC50s, and reproductive impairment statistically analyzed (no confidence limits)	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	from laboratory clone	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	15		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 05/04/2017

Other notes:

Ref: Borgmann,U., Y. Couillard, P. Doyle, and D.G. Dixon, 2005. Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.

Score: 13

Medium: Fresh water

Acceptability: Acceptable (secondary)

Substance CAS RN:

Bismuth	7440699
Gold	7440575
Indium	7440746
Iridium	7439885
Osmium	7440042
Palladium	7440053
Platinum	7440064
Rhodium	7440166
Ruthenium	7440188
Tellurium	13494809
Tungsten	7440337

Justification: Modified tox test, control measures considered, measured concentrations however, LC50 endpoints

Purity/formulated product: in preservative (varies); used lab standards, purity not reported

Test Organisms: Hyalella azteca

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Relatively large test volumes were used in order to reduce the surface area:volume ratio and decrease potential adsorption, and also to reduce pipetting variability from handling small volumes of stock solutions.	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Modified classic toxicity test in order to test a large number of substances	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	Measured and nominal	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	Only data from experiments with <=80% control survival were used.	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	1-week; considered by authors to be acute since insufficient for measuring reproduction effects	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Used lab standards in specified preservatives; used acid controls as necessary	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	LC50s reported only	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Trimmed Spearman-Karber method [9]. In cases where the confidence limits could not be computed reliably (e.g., if there were no partial effect concentrations), the concentrations tested on either side of the LC50 are listed; justification provided	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	originated from Valens Conservation Area (ON, Canada), in 1985 and were cultured as described in Borgmann et al.; for laboratory purposes 30 years prior to test being conducted - consider this equivalent to commercial, non-contaminated	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	13		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 22/02/2017

Other notes:

Ref: Buhl,K.J., and S.J. Hamilton, 1991. Relative Sensitivity of Early Life Stages of Arctic Grayling, Coho Salmon, and Rainbow Trout to Nine Inorganics. Ecotoxicol. Environ. Saf., 22: 184-197.

Medium: Freshwater

Substance CAS RN: Gold

Purity/formulated product: Auric chloride, Hydrochloride

Score: 12

Acceptability: Acceptable (secondary)

Justification: Std tox test, control measures considered, however nominal concentrations and LC50 endpoints

Test Organisms: Arctic grayling (Thymaflus arcticus), coho salmon (Oncorhynchus kisutch), and rainbow trout (0. mykiss)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	0	Not mentioned	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	Static acute toxicity tests were conducted in reconstituted soft water prepared as recommended by the American Society for Testing and Materials (ASTM, 1988). Static test procedures used in this study closely followed those outlined by ASTM (1988).	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal concentrations given here were expressed as the total inorganic toxicant added as determined from the certificate of analysis for each compound.	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	There was no mortality in the control treatments from the tests.	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	Acute (96 hr)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Yes	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	LC50s	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	The LC50 values and their 95% confidence intervals were calculated by the method of Litchfield and Wilcoxon (1949).	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Arctic grayling were obtained as eyed eggs from Flathead Lake Salmon Hatchery, Somers, Montana, in 1987 and 1988. Coho salmon were obtained as juveniles from Clear State Hatchery, Clear, Alaska, in 1985 and as eyed eggs from Puyallup Salmon Hatchery, Orting, Washington, in 1986. Rainbow trout were obtained as eyed eggs from Ennis National Fish Hatchery, Ennis, Montana, in 1986.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	12		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 10/03/2017

Other notes:

Ref: De Jong,L.E.D., 1965. Tolerance of Chlorella vulgaris for Metallic and Non-Metallic Ions. Antonie van Leeuwenhoek (Gedrukt), 31: 301-313.

Medium: Freshwater

Substance CAS RN: Indium InCl3

Purity/formulated product: analytical grade

Score: 12

Acceptability: Acceptable (secondary)

Justification: Based on comments of authors to consider results as preliminary due to replication issues

Test Organisms: Chlorella vulgaris (green algae)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	2	Complications associated with use of metal salts and basal medium; study regarded as limited scope and exploration to further future work; additional consideration of using highest solubility salts	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	23 exposure concentrations (plus control) tested	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Controls used but not reported	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	Chronic (3-month)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Medium and % concentrations tested	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	NOEC and LOEC	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	0	No details on statistics presented	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	From the Laboratory of Microbiology Technological University, Delft	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	12		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 05/04/2017

Other notes:

Ref: Farago,M.E., and P.J. Parsons, 1994. The Effects of Various Platinum Metal Species on the Water Plant Eichhornia crassipes (MART.) Solms. Chem. Spec. Bioavail, 6(1): 43070.

Medium: Freshwater

Substance CAS RN: Platinum
Palladium
Ruthenium ammonium compound not considered
Iridium
Osmium
Rhodium

Purity/formulated product: NR

Score: 6

Acceptability: Acceptable (secondary)

Justification: inferred endpoints based on narrative description
LOEC - first concentration with observed effect
NOEC - next lowest concentration without observed effect

Test Organisms: Eichhornia crassipes (water hyacinth)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	0	Not mentioned	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Growth and uptake experiments (numbers 5-10, 12-14 and 18) were carried out as described previously (Farago and Parsons, 1985, 1986). Score based on 4 exposure concentrations plus control.	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Control plants were grown at the same time in half-strength nutrient solution only.	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	14-d exposure (not defined)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	Nutrient solution, but no other information provided	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	No endpoints reported, inferred	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	0	No endpoints reported, inferred	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	1	Insufficient information	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	6		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 10/03/2017

Other notes:

Ref: Harry,H.W., and D.V. Aldrich, 1963. The Distress Syndrome in Taphius glabratus (Say) as a Reaction to Toxic Concentrations of Inorganic Ions. Malacologia, 1(2): 283-289.

Medium: Freshwater

Substance CAS RN: Gold

Purity/formulated product:

Score: Not scored as could not locate paper

Acceptability: Secondary (assumed)

Justification: From AQUIRE, not able to locate paper, assume secondary

Test Organisms: Biomphalaria glabrata (snail)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2			Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2			Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2			Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2			Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2			Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2			Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2			EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2			ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2			Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	0		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 14/03/2017

Other notes:

Ref: Jones, J.R.E., 1939. The Relation Between the Electrolytic Solution Pressures of the Metals and Their Toxicity to the Stickleback (Gasterosteus aculeatus L.). J. Exp. Biol., 16(4): 425-437.

Medium: Freshwater

Substance CAS RN: Gold HAuCl4

Purity/formulated product:

Score: 8

Acceptability: Unacceptable

Justification: No standard method; no endpoint; no measured data

Test Organisms: Gasterosteus aculeatus (stickleback)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	2	Considered decomposition of gold salts in light and also stability of the compound	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Experimental design based on previous studies (old study, no standard method menthioned)	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	0	Assume nominal, but lowest concentration tested produced toxic effects, so score 0	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Considered control survival	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	10-d, does not satisfy CCME criteria for chronic, but based on control survival so consider chronic	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	brief description of solution preparation provided	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	LC100 inferred, lowest concentration tested resulted in toxic effects	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	0	no mention of statistical calculations	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	1	no description provided	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	8		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 05/04/2017

Other notes:

Ref: Jones, J.R.E., 1940. A Further Study of the Relation Between Toxicity and Solution Pressure, with Polycelis nigra as Test Animal. J. Exp. Biol., 17: 408-415.

Medium: Freshwater

Substance CAS RN: Gold HAuCl4

Purity/formulated product: analytical grade reagent

Score: 7

Acceptability: Acceptable (secondary)

Justification: No standard method; nominal conc; not many details provided

Test Organisms: Polycelis nigra (worm)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Unstable salt solutions were renewed	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Old study, so no standard methods presented, however two series of tests were completed - the first for 4 - 5 widely spaced concentrations and then the second based on a narrower concentration range with 10-15 concentrations	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	assume nominal	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	no mention of controls other than in discussion of determining the threshold of toxicity	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	48-hr (acute)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	Reagant grade and brief description of solution preparation provided	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	only a NOEC reported	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	0	no details on statistical calculations provided	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	1	insufficient information	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	7		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 05/04/2017

Other notes:

Ref: Khangarot,B.S., 1991. Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.

Medium: Freshwater

Substance CAS RN: Palladium chloride
Platinum chloride (PtCl2)
Osmium oxide (OsO4)
Tellurium (Telluric acid (H2TeO3))

Purity/formulated product: at least reagent grade in quality

Score: 14

Acceptability: Acceptable (secondary)

Justification: Standard method, control considerations; however, acute study, nominal concentrations and EC50 immobilization endpoint

Test Organisms: Tubifex tubifex (Muller), tubicifid worm

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Consideration of solubility	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	Test concentrations were selected on a logarithmic scale as outlined in standard ethods (APHA et al. 1981)	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	In control tests, tubificid worms remained active during the test period. They were clustered at the bottom of the test container and showed typical tubificid movement.	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	Acute	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Stock solutions were prepared in distilled water	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	EC50	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	EC50 (effective concentration at which 50% immobilization response was recorded) values and 95% confidence limits were calculated by the moving average angle method (Harris 1959).	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Tubificid worms, Tubifex tubifex, were collected from Gheru Campus of ITRC, Lucknow, from natural sources and acclimatized to laboratory conditions for 7 days prior to experiments. Toxicity research centre - assume non-contaminated	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	14		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 10/03/2017

Other notes:

Ref: Khangarot,B.S., and S. Das, 2009. Acute Toxicity of Metals and Reference Toxicants to a Freshwater Ostracod, Cypris subglobosa Sowerby, 1840 and Correlation to EC50 Values of Other Test Models. J. Hazard. Mater., 172: 641-649.

Medium: Freshwater

Substance CAS RN:

Bismuth	10361441
Osmium	20816120
Palladium	158898954
Platinum	10025657
Tungsten	13472452

Purity/formulated product: Bismuth nitrate, BI(NO3)3*5H2O; Osmium oxide; Palladium chloride; Platinum chloride (PtCl2); Sodium tungstenate, NA2WO4*2H2O; 98% pure

Score: 12

Acceptability: Acceptable (secondary)

Justification: Although test method not reported, thorough study design; however, acute study and EC50 for immobilization.

Test Organisms: Cypris subglobosa (crustacean)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Consideration of physicochemical properties and metal ion toxicity	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Ostracods were exposed for 48 h to logarithmic series of concentrations (7–10) of metals and reference toxicants. Ten ostracods (C. subglobosa) were exposed to each test concentration in 20 ml glass petri dishes, and each concentration was tested in replicates of three. However, no methods/protocols cited.	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	A stock solution from each metal salt was prepared in double glass-distilled water. Serial dilutions were prepared from the respective stocks to the desired range; so all the concentrations referred in this paper are nominal.	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	In control tests, ostracods remain active throughout the test period.	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20%) (0)
5	Chronic or life cycle test was used	2	1	24-hr and 48-hr (acute)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	All the tested metallic salts were reagent grade (>98–99.9% purity) in quality and purchased from Sigma–Aldrich, BDH, SRL (India), and E. Merck (India); mixed with distilled water	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	EC50 reported only	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	EC data presented with 95% CI	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Freshwater ostracod, C. subglobosa Sowerby, 1840 were collected with the help of plankton net from fish ponds situated at Gheru Campus of IITR, Lucknow, India - this is a toxicological research center	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	12		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 17/02/2017

Other notes:

Ref: Robinson, M.G., Brown, L.N., Hall, B.D., 1997. Effect of gold(III) on the fouling diatom Amphora coffeaeformis: uptake, toxicity and interactions with copper. Biofouling, 11: 59-79.

Score: 8

Medium: Culture medium (saltwater)

Substance CAS RN: (AuCl-4)

Purity/formulated product:

Acceptability: Acceptable (secondary)

Justification: nominal concentrations, no endpoints

Test Organisms: DIATOM AMPHORA COFFEAEFORMIS

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Concentrated stocks were acidified to prevent complexation losses	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	5 exposures + control	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Controls used	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	20-d exposure (chronic)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	Stocks were freshly prepared for each experiment to avoid losses due to reduction. Gold used in all toxicity and uptake experiments was tetrachloroaurate.	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	inferred LOEC from results	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	0	no	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	1	isolated and cultured as described previously (Robinson et al, 1992), except that illumination was reduced to 4 x 1015 quanta cm"2s"', and the temperature adjusted to 15°C, conditions which produce optimal growth in this species.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	8		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 13/03/2017

Other notes:

Ref: Stokes,P.M., 1981. Multiple Metal Tolerance in Copper Tolerant Green Algae. J. Plant Nutr.3(1-4):, 3: 667-678.

Medium: Freshwater

Substance CAS RN: Gold

Purity/formulated product: NR

Score: 9

Acceptability: Acceptable (secondary)

Justification: Nominal concentrations, ">" endpoint

Test Organisms: Scenedesmus acutiformis (green algae)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	0	No information provided	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	replicate test	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Controls were used, but not reported	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	Chronic (6-8 d)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	Some details on culture medium provided, but chemical details lacking	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	EC50, reported as ">"	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	0	No information provided	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Algae were isolated as described in Stokes et al (1973a), maintained in axenic condition and grown in batch culture in 20% modified Bolds medium as described by Stokes (1975). The reference (lab) isolate was Scenedesmus acuminatus and the lake isolate Scenedesmus acutiformis f. alternans.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	9		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 10/03/2017

Other notes:

Ref: Zimmermann,S., C. Wolff, B. Sures, 2017. Toxicity of platinum, palladium and rhodium to Daphnia magna in single and binary metal exposure experiments. Environmental Pollution, in press (Feb 2017)

Score: 15

Medium: Fresh water

Acceptability: Acceptable (primary)

Substance CAS RN: Platinum (Pt(IV))
Palladium (Pd(II))
Rhodium (Rh(III))

Justification: Test completed under standardized method, measured concentrations, control measures met.

Purity/formulated product: Single metal standard solutions

Test Organisms: Daphnia magna

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Oxidation state considered/tested	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	OECD Guideline 202, with modification for feeding	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	Measured concentrations	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	not more than 10% effect in control and reference experiment was in good accordance with the expected range	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	24-hr and 48-hr duration endpoints (acute)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Test solutions prepared using OECD Guideline 202 and DIN EN ISO6341	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	EC50 (immobility) and LC50 reported	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Hill slope and 95% CI reported	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Test organisms from DaphToxKit (Laboratory for Environmental Toxicology and Aquatic Ecology)	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	15		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 05/04/2017

Other notes:

Ref: Mello-Andrade F, Cardoso CG, Silva CRE, Chen-Chen L, Melo-Reis PR, Lima AP, Oliveira R, Ferraz IBM, Grisolia CK, Almeida MAP, Batista AA, Silveira-Lacerda EP. 2018. Acute toxic effects of ruthenium (II)/amino acid/diphosphine complexes on Swiss mice and zebrafish embryos.Biomedicine & Pharmacotherapy 107 (2018) 1082–1092.

Medium: Fresh water

Substance CAS RN: [Ru(L-Met)(dppb)(bipy)]PF6

Purity/formulated product: Single metal standard

Score: 14

Acceptability: Acceptable (secondary)

Justification: Test completed under standardized method, Nominal concentrations, control measures met.

Test Organisms: Zebrafish eggs

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Yeilds considered, discussion if complexes are stable in medium	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	OECD Guidelines specified	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal concentrations	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	positive and negative controls used	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	24-hr and 48-hr duration endpoints (acute)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Test solutions prepared using OECD Guideline	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	LD50/LC50 reported	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	ANOVA followed by the Tukey test. Statistical significance was considered at $p < 0.05$. Data were expressed as means and Standard Error of Means (SEM) or SD. All statistical analyses were performed using the statistical software GraphPad Prism, version 5 for Windows	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	The zebrafish eggs and adults used in this study were obtained from the ZebTech - Tecniplast (Varese, Italy) facility at the Laboratory of Toxicological Genetics, Department of Genetics and Morphology, University of Brasília (Brazil)	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	14		

Note:

Evaluator: NT

Evaluation Date: 26/04/2019

Other notes:

Ref: Ferreira and Wolke. 1979. Acute Toxicity of Platinum to Coho Salmon (Oncorhynchus kisutch). Marine Pollution Bulletin, Vol. 10, pp. 79-83

Medium: Fresh water

Substance CAS RN: PtCl42HCI; 6 H20

Purity/formulated product: Static renewal water acute

Score: 13

Acceptability: Acceptable (secondary)

Justification: Test completed under standardized method, Nominal concentrations, control measures met.

Test Organisms: Coho salmon fry

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	2	DO, pH, and hardness considered	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	Bioassay procedures used for determining LC50 values were those recommended by APHA Standard Methods (1971); 7 exposure concentrations including a control	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal concentrations	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	One control included	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	24-hr, 48-hr, 96-hr duration endpoints (acute, according to CCME)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	Form of solution stated (PtCi42HCI'6 H20)	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	LC0/LC50/LC100 reported	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	An analysis of variance ANOVA and mean separation test (p = 0.05)	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Fish approximately 1.5 months past hatching, were obtained from a stock of coho salmon fry reared at the University of Rhode Island aquaculture facility and acclimated for 36 h prior to the experiment.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	13		

Note:

Evaluator: NT

Evaluation Date: 01/05/2019

Other notes:

Ref: I. Veltz ~, F. Arsac 2, S. Biagianti-Risbourg j, F. Habets ~-, H. Lechenault 1, G. Vernet l. 1996. Effects of Platinum (Pt 4+) on Lumbriculus variegatus Miiller (Annelida, Oligochaetae): Acute Toxicity and Bioaccumulation. Arch. Environ. Contain. Toxicol. 31, 63-67 (1996)

Medium: Fresh water

Substance CAS RN: H2PtCI6, 4.5H20.

Purity/formulated product: Static-exposure lethality

Score: 12

Acceptability: Acceptable (secondary)

Justification: Test completed under standardized method, Nominal concentrations, control measures met.

Test Organisms: Lumbriculus variegatus

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	2	DO, pH, and hardness considered, different water types tested	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Standard protocol not used but conditions well described. 6 concs +control	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal concentrations	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	One control included	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	1	24-hr, 48-hr, 72-hr, 96-hr duration endpoints (acute, according to CCME) can be inferred from graph but 96-hr reported.	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Pt 4+ stock solutions (20 _+ 0.01 rag/L, Sigma lot n ° 92H3525)	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	LC50 reported	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	1	96h LC50 were calculated, using the probit method, statstical methods used to calculate significance but not specified.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	L. var. (4.5-5.5cm long) were collected from an outdoor controlled mesocosm of the laboratory and acclimatized to laboratory conditions for 7 days. Test conditions specified.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	12		

Note:

Evaluator: NT

Evaluation Date: 01/05/2019

Other notes:

Ref: Raphaela Osterauer, Nadine Haus, Bernd Sures, Heinz-R. Köhler. 2009. Uptake of platinum by zebrafish (Danio rerio) and ramshorn snail (Marisa cornuarietis) and resulting effects on early embryogenesis. Chemosphere 77 (2009) 975–982

Medium: Freshwater

Substance CAS RN: Platinum PtCL2

Purity/formulated product:

Score: 12

Acceptability: Unacceptable

Justification: Endpoint not useable

Test Organisms: zebrafish (Danio rerio) and ramshorn snail (Marisa cornuarietis)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	0	Not discussed	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	Experimental design based on previous studies (Sures and Zimmermann, 2007). For fish, OECD Guideline 203, Annex 2 guideline used. 5 concs used and replicate tests	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	Measured, Aqueous concentrations of platinum as determined by inductively coupled plasma mass spectrometry and adsorptive cathodic stripping voltammetry in the exposure media used for tests with Danio rerio and Marisa ornuarietis. Data show means ± standard deviation of three aliquots.	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Considered controls	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	The exposure period was 96 h for D. rerio. As embryonic development in M. cornuarietis is slower, snail eggs were exposed for 14 d.	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	brief description of solution preparation provided, (platinum standard solution 1000 g/mL, Ultra Scientific, Wesel, Germany).	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	bioaccumulation rate reported. Environmentally relevant concentrations are reported which maybe be helpful for context	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	For statistical analyses means and standard deviations were calculated using Microsoft Excel. Graphs were generated using Microsoft Excel or SigmaPlot 2000 (SPSS Science, USA). For data which corresponded with normality (Shapiro–Wilk test, JMP 4.0, SAS Systems, USA) the parametric multiple comparison Tukey–Kramer test (JMP 4.0, SAS Systems, USA) was applied to compare means of all treatment groups versus the control. For non-parametric data the Wilcoxon test (JMP 4.0, SAS Systems, USA) was used to detect significant differences between the treatment groups versus the control.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Test animals used in this study were D. rerio and M. cornuarietis. A zebrafish breeding stock (D. rerio, strain: WIK, ZFIN ID: ZDBGENO-010531-2) was originally obtained from the Max-Planck- Institute for Developmental Biology, Tübingen, Germany (C. Nüsslein-Volhard group) and a breeding stock of ramshorn snail (M. cornuarietis) derived from Frankfurt/Main University, Germany (J. Oehlmann group).	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	12		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 13/05/2019

Other notes:

Ref: Raphaela Osterauera, Heinz-R. Köhlera, Rita Triebskorn. 2010a. Histopathological alterations and induction of hsp70 in ramshorn snail (Marisa cornuarietis) and zebrafish (Danio rerio) embryos after exposure to PtCl2. Aquatic Toxicology 99 (2010) 100–107

Score: 11

Medium: Freshwater

Acceptability: Unacceptable

Substance CAS RN: Platinum PtCL2

Justification: Endpoint not useable

Purity/formulated product: 1000 ug/mL

Test Organisms: zebrafish (Danio rerio) and ramshorn snail (Marisa cornuarietis)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	0	Not discussed	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	eggs of fish (n = 4 replicates of 40 eggs each) or snails (n = 4 replicates of 20 eggs each),	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal.	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Considered controls	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	The exposure period was 7 days for D. rerio. As embryonic development of M. cornuarietis is much slower than that of D. rerio, snail eggs were exposed for 26 days. D	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	platinum standard solution 1000 g/mL, Ultra Scientific, Wesel, Germany	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	Histopathological responses not applicable.	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	For normally distributed data (Shapiro–Wilk test, JMP 4.0, SAS Systems, USA), the parametric multiple comparison Tukey–Kramer test (JMP 4.0, SAS Systems, USA) was used. Data not corresponding to normal distribution were tested using the nonparametric distribution-independent Wilcoxon test (JMP 4.0, SAS Systems, USA) to detect significant differences between the respective treatment groups and the control group.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Embryos of a zebrafish breeding stock (D. rerio, strain: WIK (a commonly used wild type line of zebrafish), ZFIN ID: ZDB-GENO-010531-2) originally obtained from the Max-Planck-Institute for Developmental Biology, Tübingen, Germany (C. Nüsslein-Volhard group), and embryos of a ramshorn snail breeding stock (M. cornuarietis) originally obtained from Frankfurt/Main University, Germany (J. Oehlmann group), served as test animals in this study.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	11		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 13/05/2019

Other notes:

Ref: Raphaela Osterauer, Leonie Marschner , Oliver Betz , Matthias Gerberding, Banthita Sawasdee , Peter Cloetens , Nadine Haus , Bernd Sures et al. 2010b. Turning snails into slugs: induced body plan changes and formation of an internal shell. Evolution & Development / Volume 12, Issue 5

Medium: Freshwater

Substance CAS RN: Platinum PtCL2; PtCl , C

Purity/formulated product: 1000 ug/mL

Score: 13

Acceptability: Unacceptable

Justification: Endpoint not useable

Test Organisms: freshwater snails M. cornuarietis (Ampullariidae, prosobranch gastropod) and P. corneus (Planorbidae, pulmonate).

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Consideration given to the formulation and ions	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	The described effects occurred independently of using either tap/aquaria water or reconstituted water after the OECD Test Guideline 203 (1992)	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	Measured. Pt in the organisms was measured with adsorptive cathodic stripping voltammetry (ACSV) after digestion via high-pressure ashing according to Zimmermann et al. (2001, 2003) or with electrothermal atomic spectrometry (ET-AAS) after microwave-assisted digestion according to Sures et al. (1995)	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Considered controls	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	Chronic exposure	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	PtCl (Ultra Scienti□c, Wesel, Germany), PdCl (Sigma Aldrich, München, Germany), LiCl (≥99%, Fluka, Buchs, Switzerlañd), and, in combination with PtCl , CaCl (Merck, Darmstadt, Germany)	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	No, endpoint not applicable. Bioaccumulation	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Normally distributed data (Shapiro—Wilk's test, JUMP 4.0, SAS Systems, USA) were tested with the parametric one-way t-test (JUMP 4.0, SAS Systems, USA) to detect significant differences between the treatment group and the control. Data not corresponding to normal distributionwere tested using the nonparametric distribution-independent Wilcoxon's test (JMP 4.0, SAS Systems) to detect significant differences between the respective treatment groups and the control group. The alpha level was set at 0.05.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Origin and maintenance of the lab stock culture of the gonochoric species M. cornuarietis were described in Osterauer et al. (2009). The breeding stock of the hermaphroditic snail P. corneus was gathered in a pond near Tübingen. P. corneus were kept in 30 l aquaria containing oxygenized tap water in the following conditions: temperature: 20±1°C, pH: 8, conductivity: 800 µS/cm, and 12 h/12 h light/dark regime.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	13		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 13/05/2019

Other notes:

Ref: Raphaela Osterauer a, Christopher Faßbender, Thomas Braunbeck b, Heinz-R. Köhler. 2011. Genotoxicity of platinum in embryos of zebrafish (Danio rerio) and ramshorn snail (Marisa cornuarietis). Science of the Total Environment 409 (2011) 2114–2119

Score: 13

Medium: Freshwater

Acceptability: Unacceptable

Substance CAS RN: Platinum PtCL2; PtCl , C

Justification: Endpoint not useable

Purity/formulated product: 1000 ug/mL

Test Organisms: zebrafish (Danio rerio) and ramshorn snail (Marisa cornuarietis)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	2	Due to known precipitation of Pt during exposure (Sures and Zimmermann, 2007), real concentrations of Pt in the exposure media of identical exposure scenario as in the present study were determined as published by Osterauer et al. (2009, 2010b)	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	The described effects occurred independently of using either tap/aquaria water or reconstituted water after the OECD Test Guideline 203 (1992); comet assay according to the protocol of Kosmehl et al. (2006) and at adapting this protocol for testing the genotoxicity of identical PtCl2 concentrations in embryonic stages of the snail M. cornuarietis.	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal concentrations	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Considered controls, and medium for controls considered	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	Following the procedure by Kosmehl et al. (2006), the exposure period was 96 h for D. rerio. However, M. cornuarietis has a much longer embryonic development. Therefore, the exposure period was 8 d for M. cornuarietis.	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	platinum standard solution of 1000 µg/ml in 2% HCl, Ultra Scientific, Wesel, Germany	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	No, endpoint not applicable. Genotoxicity	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Normal distribution of data was checked with the Shapiro-Wilk test. Since not all data were normally distributed, they were analyzed for significance (ANOVA-on-ranks) using SigmaStat 3.1 software (Systat, Erkath, Germany), followed by a Dunnett post-hoc test (SigmaStat 3.1, Systat, Errath, Germany) to identify significant differences between the groups. Differences were considered to be significant for $p \leq 0.05$ (*).	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	1	origin of organisms not described but conditions well reported	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	13		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 13/05/2019

Other notes:

Ref: Candida Vannini, Guido Domingo, Milena Marsoni, Alessandro Fumagalli, Raffaele Terzaghi, Massimo Labrac, Fabrizio De Mattiac, Elisabetta Onellid, Marcella Bracale. 2011. Physiological and molecular effects associated with palladium treatment in Pseudokirchneriella subcapitata. Aquatic Toxicology 102 (2011) 104–113

Medium: Freshwater

Substance CAS RN: Palladium K2PdCl4 (99.9%, 1mm thick, 2.615

Purity/formulated product: g, 24.57 mmol)

Score: 12

Acceptability: Unacceptable

Justification: Endpoint not useable

Test Organisms: Pseudokirchneriella subcapitata

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	2	Consideration given to the solvent used to dissolved the Pd Foil	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Standard method not used, but well outlined, only 3 exposure concs plus controls	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	Measured. Performed on a Thermo-Electron atomic absorption spectrometer. Levels of Pd [ng ml−1 (ppb)], were determined using a graphite furnace (GFAA) coupled with Zeeman background correction.	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Controls consisted of untreated cells	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (>20% mortality) (0)
5	Chronic or life cycle test was used	2	2	72 hours, chronic as per CCME	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	Pd foil dissolved, carrier not provided. Calibration standard solutions were prepared daily from 1000mgl−1 standard solutions of Pd purchased from J. T. Baker Instra-Analyzed.	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	endpoint not usable, uptake	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	1	significant in Student's t-test at a level of 95%, statistical confidence considered	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	The axenic P. subcapitata Hindák strain was obtained from the Collection of Algal Cultures, Göttingen, Germany (SAG 61.81, http://www.epsag.uni-goettingen.de/html/sag.html).	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	12		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 13/05/2019

Other notes:

APPENDIX A.2: TERRESTRIAL TOXICITY STUDY EVALUATION FORMS

Ref: Carneiro, M.L.B., C.A.P. Lopes, A.L. Miranda-Vilela, G.A. Joanitti, I.C.R. da Silva, M.R. Mortari, A.R. de Souza, S.N. Báo, 2015. Acute and subchronic toxicity of the antitumor agent rhodium (II) citrate in Balb/c mice after intraperitoneal administration. Toxicology Reports, 2: 1086-1100.

Score: 12

Medium: intraperiton

Acceptability: Consulted

Substance CAS RN: Rhodium (II) citrate

Justification: Intraperitoneal exposure

Purity/formulated product: NR

Test Organisms: Mice

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	0	This rhodium compound is known to be less toxic than others.	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	5 concentrations plus control	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Acute test: The rhodium (II) citrate (Rh2Cit) solution was injected via intraperitoneal route in mice in a single dose containing 107.5 mg/kg Rh2Cit or proportional doses of it as 80.7 (75%),53.8 (50%), 26.9 (25%) or 13.8 (12.5%), while the control group wasexposed to saline solution (0.9% w/v). Chronic test: The mice were treated with 300 L of solutioncontaining different concentrations of Rh2Cit (80, 60, 40, and 20or 10 mg/kg) or paclitaxel (57.8 mg/kg, equivalent to clinical doseused in humans). The negative control group was injected with thesame volume (300 L) of saline solution (0.9% w/v). The mice ofRh2Cit or saline experimental groups received repeated doses viaintraperitoneal injections every two days, totalizing five injections,and the total maximum accumulated dose of Rh2Cit was 400 mg/Kg.The mice treated with paclitaxel received only two injections during all the experimental period (5th and 28th day), totalizing anaccumulated dose of 115.6 mg/kg.	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	Controls used and reported	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	1	Acute and sub-chronic tests	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Rhodium (II) citrate (Rh2Cit) was prepared and characterized as previously described. Briefly, Rh2Cit was synthesized by exchanging trifluoroacetate ligands from the precursor rhodium (II)trifluoroacetate with citrate ligands. The compound was obtained as a green aqueous solution with a standardized concentration of 0.054 mol/L.	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	LD50	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Statistical analysis was carried out using the SPSS (StatisticalPackage for the Social Sciences) version 17.0 and Prism version 5.0softwares. Data were expressed as mean ± SEM (standard error ofmean) and values of $p < 0.05$ were considered statistically signif-icant. Quantitative variables were tested for normal distributionwith the Shapiro–Wilk test. Possible differences among groupswere investigated by performing ANOVA or the Kruskal–Wallis test(data not normally distributed), followed respectively by Bonfer-roni's or Dunn's multiple comparison tests. The Wilcoxon test (datanot normally distributed) was used to verify differences betweeninitial and final body weight inside each group.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Ninety female Balb/c mice (12 weeks old) were purchased from the Multidisciplinary Center for Biological Investigation on Labo-ratory Animal Science (Cemib) of the State University of Campinas(Unicamp, SP/Brazil). Upon arrival, all animals were examined forhealth condition to confirm their suitability for study.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	12		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 15/03/2017

Other notes:

Ref: HOLBROOK, D.J., Jr (1976a) Assessment of toxicity of automotive metallic emissions, Vol. I: Assessment of fuel additives emission toxicity via selected assays of nucleic and protein synthesis, Research Triangle Park, North Carolina, US Environmental Protection Agency, Office of Research and Development, Health Effects Research Laboratories, 67 pp (EPA/600/1-76/010a).

Score: Not scored as from a peer reviewed source (WHO)

Medium: oral

Acceptability: Selected

Substance CAS RN: Platinum

Justification: From EHC 125, 1991

Purity/formulated product:

Test Organisms:

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2		vehicle (DMSO) considered	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2		OECD Guideline 403 (Acute Inhalation Toxicity); GLP Compliant	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2		Measured	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2		Control animals used	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2		acute inhalation; dusts	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2		Name of test material (as cited in study report): iodine- Substance type: iodine ACS/USP/BP grade- Physical state: Solid, prill.- Analytical purity: 99.8%-	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2		Only LC50 considered	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2		As this study was conducted as a limit test, no statistical analyses was required. Body weight data was statistically analysed following Student's 't' test.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2		TEST ANIMALS- Source: Animal Breeding Facility, Jai Research Foundation	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	0		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 03/03/2017

Other notes:

Ref: Iavicoli, I., V. Leso, L. Fontana, A. Marinaccio, A. Bergamaschi, E.J. Calabrese, 2014. The effects of rhodium on the renal function of female Wistar rats. Chemosphere, 104: 120-125.

Medium: Oral

Substance CAS RN: Rhodium

Purity/formulated product: NR

Score: 15

Acceptability: Selected

Justification: Statistical tests completed, well described protocol; measured concs; controls

Test Organisms: Wistar rats

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Salt Considered	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Three replicates; protocol well described but not a standard test procedure	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	Rh administration were: 0 (control group), 0.001, 0.01, 0.1, 0.25, 0.5, and 1 mg L 1, via water ad libitum	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	Controls well outlined, procedure well outlined	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	1	Sub-acute (14 Days)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Rh (III) chloride hydrate (Alfa Aesar GmbH & Co., Karlsruhe, Germany)	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	2	NOEC and LOECs were not explicitly reported but within range	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Statistical tests preformed to determine significance, including ANOVA. Firstly, the normal distribution of observed values was checked using the non-parametric Kolmogorov–Smirnov Z test. One-way analysis of variance (ANOVA) was then performed to test the significance of differences in parameter means in the exposed and control rat groups. The Dunnett post hoc multiple comparison test was used to test the significance (p value Dunnett t test <0.05) of differences in values for each parameter at different exposure levels against the control group. Box-plot or linear graphs were obtained for all analyzed parameters at different exposure levels.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Experimental Animal Production Plant of the Catholic University of Sacred Heart (Rome, Italy)	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	15		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 03/03/2017

Other notes:

Ref: Kabe, I., Omae, K., Nakashima, H., Nomiyama, T., Uemura, T., Hosoda, K., Ishizuka, C., Yamazaki, K. & Sakurai, H., 1996. In vitro solubility and in vivo toxicity of indium phosphide. J. occup. Health, 38: 6–12.

Score: 13

Medium: Oral

Acceptability: Selected

Substance CAS RN: Indium phosphide

Justification: Not a standard protocol; but measured concs and controls

Purity/formulated produc 100%

Test Organisms: ICR Mice

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Physiological saline used; solubility considered	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Not a standard protocol but 4 concentrations used including (0, 1,000, 3,000, or 5,000 mg/kg). No replicate test conducted	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	Measured	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Controls used but not a standardized procedure	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	1	Acute	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Single-crystal InP wafers (99.999% purity, Furukawa Electric)	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	LD0 >5,000 mg/kg at the highest dose tested; NOEC and LOEC can be derived, but for an Acute study	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Student's t-test or Welch's method were adopted for statistical testing of differences between means of the effect indices. The analysis of pathological findings was performed by Fisher's test.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Four-week-old male ICR mice (SPF grade) were purchased from Nippon SLC and acclimatized for one week.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	13		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 11/04/2017

Other notes:

Landolt, R.R., Berk, H.W., Russell, H.T., 1972. Studies on the toxicity of rhodium trichloride in rats and rabbits.. Toxicol Appl

Ref: Pharmacol., 21(4): 589-90. **Score:** 6

Medium: Intravenous **Acceptability:** Consulted (intravenous)

Substance CAS RN: Rhodium **Justification:** Intravenous exposure, acute study, measured concentrations, controls

Purity/formulated product: NR **Test Organisms:** Sprague Dawley, New Zealand White Rabbits

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Buffering solution considered	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	0	No replicates; reference provided of method used	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Ranges reported, measured	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Controls used	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	1	Acute	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	Ranges reported	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	LD50 only reported	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	0	No stats provided	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	0	Details on the organisms not provided.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	6		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 03/03/2017

Other notes:

Ref: Moore, W., D. Hysell, L. Hall, K. Campbell, and J. Stara, 1975. Preliminary studies on the toxicity and metabolism of palladium and platinum. Environ Health Perspect, 10: 63-71.

Medium:

Substance CAS RN:

Purity/formulated product: Palladium, Platinum

Score: not scored as from a peer reviewed source (WHO)

Acceptability: Consulted (intravenous)

Justification: WHO

Test Organisms:

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2			Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2			Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2			Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2			Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2			Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2			Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2			EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2			ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2			Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	0		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 10/03/2017

Other notes:

ROSHCHIN, A.V., VESELOV, V.G., & PANOVA, A.I. (1984) Industrial toxicology of metals of the platinum group. J. Hyg. Epidemiol. Microbiol.
Ref: Immunol., 28: 17-24.

Score: Not scored as from a peer reviewed source (WHO)

Medium: oral

Acceptability: Selected

Substance CAS RN: Platinum

Justification: From EHC 125, 1991

Purity/formulated produc

Test Organisms:

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2		vehicle (DMSO) considered	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2		OECD Guideline 403 (Acute Inhalation Toxicity); GLP Compliant	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2		Measured	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2		Control animals used	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2		acute inhalation; dusts	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2		Name of test material (as cited in study report): iodine- Substance type: iodine ACS/USP/BP grade- Physical state: Solid, prill.- Analytical purity: 99.8%-	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2		Only LC50 considered	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2		As this study was conducted as a limit test, no statistical analyses was required. Body weight data was statistically analysed following Student's 't' test.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2		TEST ANIMALS- Source: Animal Breeding Facility, Jai Research Foundation	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	0		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 03/03/2017

Other notes:

Ref: Speranza,A., K. Leopold, M. Maier, A.R. Taddei, and V. Scoccianti, 2010. Pd-Nanoparticles Cause Increased Toxicity to Kiwifruit Pollen Compared to Soluble Pd(II). Environ. Pollut., 158(3): 873-882.

Score: 12

Medium: water

Acceptability: Not acceptable

Substance CAS RN: Palladium chloride (PdCl2)

Justification: Good study, but exposure pathway and very short duration not useful

Purity/formulated product: 99% purity

Test Organisms: kiwifruit pollen

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	0	No information provided	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Three replicates per concentration were performed for each type of test.	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	Controls	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	0	Very short term exposure (90 min)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	made stock solution in ultra pure water, to obtain a final concentration of 0.1– 15 mg L 1	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	2	EC50, LC50, LOEC	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Effective median concentration (EC50) and lethal median concentration (LC50) values were calculated with the Log-probit method (Speranza et al., 2007a), from first order polynomial equations obtained plotting percent incidence (i.e., percent inhibition on growth or survival over corresponding controls) versus Log10 transformation of Pd-NP or PdCl2 concentrations.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	Kiwifruit pollen was obtained from plants of the male genotype (cv. Tomuri) of Actinidia deliciosa var. deliciosa (A. Chev) C. F. Liang et A. R. Ferguson growing in experimental plots of the Azienda Tarozzi, Faenza (Italy). Pollenwas stored at 20 C until use (Speranza et al., 2007a).	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	12		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 10/03/2017

Other notes:

Ref: Voua Otomo, P., V. Wepener, M.S. Maboeta, 2014. Single and mixture toxicity of gold nanoparticles and gold(III) to Enchytraeus buchholzi (Oligochaeta). Applied Soil Ecology, 84: 231-234.

Score: 14

Medium: Soil

Acceptability: Selected

Substance CAS RN: Gold HAuCl4-3H2O

Justification: Study details provided; end points

Purity/formulated product: obtained from Sigma-Aldrich

Test Organisms: Enchytraeus buchholzi (oligochaeta)

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	consideration of soil moisture content upper limit of 60% to not additionally stress test organisms	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	reference throughout to OECD enchytraeid reproduction test	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	nominal concentrations	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	Controls used	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	2	Reproduction test (14-d)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	test solutions added to soil as aqueous solutions	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	2	EC10, EC50, LC50	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	ANOVA, $p<0.05$	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	1	adult specimens used, source not specified	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	14		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 05/04/2017

Other notes:

Ref: Williams, M.W., J.D. Hoeschele, J.E. Turner, K.B. Jacobson, N.T. Christie, C.L. Paton, L.H. Smith, H.R. Witschi, and E.H. Lee, 1982. Chemical softness and acute metal toxicity in mice and Drosophila. Toxicol Appl Pharmacol, 63: 461-469.

Medium:

Substance CAS RN:

Score: not scored from peer-reviewed source (WHO)

Acceptability: Consulted (oral endpoint), Consulted (intraperitoneal)

Justification: WHO

Purity/formulated product: Platinum, Rhodium

Test Organisms: Mice and Drosophlia

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2			Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2			Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2			Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2			Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2			Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2			Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2			EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2			ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2			Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	0		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: KJW

Evaluation Date: 26/03/2017

Other notes:

Ref: Yutaka, K., S-K. Yohko, D. Hiroshi, 1988. The effect of intraperitoneally administered gold thioglucose on growth, food consumption and accumulation of gold in various organs of the chicken (Gallus domesticus). Comparative Biochemistry and Physiology Part C: Comparative Pharmacology, 90(2): 461-464.

Medium: Intraperitoneal

Substance CAS RN: Gold thioglucose (https://en.wikipe

Purity/formulated product: NR

Score: 10

Acceptability: Consulted (intraperitoneal)

Justification: Nominal concentrations (not measured)

Test Organisms: Single-Comb White Leghorn male and female chickens

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Vehicle - dissolved in water	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Not a standard test procedure, but there are 4 exposure concentrations	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	1	Nominal concentrations	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	1	Not a standardized procedure but control chickens were similarly injected with 1 ml distilled water.	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	1	Acute, one intraperitoneal injection	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Gold thioglucose [(1-D-glucosylthio)gold, C,H, AuO, S], which was purchased from Sigma Chemical Company (St Louis, U.S.A.),	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	NOEC and LOEC not explicitly reported. LD25 and LD100 can be derived	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	1	Statistical tests completed to determine significant difference among exposure groups	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	1	NR; from in-house (assumed)	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	10		

Note: study evaluation form based on U.S. EPA (2003) Attachment 3-2 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. November

Evaluator: NT

Evaluation Date: 11/04/2017

Other notes: Unsure about this chemical, it is quite large

Ref: Mello-Andrade F, Cardoso CG, Silva CRE, Chen-Chen L, Melo-Reis PR, Lima AP, Oliveira R, Ferraz IBM, Grisolia CK, Almeida MAP, Batista AA, Silveira-Lacerda EP. 2018. Acute toxic effects of ruthenium (II)/amino acid/diphosphine complexes on Swiss mice and zebrafish embryos.Biomedicine & Pharmacotherapy 107 (2018) 1082–1092.

Medium: a single dose by oral gavage

Substance CAS RN: [Ru(L-Met)(dppb)(bipy)]PF6(RuMet

Score: 13

Acceptability: Unacceptable (complex, single dose)

Justification: Test completed under standardized method, controls inc

Purity/formulated product: complex

Test Organisms: Swiss albino 6–8 week-old mice

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Yeilds considered, discussion if complexes are stable in medium	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	OECD Guidelines specified	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	nominal concentrations	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	positive and negative controls used	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	0	1 time does observed for 14 days after treatment	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	2	Test solutions prepared using OECD Guideline	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	LD50/LC50 reported	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	ANOVA followed by the Tukey test. Statistical significance was considered at $p < 0.05$. Data were expressed as means and Standard Error of Means (SEM) or SD. All statistical analyses were performed using the statistical software GraphPad Prism, version 5 for Windows	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	1	Swiss albino 6–8 week-old mice, with an average body weight of 25–35 g, were used for the experiments. Source not provided, but the lab conditions they were kept in were outlined	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	13		

Note:

Evaluator: NT

Evaluation Date: 26/04/2019

Other notes: For complex

Ref: Schertzinger G, Zimmermann S, Grabner D, Sures B. 2017. Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium. Environmental Pollution 230 (2017) 31e39

Score: 14

Medium: Single PGE standard solutions wer

Acceptability: Consulted (aquatic toxicity)

Substance CAS RN: Pt, Pd, Rh

Justification: Details reported, measured concs

Purity/formulated product: Solution

Test Organisms: nematode Caenorhabditis elegans

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	1	Previous to metal toxicity tests, the sensitivity and validity of the test system was checked	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	2	aquatic toxicity tests were performed according to ISO 10872 with some modifications, mods identified	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	Nominal concentrations and qualified concentrations (measured)	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	positive and negative controls were used	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	1	96 hour endpoints (acute)	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	Range finding tests were performed, no homogeneity	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	1	EC50 reported	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	The software GraphPad Prism 6 was used to create the graphs and to perform the statistical analysis. Confidence intervales reported.	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	2	The wild type strain N2 of C. elegans var. Bristol was cultivated from a Dauer larvae stock on nematode growth medium agar plates (NGM-agar plates) containing a lawn of Escherichia coli (OP50, uracil deficient strain) as food source. Both organisms were obtained from the Caenorhabditis Genetics Center (CGC) at the University of Minnesota.	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	14		

Note:

Evaluator: NT

Evaluation Date: 29/04/2019

Other notes:

Ref: Ksenia S. Egorova, Andrey A. Sinjushin, Alexandra V. Posvyatenko, Dmitry B. Eremin, Alexey S. Kashin, Alexey S. Galushko, Valentine P. Ananikov. 2019. Evaluation of phytotoxicity and cytotoxicity of industrial catalyst components (Fe, Cu, Ni, Rh and Pd): A case of lethal toxicity of a rhodium salt in terrestrial plants. Chemosphere 223 (2019) 738-747

Medium: Single PGE standard solutions were

Substance CAS RN: Rh Pd

Purity/formulated product:

Score: 11

Acceptability: Unacceptable (growth medium, concentrations)

Justification: Details reported

Test Organisms: Pisum sativum, Lupinus angustifolius and Cucumis sativus

Criterion	Description	Points	Score	Comment	Guidance
1	Test completed under conditions of high bioavailability	2	2	Rh(acac)3 was synthesized according to the following procedure (Collins et al., 1995). Consideration to modifying factors	Bioavailability and consideration of other toxicity modifying factors
2	Experimental design documented and appropriate	2	1	Methods reported, but not a known protocol	Standard methods or protocols cited (2); ANOVA, 4 or 5 exposure concentrations (incl. control), or replicate test (1)
3	Concentration of substance reported	2	2	Measured Concentrations	Measured concentration reported (2), toxicity values based on nominal concentrations (1), all other (0)
4	Control measures applied	2	2	Controls used and reported	Standardized procedure and negative control values within guidelines (2), controls not reported or ambiguous (1), control results not within acceptable range (0)
5	Chronic or life cycle test was used	2	1	Acute and subacute	Chronic or life cycle test (2), acute (1), very short term exposure (0)
6	Chemical dosing procedure reported and appropriate	2	1	Metal salts used in the study (see Table S1) were obtained from 'Sigma-Aldrich', 'Acros', or 'Alfa Aesar'. RhCl3$xH2O was obtained from 'Sigma-Aldrich', 'Alfa Aesar' and 'Krastsvetmet' (Russia).	Form, carrier, homogeneity information provided (2), no details or cannot be inferred (0)
7	A dose-response relationship reported or can be estimated from reported data	2	0	No endpoints for plants reported	EC_{10}-EC_{20} reported or NOEC and LOEC within 3x of each other (2), NOEC and LOEC > 3x but < 10x (1), no reported EC_x, difference > 10x for NOEC and LOEC, or only a NOEC or LOEC reported (0)
8	Statistical tests used to calculate the benchmark and levels of significance were described	2	2	Statistical data processing was carried out using Microsoft Excel 2010 (Microsoft). The significance of differences between samples was assessed by the two-tailed Mann-Whitney test (Statistica 8.0, StatSoft).	ANOVA or other statistical test based on P=0.05 (2), ANOVA completed but P level not provided or P > 0.05, if EC data presented, but no 95% CI reported or 90% CI used (1), no details on statistical calculations provided (0)
9	Origin of the test organisms described	2	0	Origin unknown	Source and condition of test organisms known and described and from commercial, non-contaminated source (2), organisms obtained from non-commercial source not adequately described, or insufficient information (1), organisms from known contaminated site (0)
	Total Score	18	11		

Note:

Evaluator: NT

Evaluation Date: 29/04/2019

Other notes:

APPENDIX B.1: COMPILED AQUATIC TOXICITY DATA

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Literature Citation			Chemical Identity				Test Organism(s)				Experimental Design - Water Conditions				
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	pH	Test Conditions (Laboratory/Field)	Hardness	Conductivity	Salinity
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Gold	7440575	NR	Tap water	Hyalella azteca	Amphipod	Partial	1-11 d	8.2	Laboratory	124	345	NA
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Gold	7440575	NR	Soft water (deionized)	Hyalella azteca	Amphipod	Partial	1-11 d	7.39	Laboratory	18	66	NA
Buhl and Hamilton	1991	Relative Sensitivity of Early Life Stages of Arctic Grayling, Coho Salmon, and Rainbow Trout to Nine Inorganics. Ecotoxicol. Environ. Saf., 22: 184-197.	Auric chloride, Hydrochloride	10294-29-8	HAuC& - 3H20	deionized water	Thymallus arcticus	Arctic grayling	Partial	alevin	7.1-8	Laboratory	41	156	NA
Buhl and Hamilton	1991	Relative Sensitivity of Early Life Stages of Arctic Grayling, Coho Salmon, and Rainbow Trout to Nine Inorganics. Ecotoxicol. Environ. Saf., 22: 184-197.	Auric chloride, Hydrochloride	10294-29-8	HAuC& - 3H20	deionized water	Thymallus arcticus	Arctic grayling	Partial	juvenile	7.1-8	Laboratory	41	156	NA
Buhl and Hamilton	1991	Relative Sensitivity of Early Life Stages of Arctic Grayling, Coho Salmon, and Rainbow Trout to Nine Inorganics. Ecotoxicol. Environ. Saf., 22: 184-197.	Auric chloride, Hydrochloride	10294-29-8	HAuC& - 3H20	deionized water	Oncorhynchus kisutch	Coho salmon	Partial	alevin	7.1-8	Laboratory	41	156	NA
Buhl and Hamilton	1991	Relative Sensitivity of Early Life Stages of Arctic Grayling, Coho Salmon, and Rainbow Trout to Nine Inorganics. Ecotoxicol. Environ. Saf., 22: 184-197.	Auric chloride, Hydrochloride	10294-29-8	HAuC& - 3H20	deionized water	Oncorhynchus kisutch	Coho salmon	Partial	juvenile	7.1-8	Laboratory	41	156	NA
Buhl and Hamilton	1991	Relative Sensitivity of Early Life Stages of Arctic Grayling, Coho Salmon, and Rainbow Trout to Nine Inorganics. Ecotoxicol. Environ. Saf., 22: 184-197.	Auric chloride, Hydrochloride	10294-29-8	HAuC& - 3H20	deionized water	Oncorhynchus mykiss	Rainbow trout	Partial	alevin	7.1-8	Laboratory	41	156	NA
Buhl and Hamilton	1991	Relative Sensitivity of Early Life Stages of Arctic Grayling, Coho Salmon, and Rainbow Trout to Nine Inorganics. Ecotoxicol. Environ. Saf., 22: 184-197.	Auric chloride, Hydrochloride	10294-29-8	HAuC& - 3H20	deionized water	Oncorhynchus mykiss	Rainbow trout	Partial	juvenile	7.1-8	Laboratory	41	156	NA
Stokes	1981	Multiple Metal Tolerance in Copper Tolerant Green Algae. J. Plant Nutr.3(1-4):, 3: 667-678.	Gold	7440575	NR	culture medium	Scenedesmus acutiformis	Green algae	Full	NR	NR	Laboratory	NR	NR	NA
Robinson et al.	1997	Effect of gold(III) on the fouling diatom Amphora coffeaeformis: uptake, toxicity and interactions with copper. . Biofouling, 11: 59-79.	Tetrachloroaurate	NR	AuCl4-	culture medium	Amphora coffeaeformis	Diatom	Partial	NR	NR	Laboratory	NR	NR	NR
Biesinger and Christensen	1972	Effects of Various Metals on Survival, Growth, Reproduction and Metabolism of Daphnia magna. J. Fish. Res. Board Can., 29(12): 1691-1700.	Auric chloride, Hydrochloride	16903358	HAuCl4-3H2O	lake water	Daphnia magna	Water flea	NR	12 hr	7.74	Laboratory	45.3	NR	NA
Biesinger and Christensen	1972	Effects of Various Metals on Survival, Growth, Reproduction and Metabolism of Daphnia magna. J. Fish. Res. Board Can., 29(12): 1691-1700.	Auric chloride, Hydrochloride	16903358	HAuCl4-3H2O	lake water	Daphnia magna	Water flea	NR	12 hr	7.74	Laboratory	45.3	NR	NA
Biesinger and Christensen	1972	Effects of Various Metals on Survival, Growth, Reproduction and Metabolism of Daphnia magna. J. Fish. Res. Board Can., 29(12): 1691-1700.	Auric chloride, Hydrochloride	16903358	HAuCl4-3H2O	lake water	Daphnia magna	Water flea	NR	12 hr	7.74	Laboratory	45.3	NR	NA
Harry and Aldrich	1963	The Distress Syndrome in Taphius glabratus (Say) as a Reaction to Toxic Concentrations of Inorganic Ions. Malacologia, 1(2): 283-289.	Auric chloride, Hydrochloride	16903358	NR	NR	Biomphalaria glabrata	Snail	NR	Adult	NR	Laboratory	NR	NR	NA
Jones	1939	The Relation Between the Electrolytic Solution Pressures of the Metals and Their Toxicity to the Stickleback (Gasterosteus aculeatus L.). J. Exp. Biol., 16(4): 425-437.	Auric chloride, Hydrochloride	16903358	HAuCl4	tap water	Gasterosteus aculeatus	Threespine Stickleback	NR	NR	6-6.8	Laboratory	NR	NR	NA
Jones	1940	A Further Study of the Relation Between Toxicity and Solution Pressure, with Polycelis nigra as Test Animal. J. Exp. Biol., 17: 408-415.	Auric chloride, Hydrochloride	16903358	HAuCl4	distilled water	Polycelis nigra	Planarian	NR	NR	6	Laboratory	NR	NR	NA

NA Not applicable (i.e., salinity is not applicable to freshwater studies)
NR Not reported in the study

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Experimental Design			Results						CanNorth Team		Classification			
Freshwater or Marine	Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/L)	Ranking of Study	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group	Acute/Chronic	
Freshwater	Static non-renewal	7 d	Mortality	LC50	>3.15	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	authors, acute designatio
Freshwater	Static non-renewal	7 d	Mortality	LC50	0.446	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Completed for Bismuth, Gold, Indium, Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	per authors, acute designatio n
Freshwater	Static	96 hr	Mortality	LC50	16.8	Secondary	Std tox test, control measures considered, however nominal concentrations and LC50 endpoints	NA	KJW	10/03/2017	Secondary	Fish	Acute	
Freshwater	Static	96 hr	Mortality	LC50	14.4	Secondary	Std tox test, control measures considered, however nominal concentrations and LC50 endpoints	NA	KJW	10/03/2017	Secondary	Fish	Acute	
Freshwater	Static	96 hr	Mortality	LC50	33.5	Secondary	Std tox test, control measures considered, however nominal concentrations and LC50 endpoints	NA	KJW	10/03/2017	Secondary	Fish	Acute	
Freshwater	Static	96 hr	Mortality	LC50	14.1	Secondary	Std tox test, control measures considered, however nominal concentrations and LC50 endpoints	NA	KJW	10/03/2017	Secondary	Fish	Acute	
Freshwater	Static	96 hr	Mortality	LC50	9.1	Secondary	Std tox test, control measures considered, however nominal concentrations and LC50 endpoints	NA	KJW	10/03/2017	Secondary	Fish	Acute	
Freshwater	Static	96 hr	Mortality	LC50	10.7	Secondary	Std tox test, control measures considered, however nominal concentrations and LC50 endpoints	NA	KJW	10/03/2017	Secondary	Fish	Acute	
Freshwater	Culture	7 d	Growth	EC50	>1	Secondary	Low score, nominal concentrations, ">" endpoint	NA	KJW	10/03/2017	Secondary	Algae	Chronic	
Marine	Culture	20 d	Metabolism	LOEL	0.17	Secondary	Low score, nominal concentrations, endpoint	inferred endpoint from results discussion	KJW	13/03/2017	Secondary	Marine Diatom	Chronic	
Freshwater	Renewal	21 d	Mortality	LC50	1.05	Secondary	Old study but robust methodology; nominal concentrations	NA	KJW	05/04/2017	Secondary	Aquatic invertebrate	Chronic	
Freshwater	Renewal	21 d	Reproduction	EC16	0.06	Secondary	Old study but robust methodology; nominal concentrations	NA	KJW	05/04/2017	Secondary	Aquatic invertebrate	Chronic	
Freshwater	Renewal	21 d	Reproduction	EC50	0.18	Secondary	Old study but robust methodology; nominal concentrations	NA	KJW	05/04/2017	Secondary	Aquatic invertebrate	Chronic	
Freshwater	Static	1 d	Behaviour	NOEC	10	Secondary	not scored - assumed secondary from AQUIRE (literature not obtained)	inferred NOEC from no effects observed	KJW	14/03/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Renewal	10 d	Mortality	LC100	0.4	Not acceptable	Low score, endpoint	inferred LC100 - 100% mortality	KJW	14/03/2017	Unacceptable	Fish	Chronic	
Freshwater	Renewal	2 d	Mortality	NOEC	0.6	Secondary	Low score, old paper, not many details provided	inferred NOEC - 0% mortality	KJW	05/04/2017	Secondary	Aquatic invertebrate	Acute	

Literature Citation			Chemical Identity				Test Organism(s)				Experimental Design - Water Conditions				
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	pH	Test Conditions (Laboratory/Field)	Hardness	Conductivity	Salinity
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Iridium	7439885	NR	Tap water	Hyalella azteca	Amphipod	Partial	1-11 d	8.3	Laboratory	124	515	NA
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Iridium	7439885	NR	Soft water (deionized)	Hyalella azteca	Amphipod	Partial	1-11 d	7.71	Laboratory	18	235	NA
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Plant Eichhornia crassipes (MART.) Solms. Chem. Spec. Bioavail, 6(1): 43070.	Iridium	NR	Na3[IrCI6]	Nutrient solution	Eichhornia crassipes	Water-Hyacinth	Partial	NR	NR	Laboratory	NR	NR	NR
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Plant Eichhornia crassipes (MART.) Solms. Chem. Spec. Bioavail, 6(1): 43070.	Iridium	NR	Na3[IrCI6]	Nutrient solution	Eichhornia crassipes	Water-Hyacinth	Partial	NR	NR	Laboratory	NR	NR	NR

NA Not applicable (i.e., salinity is not applicable to freshwater studies)
NR Not reported in the study

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Experimental Design			Results						CanNorth Team		Classification			
Freshwater or Marine	Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/L)	Ranking of Study	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group	Acute/Chronic	
Freshwater	Static non-renewal	7 d	Mortality	LC50	>3.15	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	authors, acute designatio
Freshwater	Static non-renewal	7 d	Mortality	LC50	>1	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Completed for Bismuth, Gold, Indium, Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	per authors, acute designatio n
Freshwater	Renewal	14 d	Growth (slight drop in yield at 2.5 ug mL-1. No vegetative reproduction, young roots stunted and blackened.)	LOEC	2.5	Secondary	inferred endpoints based on narrative description and concentrations tested	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain
Freshwater	Renewal	14 d	Growth (slight drop in yield at 2.5 ug mL-1. No vegetative reproduction, young roots stunted and blackened.)	NOEC	0.5	Secondary	inferred endpoints based on narrative description and concentrations tested	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain

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Literature Citation			Chemical Identity				Test Organism(s)				Experimental Design - Water Conditions				
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	pH	Test Conditions (Laboratory/Field)	Hardness	Conductivity	Salinity
Khangarot,B.S., and S. Das	2009	Acute Toxicity of Metals and Reference Toxicants to a Freshwater Ostracod, Cypris subglobosa Sowerby, 1840 and Correlation to EC50 Values of Other Test Models. J. Hazard. Mater., 172: 641-649.	Osmium oxide	20816120	OsO4	Distilled water	Cypris subglobosa	Ostracod	Partial	NR	7.6 (7.4–7.7)	Laboratory	245 (230–250)	NR	NA
Khangarot,B.S., and S. Das	2009	Acute Toxicity of Metals and Reference Toxicants to a Freshwater Ostracod, Cypris subglobosa Sowerby, 1840 and Correlation to EC50 Values of Other Test Models. J. Hazard. Mater., 172: 641-649.	Osmium oxide	20816120	OsO4	Distilled water	Cypris subglobosa	Ostracod	Partial	NR	7.6 (7.4–7.7)	Laboratory	245 (230–250)	NR	NA
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Osmium	7440042	NR	Tap water	Hyalella azteca	Amphipod	Partial	1-11 d	8.3	Laboratory	124	515	NA
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Osmium	7440042	NR	Soft water (deionized)	Hyalella azteca	Amphipod	Partial	1-11 d	7.71	Laboratory	18	235	NA
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Plant Eichhornia crassipes (MART.) Solms. Chem. Spec. Bioavail, 6(1): 43070.	Osmium sodium chloride	NR	Na2[OsCl 6]	Nutrient solution	Eichhornia crassipes	Water-Hyacinth	Partial	NR	NR	Laboratory	NR	NR	NA
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Plant Eichhornia crassipes (MART.) Solms. Chem. Spec. Bioavail, 6(1): 43070.	Osmium sodium chloride	NR	Na2[OsCl 6]	Nutrient solution	Eichhornia crassipes	Water-Hyacinth	Partial	NR	NR	Laboratory	NR	NR	NA
Khangarot	1991	Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.	Osmium oxide	20816120	OsO4	Distilled water	Tubifex tubifex	Tubificid Worm	Partial	NR	7.6	Laboratory	245	NR	NA
Khangarot	1991	Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.	Osmium oxide	20816120	OsO4	Distilled water	Tubifex tubifex	Tubificid Worm	Partial	NR	7.6	Laboratory	245	NR	NA
Khangarot	1991	Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.	Osmium oxide	20816120	OsO4	Distilled water	Tubifex tubifex	Tubificid Worm	Partial	NR	7.6	Laboratory	245	NR	NA
Bengtsson and Tarkpea	1983	The Acute Aquatic Toxicity of Some Substances Carried by Ships. Mar. Pollut. Bull, 14(6): 213-214.	Osmium oxide	20816120	OsO4	NR	Nitocra spinipes	Harpacticoid Copepod	Partial	NR	NR	NR	NR	NR	0.07%

NA Not applicable (i.e., salinity is not applicable to freshwater studies)
NR Not reported in the study

Experimental Design			Results						CanNorth Team		Classification			
Freshwater or Marine	Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/L)	Ranking of Study	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group	Acute/Chronic	
Freshwater	Short-term static renewal	24 hr	Immobilization	EC50	0.011	Secondary	Although test method not reported, thorough study design; however, acute study and EC50 for immobilization.	Completed for Bismuth, Osmium, Palladium, Platinum, Tungsten	KJW	17/02/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Short-term static renewal	48 hr	Immobilization	EC50	0.007	Secondary	Although test method not reported, thorough study design; however, acute study and EC50 for immobilization.	Completed for Bismuth, Osmium, Palladium, Platinum, Tungsten	KJW	17/02/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Static non-renewal	7 d	Mortality	LC50	0.057	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	authors, acute designatio
Freshwater	Static non-renewal	7 d	Mortality	LC50	0.081	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Completed for Bismuth, Gold, Indium, Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	per authors, acute designatio n
Freshwater	Renewal	14 d	Growth (growth restricted at 10 ug mL-1)	LOEC	10	Secondary	inferred endpoints based on narrative description and concentrations tested	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain
Freshwater	Renewal	14 d	Growth (growth restricted at 10 ug mL-1)	NOEC	2.5	Secondary	inferred endpoints based on narrative description and concentrations tested	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain
Freshwater	Renewal	24 hr	Immobilization	EC50	0.014	Secondary	Standard method, control considerations; however, nominal concentrations and EC50 immobilization endpoint	-	KJW	10/03/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Renewal	48 hr	Immobilization	EC50	0.009	Secondary	Standard method, control considerations; however, nominal concentrations and EC50 immobilization endpoint	-	KJW	10/03/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Renewal	96 hr	Immobilization	EC50	0.0067	Secondary	Standard method, control considerations; however, nominal concentrations and EC50 immobilization endpoint	-	KJW	10/03/2017	Secondary	Aquatic invertebrate	Acute	
Saltwater	NR	96 hr	Mortality	LC50	0.01	Not acceptable	very little information provided and statistical test failed for osmium, units assumed based on AQUIRE	-	KJW	10/03/2017	Unacceptable	Aquatic invertebrate	Acute	

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Literature Citation			Chemical Identity				Test Organism(s)				Experimental Design - Water Conditions				
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	pH	Test Conditions (Laboratory/Field)	Hardness	Conductivity	Salinity
Khangarot,B.S., and S. Das	2009	Acute Toxicity of Metals and Reference Toxicants to a Freshwate Ostracod, Cypris subglobosa Sowerby, 1840 and Correlation to EC50 Values of Other Test Models. J. Hazard. Mater., 172: 641-649.	Palladium chloride	158898954	PdCl	Distilled water	Cypris subglobosa	Ostracod	Partial	NR	7.6 (7.4–7.7)	Laboratory	245 (230–250)	NR	NA
Khangarot,B.S., and S. Das	2009	Acute Toxicity of Metals and Reference Toxicants to a Freshwate Ostracod, Cypris subglobosa Sowerby, 1840 and Correlation to EC50 Values of Other Test Models. J. Hazard. Mater., 172: 641-649.	Palladium chloride	158898954	PdCl	Distilled water	Cypris subglobosa	Ostracod	Partial	NR	7.6 (7.4–7.7)	Laboratory	245 (230–250)	NR	NA
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Palladium	7440053	NR	Tap water	Hyalella azteca	Amphipod	Partial	1-11 d	8.2	Laboratory	124	345	NA
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Palladium	7440053	NR	Soft water (deionized)	Hyalella azteca	Amphipod	Partial	1-11 d	7.39	Laboratory	18	66	NA
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Plan	Palladium	NR	K2[PdC14]	Nutrient so	Eichhornia cr	Water-Hyacinth	Partial	NR	NR	Laboratory	NR	NR	NA
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Plan	Palladium	NR	K2[PdC14]	Nutrient so	Eichhornia cr	Water-Hyacinth	Partial	NR	NR	Laboratory	NR	NR	NA
Khangarot	1991	Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.	Palladium	7647101	PdCl 2	Distilled water	Tubifex tubifex	Tubificid Worm	Partial	NR	7.6	Laboratory	245	NR	NA
Khangarot	1991	Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.	Palladium	7647101	PdCl 2	Distilled water	Tubifex tubifex	Tubificid Worm	Partial	NR	7.6	Laboratory	245	NR	NA
Khangarot	1991	Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.	Palladium	7647101	PdCl 2	Distilled water	Tubifex tubifex	Tubificid Worm	Partial	NR	7.6	Laboratory	245	NR	NA
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna i	Palladium(	NR	Pd Cl	Standard fr	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna i	Palladium(	NR	Pd Cl	Standard fr	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna i	Palladium(	NR	Pd Cl	Standard fr	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna i	Palladium(	NR	Pd Cl	Standard fr	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna i	Palladium(	NR	Pd Cl	Standard fr	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna i	Palladium(	NR	Pd Cl	Standard fr	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA

NA Not applicable (i.e., salinity is not applicable to freshwater studies)
NR Not reported in the study

Pd

	Experimental Design		Results						CanNorth Team		Classification			
Freshwater or Marine	Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/L)	Ranking of Study	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group	Acute/Chronic	
Freshwater	Short-term static renewal	24 hr	Immobilization	EC50	0.351	Secondary	Although test method not reported, thorough study design; however, acute study and EC50 for immobilization.	Completed for Bismuth, Osmium, Palladium, Platinum, Tungsten	KJW	17/02/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Short-term static renewal	48 hr	Immobilization	EC50	0.195	Secondary	Although test method not reported, thorough study design; however, acute study and EC50 for immobilization.	Completed for Bismuth, Osmium, Palladium, Platinum, Tungsten	KJW	17/02/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Static non-renewal	7 d	Mortality	LC50	0.57	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	per authors, acute designation
Freshwater	Static non-renewal	7 d	Mortality	LC50	>1	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Completed for Bismuth, Gold, Indium, Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	per authors, acute designation
Freshwater	Renewal	14 d	Growth (chlorosis and drop in yield)	LOEC	2.5	Secondary	inferred endpoints based on narrative de	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain
Freshwater	Renewal	14 d	Growth (chlorosis and drop in yield)	NOEC	0.5	Secondary	inferred endpoints based on narrative de	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain
Freshwater	Renewal	24 hr	Immobilization	EC50	0.237	Secondary	Standard method, control considerations; however, nominal concentrations and EC50 immobilization endpoint	-	KJW	10/03/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Renewal	48 hr	Immobilization	EC50	0.142	Secondary	Standard method, control considerations; however, nominal concentrations and EC50 immobilization endpoint	-	KJW	10/03/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Renewal	96 hr	Immobilization	EC50	0.092	Secondary	Standard method, control considerations; however, nominal concentrations and EC50 immobilization endpoint	-	KJW	10/03/2017	Secondary	Aquatic invertebrate	Acute	
Freshwater	Static non-	24 hr	Immobilization	EC50	0.019	Primary	Test completed under standardized meth	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Freshwater	Static non-	48 hr	Immobilization	EC50	0.013	Primary	Test completed under standardized meth	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Freshwater	Static non-	24 hr	Lethality	LC50	0.014	Primary	Test completed under standardized meth	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Freshwater	Static non-	48 hr	Lethality	LC50	0.014	Primary	Test completed under standardized meth	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Freshwater	Static non-	24 hr	Immobilization	EC20	0.011	Primary	Test completed under standardized meth	Derived from tox curve	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Freshwater	Static non-	48 hr	Immobilization	EC20	0.007	Primary	Test completed under standardized meth	Derived from tox curve	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	

Literature Citation			Chemical Identity				Test Organism(s)				Experimental Design - Water Conditions						Experimental Design		Results
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	pH	Test Conditions (Laboratory/Field)	Hardness	Conductivity	Salinity	Freshwater or Marine	Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)
Khangarot,B.S., and S. Das	2009	Acute Toxicity of Metals and Reference Toxicants to a Freshwater Ostracod, Cypris subglobosa Sowerby, 1840 and Correlation to EC50 Values of Other Test Models. J. Hazard. Mater., 172: 641-649.	Platinum chloride	10025657	PtCl	Distilled water	Cypris subglobosa	Ostracod	Partial	NR	7.6 (7.4–7.7)	Laboratory	245 (230–250)	NR	NA	Freshwater	Short-term static renewal	24 hr	Immobilization
Khangarot,B.S., and S. Das	2009	Acute Toxicity of Metals and Reference Toxicants to a Freshwater Ostracod, Cypris subglobosa Sowerby, 1840 and Correlation to EC50 Values of Other Test Models. J. Hazard. Mater., 172: 641-649.	Platinum chloride	10025657	PtCl	Distilled water	Cypris subglobosa	Ostracod	Partial	NR	7.6 (7.4–7.7)	Laboratory	245 (230–250)	NR	NA	Freshwater	Short-term static renewal	48 hr	Immobilization
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Platinum	7440064	NR	Tap water	Hyalella azteca	Amphipod	Partial	1-11 d	8.2	Laboratory	124	345	NA	Freshwater	Static non-renewal	7 d	Mortality
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Platinum	7440064	NR	Soft water (deionized)	Hyalella azteca	Amphipod	Partial	1-11 d	7.39	Laboratory	18	66	NA	Freshwater	Static non-renewal	7 d	Mortality
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Plant Eichhornia crassipes (MART.) Solms. Chem. Spec. Bioavail, 6(1): 43070.	Platinum chloride	NR	K2[PtC14]	Nutrient solution	Eichhornia crassipes	Water-Hyacinth	Partial	NR	NR	Laboratory	NR	NR	NR	Freshwater	Renewal	14 d	Growth (chlorosis and drop in yield)
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Plant Eichhornia crassipes (MART.) Solms. Chem. Spec. Bioavail, 6(1): 43070.	Platinum chloride	NR	K2[PtC14]	Nutrient so	Eichhornia cra	Water-Hyacintl	Partial	NR	NR	Laboratory	NR	NR	NR	Freshwater	Renewal	14 d	Growth (chlorosis and drop in yield)
Khangarot	1991	Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.	Platinum chloride	10025657	PtCl 2	Distilled water	Tubifex tubifex	Tubificid Worm	Partial	NR	7.6	Laboratory	245	NR	NA	Freshwater	Renewal	24 hr	Immobilization
Khangarot	1991	Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.	Platinum chloride	10025657	PtCl 2	Distilled water	Tubifex tubifex	Tubificid Worm	Partial	NR	7.6	Laboratory	245	NR	NA	Freshwater	Renewal	48 hr	Immobilization
Khangarot	1991	Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol., 46: 906-912.	Platinum chloride	10025657	PtCl 2	Distilled water	Tubifex tubifex	Tubificid Worm	Partial	NR	7.6	Laboratory	245	NR	NA	Freshwater	Renewal	96 hr	Immobilization
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna in single and binary metal exposure experiments. Environmental Pollution, in press (Feb 2017)	Platinum IV	NR	PtCl6	Standard fi	Daphnia magna	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater	Static non-renewal	24 hr	Immobilization
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna in single and binary metal exposure experiments. Environmental Pollution, in press (Feb 2017)	Platinum IV	NR	PtCl6	Standard fi	Daphnia magna	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater	Static non-renewal	48 hr	Immobilization
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna in single and binary metal exposure experiments. Environmental Pollution, in press (Feb 2017)	Platinum IV	NR	PtCl6	Standard fi	Daphnia magna	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater	Static non-renewal	48 hr	Lethality
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna in single and binary metal exposure experiments. Environmental Pollution, in press (Feb 2017)	Platinum IV	NR	PtCl6	Standard fi	Daphnia magna	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater	Static non-renewal	24 hr	Immobilization
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna in single and binary metal exposure experiments. Environmental Pollution, in press (Feb 2017)	Platinum IV	NR	PtCl6	Standard fi	Daphnia magna	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater	Static non-renewal	48 hr	Immobilization
Biesinger and Christensen	1972	Effects of Various Metals on Survival, Growth, Reproduction and Metabolism of Daphnia magna. J. Fish. Res. Board Can., 29(12): 1691-1700.	Platinum	NR	H2PtCl6-6H2O	lake water	Daphnia magna	Water flea	NR	12 hr	7.74	Laboratory	45.3	NR	NA	Freshwater	Renewal	21 d	Mortality
Biesinger and Christensen	1972	Effects of Various Metals on Survival, Growth, Reproduction and Metabolism of Daphnia magna. J. Fish. Res. Board Can., 29(12): 1691-1700.	Platinum	NR	H2PtCl6-6H2O	lake water	Daphnia magna	Water flea	NR	12 hr	7.74	Laboratory	45.3	NR	NA	Freshwater	Renewal	21 d	Reproduction
Biesinger and Christensen	1972	Effects of Various Metals on Survival, Growth, Reproduction and Metabolism of Daphnia magna. J. Fish. Res. Board Can., 29(12): 1691-1700.	Platinum	NR	H2PtCl6-6H2O	lake water	Daphnia magna	Water flea	NR	12 hr	7.74	Laboratory	45.3	NR	NA	Freshwater	Renewal	21 d	Reproduction
Ferreira and Wolke	1979	Acute Toxicity of Platinum to Coho Salmon (Oncorhynchus kisutch)	Platinum IV	NR	PtCl42HCl; 6 H20	Distilled water	Oncorhynchus kisutch	Coho Salmon	Partial	1.5 months post hatch	6.5 +/- 0.4	Laboratory	55.9 +/- 3.5 mg/L (as CaCo3)	NR	NA	Freshwater	Static rene	24 hr	Survival
Ferreira and Wolke	1979	Acute Toxicity of Platinum to Coho Salmon (Oncorhynchus kisutch)	Platinum IV	NR	PtCl42HCl; 6 H20	Distilled water	Oncorhynchus kisutch	Coho Salmon	Partial	1.5 months post hatch	6.5 +/- 0.4	Laboratory	55.9 +/- 3.5 mg/L (as CaCo3)	NR	NA	Freshwater	Static rene	48 hr	Survival
Ferreira and Wolke	1979	Acute Toxicity of Platinum to Coho Salmon (Oncorhynchus kisutch)	Platinum IV	NR	PtCl42HCl; 6 H20	Distilled water	Oncorhynchus kisutch	Coho Salmon	Partial	1.5 months post hatch	6.5 +/- 0.4	Laboratory	55.9 +/- 3.5 mg/L (as CaCo3)	NR	NA	Freshwater	Static rene	96-hr	Survival
Veltz et al.	1996	Effects of Platinum (Pt 4+) on Lumbriculus variegatus Miiller (Annelida, Oligochaetae): Acute Toxicity and Bioaccumulation	Platinum IV	NR	H2PtCI6, 4.5H20	Distilled water	Lumbriculus variegatus	Worm	Partial	4.5-5.5cm long	7.6 ± 0.4	Laboratory	0 mg/L CaCO3	NR	NA	Freshwater	Static	96-hr	Survival
Veltz et al.	1996	Effects of Platinum (Pt 4+) on Lumbriculus variegatus Miiller (Annelida, Oligochaetae): Acute Toxicity and Bioaccumulation	Platinum IV	NR	H2PtCI6, 4.5H20	Reconstituted Water	Lumbriculus variegatus	Worm	Partial	4.5-5.5cm long	7.6 ± 0.4	Laboratory	250 +/- 25 mg/L CaCO3	NR	NA	Freshwater	Static	96-hr	Survival
Veltz et al.	1996	Effects of Platinum (Pt 4+) on Lumbriculus variegatus Miiller (Annelida, Oligochaetae): Acute Toxicity and Bioaccumulation	Platinum IV	NR	H2PtCI6, 4.5H20	Cristaline Water	Lumbriculus variegatus	Worm	Partial	4.5-5.5cm long	7.6 ± 0.4	Laboratory	300 +/- 10 mg/L CaCO3	NR	NA	Freshwater	Static	96-hr	Survival

NA Not applicable (i.e., salinity is not applicable to freshwater studies)
NR Not reported in the study

					CanNorth Team		Classification			
Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/L)	Ranking of Study	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group	Acute/Chronic	
EC50	0.114	Secondary	Although test method not reported, thorough study design; however, acute study and EC50 for immobilization.	Completed for Bismuth, Osmium, Palladiu	KJW	17/02/2017	Secondary	Aquatic invertebr	Acute	
EC50	0.095	Secondary	Although test method not reported, thorough study design; however, acute study and EC50 for immobilization.	Completed for Bismuth, Osmium, Palladiu	KJW	17/02/2017	Secondary	Aquatic invertebr	Acute	
LC50	0.221	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Completed for Bismuth, Gold, Indium, Irid	KJW	22/02/2017	Secondary	Aquatic invertebr	Acute	per authors, acute designation
LC50	0.11	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Completed for Bismuth, Gold, Indium, Irid	KJW	22/02/2017	Secondary	Aquatic invertebr	Acute	per authors, acute designation
LOEC	2.5	Secondary	inferred endpoints based on narrative description and concentrations tested	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain
NOEC	0.5	Secondary	inferred endpoints based on narrative description and concentrations tested	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain
EC50	0.095	Secondary	Standard method, control considerations; however, nominal concentrations and EC50 immobilization endpoint	-	KJW	10/03/2017	Secondary	Aquatic invertebrate	Acute	
EC50	0.086	Secondary	Standard method, control considerations; however, nominal concentrations and EC50 immobilization endpoint	-	KJW	10/03/2017	Secondary	Aquatic invertebrate	Acute	
EC50	0.061	Secondary	Standard method, control considerations; however, nominal concentrations and EC50 immobilization endpoint	-	KJW	10/03/2017	Secondary	Aquatic invertebrate	Acute	
EC50	0.276	Primary	Test completed under standardized method, measured concentrations, control measures met	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
EC50	0.11	Primary	Test completed under standardized method, measured concentrations, control measures met	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
LC50	0.157	Primary	Test completed under standardized method, measured concentrations, control measures met	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
EC20	0.178	Primary	Test completed under standardized method, measured concentrations, control measures met	Derived from tox curve	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
EC20	0.063	Primary	Test completed under standardized method, measured concentrations, control measures met	Derived from tox curve	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
LC50	0.52	Secondary	Old study but robust methodology; nominal concentrations	-	KJW	05/04/2017	Secondary	Aquatic invertebrate	Chronic	
EC16	0.014	Secondary	Old study but robust methodology; nominal concentrations	-	KJW	05/04/2017	Secondary	Aquatic invertebrate	Chronic	
EC50	0.082	Secondary	Old study but robust methodology; nominal concentrations	-	KJW	05/04/2017	Secondary	Aquatic invertebrate	Chronic	
LC50	15.5	Secondary	Test completed under standardized method, Nominal concentrations, control measures met		NT	01/05/2019	Secondary	Fish	Acute	
LC50	5.2	Secondary	Test completed under standardized method, Nominal concentrations, control measures met		NT	01/05/2019	Secondary	Fish	Acute	
LC50	2.5	Secondary	Test completed under standardized method, Nominal concentrations, control measures met		NT	01/05/2019	Secondary	Fish	Acute	
LC50	0.397	Secondary	Test completed under standardized method, Nominal concentrations, control measures met		NT	08/05/2019	Secondary	Aquatic invertebrate	Acute	
LC50	4	Secondary	Test completed under standardized method, Nominal concentrations, control measures met		NT	08/05/2019	Secondary	Aquatic invertebrate	Acute	
LC50	30	Secondary	Test completed under standardized method, Nominal concentrations, control measures met		NT	08/05/2019	Secondary	Aquatic invertebrate	Acute	

Literature Citation			Chemical Identity				Test Organism(s)				Experimental Design - Water Conditions					
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	pH	Test Conditions (Laboratory/F ield)	Hardness	Conductivity	Salinity	Freshwater or Marine
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Rhodium	7440166	NR	Tap water	Hyalella azteca	Amphipod	Partial	1-11 d	8.3	Laboratory	124	515	NA	Freshwater
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Rhodium	7440166	NR	Soft water (deionized)	Hyalella azteca	Amphipod	Partial	1-11 d	7.71	Laboratory	18	235	NA	Freshwater
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Pla	Rhodium	NR	Na3[RhCl6]:	Nutrient solution	Eichhornia c	Water-Hyacint	Partial	NR	NR	Laboratory	NR	NR	NR	Freshwater
Farago and Parsons	1994	The Effects of Various Platinum Metal Species on the Water Pla	Rhodium	NR	Na3[RhCl6]:	Nutrient solution	Eichhornia c	Water-Hyacint	Partial	NR	NR	Laboratory	NR	NR	NR	Freshwater
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna	Rhodium (	NR	RhCl3-3H2O	Standard freshwater	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna	Rhodium (	NR	RhCl3-3H2O	Standard freshwater	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna	Rhodium (	NR	RhCl3-3H2O	Standard freshwater	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna	Rhodium (	NR	RhCl3-3H2O	Standard freshwater	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater
Zimmerman et al.	2017	Toxicity of platinum, palladium and rhodium to Daphnia magna	Rhodium (	NR	RhCl3-3H2O	Standard freshwater	Daphnia mag	Water flea	Partial	Neonates	6-9	Laboratory	NR	NR	NA	Freshwater
Aquatox	2017		Rhodium	NR	Rh in 5% HCl	Well water	Ceriodaphnia dubia	Water flea	Partial	<9hr	7.9-8.2	Laboratory	260	722-728	NA	Freshwater
Aquatox	2017		Rhodium	NR	Rh in 5% HCl	Well water	Ceriodaphnia dubia	Water flea	Partial	<9hr	7.9-8.2	Laboratory	260	722-728	NA	Freshwater
Aquatox	2017		Rhodium	NR	Rh in 5% HCl	Well water	Pimephales promelas	Fathead Minno	Partial	<24 hr	7.9-8.3	Laboratory	260	722-728	NA	Freshwater
Aquatox	2017		Rhodium	NR	Rh in 5% HCl	Well water	Pimephales promelas	Fathead Minno	Partial	<24 hr	7.9-8.3	Laboratory	260	722-728	NA	Freshwater
Aquatox	2017		Rhodium	NR	Rh in 5% HCl	Well water	Hyalella azteca	Amphipod	Partial	5-8 days old	7.9-8.4	Laboratory	NR	785-810	NA	Freshwater
Aquatox	2017		Rhodium	NR	Rh in 5% HCl	Well water	Hyalella azteca	Amphipod	Partial	5-8 days old	7.9-8.4	Laboratory	NR	785-810	NA	Freshwater
Aquatox	2018		Rhodium	NR	Rh in 5% HCl	Well water	Oncorhynchus mykiss	Rainbow Trout	Partial	embryo	7.9-8.3	Laboratory	NR	739-761	NA	Freshwater
Aquatox	2018		Rhodium	NR	Rh in 5% HCl	Well water	Oncorhynchus mykiss	Rainbow Trout	Partial	embryo	7.9-8.3	Laboratory	NR	739-761	NA	Freshwater

NA Not applicable (i.e., salinity is not applicable to freshwater studies)
NR Not reported in the study

Rh

Experimental Design		Results						CanNorth Team		Classification			
Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/L)	Ranking of Study	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group	Acute/Chronic	
Static non-renewal	7 d	Mortality	LC50	>3.15	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	per authors, acute designation
Static non-renewal	7 d	Mortality	LC50	0.804	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Completed for Bismuth, Gold, Indium, Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	per authors, acute designation
Renewal	14 d	Growth (Plants appeared healthy and large, no toxic effects at 10 ug mL -I, plants also grown in 20 and 30 ug mL-1. where some mild chlorosis was noted. Enhanced pigmentation in roots compared with controls.)	LOEC	20	Secondary	inferred endpoints based on narrative d	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain
Renewal	14 d	Growth (Plants appeared healthy and large, no toxic effects at 10 ug mL -I, plants also grown in 20 and 30 ug mL-1. where some mild chlorosis was noted. Enhanced pigmentation in roots compared with controls.)	NOEC	10	Secondary	inferred endpoints based on narrative d	accumulation study	KJW	10/03/2017	Secondary	Aquatic plant	Acute	uncertain
Static non-	24 hr	Immobilization	EC50	83.8	Primary	Test completed under standardized method, measured concentrations, control measures met	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Static non-	48 hr	Immobilization	EC50	12.3	Primary	Test completed under standardized method, measured concentrations, control measures met	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Static non-	48 hr	Lethality	LC50	56.8	Primary	Test completed under standardized method, measured concentrations, control measures met	Completed for Pt, Pd, Rh	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Static non-	24 hr	Immobilization	EC20	50.119	Primary	Test completed under standardized method, measured concentrations, control measures met	Derived from tox curve	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Static non-	48 hr	Immobilization	EC20	5.370	Primary	Test completed under standardized method, measured concentrations, control measures met	Derived from tox curve	KJW	05/04/2017	Primary	Aquatic invertebrate	Acute	
Renewal	7 d	Reproduction	IC25	>0.1	Primary			KJW	02/21/2019	Primary	Aquatic invertebrate	Chronic	
Renewal	7 d	Survival	LC50	>0.1	Primary			KJW	02/21/2019	Primary	Aquatic invertebrate	Chronic	
Static renewal	7 d	Growth (from biomass)	IC25	>0.1	Primary			KJW	02/21/2019	Primary	Fish	Chronic	
Static renewal	7 d	Survival	LC50	>0.1	Primary			KJW	02/21/2019	Primary	Fish	Chronic	
Static renewal	14 d	Growth	IC25	>0.1	Primary			KJW	02/21/2019	Primary	Aquatic invertebrate	Chronic	
Static renewal	14 d	Survival	LC50	>0.1	Primary			KJW	02/21/2019	Primary	Aquatic invertebrate	Chronic	
Static renewal E-test	7 d	Reproduction	EC25	>0.1	Primary			KJW	02/21/2019	Primary	Fish	Chronic	
Static renewal E-test	7 d	Reproduction	EC50	>0.1	Primary			KJW	02/21/2019	Primary	Fish	Chronic	

Literature Citation			Chemical Identity				Test Organism(s)				Experimental Design - Water Conditions					
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	pH	Test Conditions (Laboratory/Field)	Hardness	Conductivity	Salinity	Freshwater or Marine
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Ruthenium	7440188	NR	Tap water	Hyalella azteca	Amphipod	Partial	1-11 d	8.3	Laboratory	124	515	NA	Freshwater
Borgmann et al.	2005	Toxicity of Sixty-Three Metals and Metalloids to Hyalella azteca at Two Levels of Water Hardness. Environ. Toxicol. Chem., 24(3): 641-652.	Ruthenium	7440188	NR	Soft water (deionized)	Hyalella azteca	Amphipod	Partial	1-11 d	7.71	Laboratory	18	235	NA	Freshwater
Aquatox	2018		Ruthenium	NR	in 5% HCl	Well water	Oncorhynchus mykiss	Rainbow Trout	Partial	embryo	7.9-8.3	Laboratory	NR	742-825	NA	Freshwater
Aquatox	2018		Ruthenium	NR	in 5% HCl	Well water	Oncorhynchus mykiss	Rainbow Trout	Partial	embryo	7.9-8.3	Laboratory	NR	742-825	NA	Freshwater
Aquatox	2018		Ruthenium	NR	in 5% HCl	Well water	Oncorhynchus mykiss	Rainbow Trout	Partial	embryo	7.9-8.3	Laboratory	NR	742-825	NA	Freshwater
Aquatox	2017		Ruthenium	NR	in 5% HCl	Well water	Ceriodaphnia dubia	Water flea	Partial	<9hr	7.9-8.3	Laboratory	260	722-730	NA	Freshwater
Aquatox	2017		Ruthenium	NR	in 5% HCl	Well water	Ceriodaphnia dubia	Water flea	Partial	<9hr	7.9-8.3	Laboratory	260	722-730	NA	Freshwater
Aquatox	2017		Ruthenium	NR	in 5% HCl	Well water	Pimephales promelas	Fathead Minno	Partial	<24 hr	7.8-8.1	Laboratory	260	723-733	NA	Freshwater
Aquatox	2017		Ruthenium	NR	in 5% HCl	Well water	Pimephales promelas	Fathead Minno	Partial	<24 hr	7.8-8.1	Laboratory	260	723-733	NA	Freshwater
Aquatox	2017		Ruthenium	NR	in 5% HCl	Well water	Hyalella azteca	Amphipod	Partial	5-8 days old	7.9-8.4	Laboratory	NR	728-748	NA	Freshwater
Aquatox	2017		Ruthenium	NR	in 5% HCl	Well water	Hyalella azteca	Amphipod	Partial	5-8 days old	7.9-8.4	Laboratory	NR	728-748	NA	Freshwater
Mello-Andrade et al.	2018	Acute toxic effects of ruthenium (II)/amino acid/diphosphine complexes on Swiss mice and zebrafish embryos.Biomedicine & Pharmacotherapy 107 (2018) 1082–1092.	RuMet	NR	NR	Water	Zebrafish eggs	Zebrafish eggs	Partial	30 min after natural mating	pH at 7.0 ± 0.5	Laboratory	NR	750 ± 50 μS/cm	NR	Freshwater
Mello-Andrade et al.	2018	Acute toxic effects of ruthenium (II)/amino acid/diphosphine complexes on Swiss mice and zebrafish embryos.Biomedicine & Pharmacotherapy 107 (2018) 1082–1092.	RuTrp	NR	NR	Water	Zebrafish eggs	Zebrafish eggs	Partial	30 min after natural mating	pH at 7.0 ± 0.5	Laboratory	NR	750 ± 50 μS/cm	NR	Freshwater

NA Not applicable (i.e., salinity is not applicable to freshwater studies)
NR Not reported in the study

Experimental Design		Results						CanNorth Team		Classification			
Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/L)	Ranking of Study	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group	Acute/Chronic	
Static non-renewal	7 d	Mortality	LC50	>3.15	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	per authors, acute designation
Static non-renewal	7 d	Mortality	LC50	>1	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	Completed for Bismuth, Gold, Indium, Iridium, Osmium, Palladium, Platinum, Rhodium, Ruthenium, Tellurium, Tungsten	KJW	22/02/2017	Secondary	Aquatic invertebrate	Acute	per authors, acute designation
Static renewal E-test	7 d	Reproduction	EC10	>0.1	Primary		Selected endpoint with correction for control effects	KJW	02/21/2019	Primary	Fish	Chronic	
Static renewal E-test	7 d	Reproduction	EC25	>0.1	Primary			KJW	02/21/2019	Primary	Fish	Chronic	
Static renewal E-test	7 d	Reproduction	EC50	>0.1	Primary			KJW	02/21/2019	Primary	Fish	Chronic	
Renewal	7 d	Reproduction	IC25	>0.1	Primary			KJW	02/21/2019	Primary	Aquatic invertebrate	Chronic	
Renewal	7 d	Survival	LC50	>0.1	Primary			KJW	02/21/2019	Primary	Aquatic invertebrate	Chronic	
Static renewal	7 d	Growth (from biomass)	IC25	>0.1	Primary			KJW	02/21/2019	Primary	Fish	Chronic	
Static renewal	7 d	Survival	LC50	>0.1	Primary			KJW	02/21/2019	Primary	Fish	Chronic	
Static renewal	14 d	Growth	IC25	>0.1	Primary			KJW	02/21/2019	Primary	Aquatic invertebrate	Chronic	
Static renewal	14 d	Survival	LC50	>0.1	Primary			KJW	02/21/2019	Primary	Aquatic invertebrate	Chronic	
Static	96 hour	Survival	LC50	>100	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	For complexes	NT	04/29/2019	Secondary	Fish	Acute	
Static	96 hour	Survival	LC50	47.8	Secondary	Modified tox test, control measures considered, measured concentrations; however, LC50 endpoints	For complexes	NT	04/29/2019	Secondary	Fish	Acute	

APPENDIX B.2: COMPILED TERRESTRIAL TOXICITY DATA

Literature Citation			Chemical Identity					Test Organism(s)				Experimental
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Background Concentration	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	Exposure
Williams et al.	1982	Toxicol Appl Pharmacol, 63: 461-469.	Sodium tetrachloroaurate(III)	NR	NaAuCl4	NR	NR	BALB/c	Mouse	NR	NR	Intraperitoneal
Voua Otomo et al.	2014	Single and mixture toxicity of gold nanoparticles and gold(III) to Enchytraeus buchholzi (Oligochaeta). Applied Soil Ecology, 84: 231-234.	Gold (III) chloride hydrate	NR	HAuCl4-3H2O	NR	NR	Enchytraeus buchholzi	Oligochaeta	NR	Adult	Amended soil
Voua Otomo et al.	2014	Single and mixture toxicity of gold nanoparticles and gold(III) to Enchytraeus buchholzi (Oligochaeta). Applied Soil Ecology, 84: 231-234.	Gold (III) chloride hydrate	NR	HAuCl4-3H2O	NR	NR	Enchytraeus buchholzi	Oligochaeta	NR	Adult	Amended soil
Voua Otomo et al.	2014	Single and mixture toxicity of gold nanoparticles and gold(III) to Enchytraeus buchholzi (Oligochaeta). Applied Soil Ecology, 84: 231-234.	Gold (III) chloride hydrate	NR	HAuCl4-3H2O	NR	NR	Enchytraeus buchholzi	Oligochaeta	NR	Adult	Amended soil
Yataka et al.	1988	administered gold thioglucose on	Gold thioglucose	NR	glucosylthio)	Water	NR	NR	Comb	Partial	Old	Intraperitoneal
Yataka et al.	1988	The effect of intraperitoneally administered gold thioglucose on growth, food consumption and accumulation of gold in various organs of the chicken (Gallus domesticus). Comparative Biochemistry and Physiology Part C: Comparative Pharmacology, 90(2): 461-464.	Gold thioglucose	NR	[(1 -D-glucosylthio) gold, C,H, , AuO, S],	Water	NR	NR	Single-Comb White Leghorn chickens	Partial	10 Days Old	Intraperitoneal
Yataka et al.	1988	The effect of intraperitoneally administered gold thioglucose on growth, food consumption and accumulation of gold in various organs of the chicken (Gallus domesticus). Comparative Biochemistry and Physiology Part C: Comparative Pharmacology, 90(2): 461-464.	Gold thioglucose	NR	[(1 -D-glucosylthio) gold, C,H, , AuO, S],	Water	NR	NR	Single-Comb White Leghorn chickens	Partial	10 Days Old	Intraperitoneal

Design	Results						CanNorth Team		Classification	
Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration	Ranking of Study (Selected, Consulted, Not Acceptable)	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group
14 d	Mortality	LD50	39.4 ug/g bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
14 d	Reproduction	EC10	24.3 ug/g soil	Selected	Study details provided	wet/dry weight not specified	KJW	05/04/2017	Selected	Invertebrate
14 d	Reproduction	EC50	35.5 ug/g soil	Selected	Study details provided	wet/dry weight not specified	KJW	05/04/2017	Selected	Invertebrate
14 d	Mortality	LC50	>37.5 ug/g soil	Selected	Study details provided	Survival remained relatively unaffected by the concentrations tested	KJW	05/04/2017	Selected	Invertebrate
Once	Mortality (M/F)	LD100	0.8 mg/g	Consulted	Intraperitoneal	Not statistically significant	NT	11/04/2017	Consulted	Bird
Once	Mortality (M)	LD25	0.4 mg/g	Consulted	Intraperitoneal	Not statistically significant	NT	11/04/2017	Consulted	Bird
Once	Mortality (F)	LD25	0.2 mg/g	Consulted	Intraperitoneal	Not statistically significant	NT	11/04/2017	Consulted	Bird

Literature Citation			Chemical Identity					Test Organism(s)				Experimental Design	
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Background Concentration	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	Exposure	Duration
Williams et al.	1982	Toxicol Appl Pharmacol, 63: 461-469.	Indium (III) chloride, tetrahydrate	NR	InCl3-4H2O	NR	NR	BALB/c	Mouse	NR	NR	Intraperitonal	14 d
Williams et al.	1982	Toxicol Appl Pharmacol, 63: 461-469.	Indium (III) chloride, tetrahydrate	NR	InCl3-4H2O	NR	NR	Drosophila melanogaster	Fruit fly	Partial	0-1 day old	Oral	4 d
Kabe et al.	1996	of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Intraperitonal	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Oral	Once
Kabe et al.	1996	In Vitro Solubility and In Vivo Toxicity of Indium Phosphide	Indium Phosphide	NR	InP	NR	NR	ICR Mice	Mouse	Partial	4 weeks old	Oral	Once

Results						CanNorth Team		Classification	
Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration	Ranking of Study (Selected, Consulted, Not Acceptable)	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group
Mortality	LD50	4.6 ug/g bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Mortality	LD50	4019 ug/g bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Insect
Macroscopic (Lung Lesions/InP in lymph nodes)	LOEC	3938 ug/g	Consulted	other strengths	exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Macroscopic (Lung Lesions/InP in lymph nodes)	NOEC	2363 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Microscopic (Spleen - granuals of InP/proliferation)	LOEC	2363 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Microscopic (Spleen - granuals of InP/proliferation)	NOEC	788 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Microscopic (Liver - granuals of InP/extramedullary granulopoises)	LOEC	2363 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Microscopic (Liver - granuals of InP/extramedullary granulopoises)	NOEC	1000 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Microscopic (Lungs - granuals of InP/eosinophilic exudates)	LOEC	2363 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Microscopic (Lungs - granuals of InP/eosinophilic exudates)	NOEC	788 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Organ Weight (testes)	LOEC	788 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Hemetological (monocytes/ neutraphils)	LOEC	3938 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Hemetological (monocytes/ neutraphils)	NOEC	2363 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Blood Biochemical (TP)	LOEC	788 ug/g	Consulted	Not std protocol, but other strengths	Intraperitoneal exposure	NT	11/04/2017	Consulted	Laboratory Rodent
Blood Biochemical (BUN)	LOEC	3938 ug/g	Selected	Not std protocol, but other strengths	-	NT	11/04/2017	Selected	Laboratory Rodent
Blood Biochemical (BUN)	NOEC	2363 ug/g	Selected	Not std protocol, but other strengths	-	NT	11/04/2017	Selected	Laboratory Rodent

Literature Citation			Chemical Identity					Test Organism(s)				Experimental Design		Results						CanNorth Team		Classification	
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Background Concentration	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/kg dry soil)	Ranking of Study (Selected, Consulted, Not Acceptable)	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group
Moore et al.	1975	Environ Health Perspect, 10: 63-71.	Palladium (II) chloride	NR	PdCl2	NR	NR	Charles River CD-1	Rat	NR	NR	oral	NR	Mortality	LD50	200 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
Phielepeit et al.	1989	Arch Toxicol, Suppl, 13: 357-362.	Palladium (II) chloride	NR	PdCl2	NR	NR	NMRI	Mouse	NR	NR	oral	NR	Mortality	LD50	> 1000 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
Moore et al.	1975	Environ Health Perspect, 10: 63-71.	Palladium (II) chloride	NR	PdCl2	NR	NR	Charles River CD-1	Rat	NR	NR	iv	14 d	Mortality	LD50	3 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Moore et al.	1975	Environ Health Perspect, 10: 63-71.	Palladium (II) chloride	NR	PdCl2	NR	NR	Charles River CD-1	Rat	NR	NR	iv	NR	Mortality	LD50	5 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Moore et al.	1975	Environ Health Perspect, 10: 63-71.	Palladium (II) chloride	NR	PdCl2	NR	NR	NR	Rabbit	NR	NR	iv	NR	Mortality	LD50	5 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Mammal
Moore et al.	1975	Environ Health Perspect, 10: 63-71.	Palladium (II) chloride	NR	PdCl2	NR	NR	Charles River CD-1	Rat	NR	NR	intraperitoneal	NR	Mortality	LD50	70 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Moore et al.	1975	Environ Health Perspect, 10: 63-71.	Palladium (II) chloride	NR	PdCl2	NR	NR	Charles River CD-1	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD50	123 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Phielepeit et al.	1989	Arch Toxicol, Suppl, 13: 357-362.	Palladium (II) chloride	NR	PdCl2	NR	NR	NMRI	Mouse	NR	NR	intraperitoneal	NR	Mortality	LD50	87 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Moore et al.	1975	Environ Health Perspect, 10: 63-71.	Palladium (II) chloride	NR	PdCl2	NR	NR	Charles River CD-1	Rat	NR	NR	intratracheal	NR	Mortality	LD50	6 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium (II) chloride	NR	PdCl2-2H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD50	290 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium sulphate	NR	PdSO4	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD50	>790 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium oxide	NR	PdO	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD50	>8700 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
Jones et al.	1979	Toxicol Appl Pharmacol, 49: 41-44.	Sodium tetrachloropalladate	NR	Na2PdCl4-3H	NR	NR	ICR, Swiss	Mouse	NR	NR	intraperitoneal	24 hr	Mortality	LD50	122 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Moore et al.	1975	Environ Health Perspect, 10: 63-71.	Potassium tetrachloropalladate(II)	NR	K2PdCl4	NR	NR	Charles River CD-1	Rat	NR	NR	iv	14 d	Mortality	LD50	6.4 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Williams et al.	1982	Toxicol Appl Pharmacol, 63: 461-469.	Potassium tetrachloropalladate(II)	NR	K2PdCl4	NR	NR	BALB/c	Mouse	NR	NR	intraperitoneal	14 d	Mortality	LD50	153 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Speranza et al.	2010	Pd-Nanoparticles Cause Increased Toxicity to Kiwifruit Pollen Compared to Soluble Pd(II). Environ. Pollut., 158(3): 873-882.	Palladium (II) chloride	NR	PdCl2	NR	NR	Actinidia deliciosa	Kiwi Fruit	pollen	NR	culture	90 min	Morphology (pollen tube lengt	EC50	3.6 mg/L	Not acceptable	Good study, expos	-	KJW	10/03/2017	Not acceptable	Plant
Speranza et al.	2010	Pd-Nanoparticles Cause Increased Toxicity to Kiwifruit Pollen Compared to Soluble Pd(II). Environ. Pollut., 158(3): 873-882.	Palladium (II) chloride	NR	PdCl2	NR	NR	Actinidia deliciosa	Kiwi Fruit	pollen	NR	culture	90 min	Mortality	LC50	8 mg/L	Not acceptable	Good study, expos	-	KJW	10/03/2017	Not acceptable	Plant
Speranza et al.	2010	Pd-Nanoparticles Cause Increased Toxicity to Kiwifruit Pollen Compared to Soluble Pd(II). Environ. Pollut., 158(3): 873-882.	Palladium (II) chloride	NR	PdCl2	NR	NR	Actinidia deliciosa	Kiwi Fruit	pollen	NR	culture	90 min	Morphology (pollen tube lengt	LOEL	2.5 mg/L	Not acceptable	Good study, expos	-	KJW	10/03/2017	Not acceptable	Plant
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium (II) chloride	NR	PdCl2-2H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD10	166 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium (II) chloride	NR	PdCl2-2H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD90	520 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium (II) chloride	NR	PdCl2-2H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD50	60 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium (II) chloride	NR	PdCl2-2H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD10	42 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium (II) chloride	NR	PdCl2-2H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD90	87 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium sulphate	NR	PdSO4	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD50	151 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium sulphate	NR	PdSO4	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD10	82 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Palladium sulphate	NR	PdSO4	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD90	195 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Schertzinger et al.	2017	Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium	Palladium	NR	NR	HCl	NR	Caenorhabditis elegans	Nematode	Larvae	NR	Exposure medium	96 hour	Growth	EC50	>1000 ug/L	Consulted	aquatic toxicity	14	NT	29/04/2019	Consulted	Nematode
Schertzinger et al.	2017	Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium	Palladium	NR	NR	HCl	NR	Caenorhabditis elegans	Nematode	Larvae	NR	Exposure medium	96 hour	Fertility	EC50	>1000 ug/L	Consulted	aquatic toxicity	14	NT	29/04/2019	Consulted	Nematode
Schertzinger et al.	2017	Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium	Palladium	NR	NR	HCl	NR	Caenorhabditis elegans	Nematode	Larvae	NR	Exposure medium	96 hour	Reproduction	EC50	>1000 ug/L	Consulted	aquatic toxicity	14	NT	29/04/2019	Consulted	Nematode
Egorova et al.	2019	Evaluation of phytotoxicity and cytotoxicity of industrial catalyst components (Fe, Cu, Ni, Rh and Pd): A case of lethal toxicity of a rhodium salt in terrestrial plants. Chemosphere 223 (2019) 738e747	Palladium	NR	H20	NR	NR	Pisum sativum	Pea Plant	Partial	Seed	Exposure medium	10 day	Growth	IC50	Graph but no data	Not acceptable	growth medium, concentrations not environmentally relevant	11	NT	30/04/2019	Not acceptable	Plant
Egorova et al.	2019	Evaluation of phytotoxicity and cytotoxicity of industrial catalyst components (Fe, Cu, Ni, Rh and Pd): A case of lethal toxicity of a rhodium salt in terrestrial plants. Chemosphere 223 (2019) 738e747	Palladium	NR	H20	NR	NR	Lupinus angustifolius	Lupine	Partial	Seed	Exposure medium	10 day	Growth	IC50	Graph but no data	Not acceptable	growth medium, concentrations not environmentally relevant	11	NT	30/04/2019	Not acceptable	Plant
Egorova et al.	2019	Evaluation of phytotoxicity and cytotoxicity of industrial catalyst components (Fe, Cu, Ni, Rh and Pd): A case of lethal toxicity of a rhodium salt in terrestrial plants. Chemosphere 223 (2019) 738e747	Palladium	NR	H20	NR	NR	Cucumis sativus	Cucumber	Partial	Seed	Exposure medium	10 day	Growth	IC50	Graph but no data	Not acceptable	growth medium, concentrations not environmentally relevant	11	NT	30/04/2019	Not acceptable	Plant

Literature Citation			Chemical Identity					Test Organism(s)				Experimental Design		Results						CanNorth Team		Classification	
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Background Concentration	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/kg dry soil)	Ranking of Study (Selected, Consulted, Not Acceptable)	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum sulphate	NR	Pt(SO4)2-4H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD50	132 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Williams et al.	1982	Toxicol Appl Pharmacol, 63: 461-469.	Potassium tetrachloroplatinate(II)	NR	K2PtCl4	NR	NR	BALB/c	Mouse	NR	NR	intraperitoneal	14 d	Mortality	LD50	31 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum tetrachloride	NR	PtCl4	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD50	22 mg/kg bw	Consulted	WHO EHC	Not scored	NT	16/03/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum sulphate	NR	Pt(SO4)2-4H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD10	110 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum sulphate	NR	Pt(SO4)2-4H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD90	160 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum sulphate	NR	Pt(SO4)-4H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD50	59 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum sulphate	NR	Pt(SO4)-4H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD10	39 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum sulphate	NR	Pt(SO4)-4H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD90	78 mg/kg bw	Consulted	WHO EHC	Not scored	KJW	28/02/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum chloride	NR	PtCl2	NR	NR	Sprague-Dawley	Rat	NR	NR	intraperitoneal	14 d	Mortality	LD50	490 mg/kg bw	Consulted	WHO EHC	Not scored	NT	16/03/2017	Consulted	Laboratory Rodent
Moore et al.	1975	Environ Health Perspect, 10: 63-71.	Platinum chloride	NR	PtCl4	NR	NR	Charles River CD-1	Rat	NR	NR	intravenous	NR	Mortality	LD50	15 mg/kg bw	Consulted	WHO EHC	The results of a preliminary range finding study on the acute toxicity of IV PtCl4 in rats is given in Table 3. The high incidence of mortality at the lowest dose precluded determination of the LD50 (14 days). However, the lowest dose would appear to be a reasonable approximation.	KJW	27/03/2017	Consulted	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum oxide	NR	PtO2	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD50	>6900 mg/kg	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum chloride	NR	PtCl2	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD50	>1400 mg/kg	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum tetrachloride	NR	PtCl4	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD50	136 mg/kg bw	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum sulphate	NR	Pt(SO4)2 .4 H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD50	430 mg/kg bw	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Roshchin et al.	1984	ENVIRONMENTAL HEALTH CRITERIA 125	Platinum chloride	NR	PtCl2	NR	NR	NR	Rat	NR	NR	oral	NR	Mortality	LD50	3423	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Roshchin et al.	1984	ENVIRONMENTAL HEALTH CRITERIA 125	Platinum tetrachloride	NR	PtCl4	NR	NR	NR	Rat	NR	NR	oral	NR	Mortality	LD50	276	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum tetrachloride	NR	PtCl4	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD10	60 mg/kg bw	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum tetrachloride	NR	PtCl4	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD90	310 mg/kg bw	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum sulphate	NR	Pt(SO4)2 .4 H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD10	270 mg/kg bw	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Platinum sulphate	NR	Pt(SO4)2 .4 H2O	NR	NR	Sprague-Dawley	Rat	NR	NR	oral	14 d	Mortality	LD90	690 mg/kg bw	Selected	WHO EHC	Not scored	NT	16/03/2017	Selected	Laboratory Rodent
Schertzinger et al.	2017	Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium	Platinum	NR	NR	HCl	NR	Caenorhabditis elegans	Nematode	Larvae	NR	Exposure medium	96 hour	Growth	EC50	808 ug/L	Consulted	aquatic toxicity	14	NT	29/04/2019	Consulted	Nematode
Schertzinger et al.	2017	Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium	Platinum	NR	NR	HCl	NR	Caenorhabditis elegans	Nematode	Larvae	NR	Exposure medium	96 hour	Fertility	EC50	726 ug/L	Consulted	aquatic toxicity	14	NT	29/04/2019	Consulted	Nematode
Schertzinger et al.	2017	Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium	Platinum	NR	NR	HCl	NR	Caenorhabditis elegans	Nematode	Larvae	NR	Exposure medium	96 hour	Reproduction	EC50	497 ug/L	Consulted	aquatic toxicity	14	NT	29/04/2019	Consulted	Nematode

Literature Citation			Chemical Identity					Test Organism(s)				Experimental Design	
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Background Concentration	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)	Life Cycle Stage (age)	Exposure	Duration
Carneiro et al.	2015	Acute and subchronic toxicity of the antitumor agent rhodium (II) citrate in Balb/c mice after intraperitoneal administration. Toxicology Reports, 2: 1086-1100.	Rhodium (II) citrate	NR	NR	NR	NR	Balb/c	Mice	Partial	12 weeks	Intraperitonal	once
Carneiro et al.	2015	Acute and subchronic toxicity of the antitumor agent rhodium (II) citrate in Balb/c mice after intraperitoneal administration. Toxicology Reports, 2: 1086-1100.	Rhodium (II) citrate	NR	NR	NR	NR	Balb/c	Mice	Partial	12 weeks	Intraperitonal	44 d
Williams et al.	1982	Toxicol Appl Pharmacol, 63: 461-469.	Rhodium (III) chloride, hydrate	NR	RhCl3-2.88H2O	NR	NR	BALB/c	Mouse	NR	NR	Intraperitonal	14 d
Landolt et al.	1971	Studies on the toxicity of rhodium trichloride in rats and rabbits.. Toxicol Appl Pharmacol., 21(4): 589-90.	Rhodium (III) chloride	NR	RhCl3	Phosphate Buffer Solution	NR	Sprague-Dawley	Rat	Partial	63 days old	Intravenous	Once
Landolt et al.	1971	Studies on the toxicity of rhodium trichloride in rats and rabbits.. Toxicol Appl Pharmacol., 21(4): 589-90.	Rhodium (III) chloride	NR	RhCl3	Phosphate Buffer Solution	NR	New Zealand White Rabbits	Rabbit	Partial	63 days old	Intravenous	Once
Williams et al.	1982	Toxicol Appl Pharmacol, 63: 461-469.	Rhodium (III) chloride, hydrate	NR	RhCl3-2.88H2O	NR	NR	Drosophila melanogaster	Fruit fly	Partial	0-1 day old	Oral	4 d
Iavicoli, I., V. Leso, L. Fontana, A. Marinaccio, A. Bergamaschi, E.J. Calabrese,	2014	The effects of rhodium on the renal function of female Wistar rats. Chemosphere, 104: 120-125.	Rhodium (III) chloride, hydrate	NR	RhCl3	Salt Considered but not reported	NR	Wistar rats	Rat	Partial	3 months	Oral	14 days
Iavicoli, I., V. Leso, L. Fontana, A. Marinaccio, A. Bergamaschi, E.J. Calabrese,	2014	The effects of rhodium on the renal function of female Wistar rats. Chemosphere, 104: 120-125.	Rhodium (III) chloride, hydrate	NR	RhCl3	Salt Considered but not reported	NR	Wistar rats	Rat	Partial	3 months	Oral	14 days
Iavicoli, I., V. Leso, L. Fontana, A. Marinaccio, A. Bergamaschi, E.J. Calabrese,	2014	The effects of rhodium on the renal function of female Wistar rats. Chemosphere, 104: 120-125.	Rhodium (III) chloride, hydrate	NR	RhCl3	Salt Considered but not reported	NR	Wistar rats	Rat	Partial	3 months	Oral	14 days
Iavicoli, I., V. Leso, L	2014	The effects of rhodium on the renal function of female Wistar rats. Chemosphere, 104: 120-125.	Rhodium (III) chloride, hydrate	NR	RhCl3	Salt Considered but not reported	NR	Wistar rats	Rat	Partial	3 months	Oral	14 days
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Eisenia andrei	Earthworm	Partial	NR	Soil	28 day
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Eisenia andrei	Earthworm	Partial	NR	Soil	56 day
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Eisenia andrei	Earthworm	Partial	NR	Soil	56 day
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial	Seed	Soil	14 d
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial	Seed	Soil	14 d
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial	Seed	Soil	14 d
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial	Seed	Soil	14 d
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial	Seed	Soil	14 d
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial	Seed	Soil	21 d
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial	Seed	Soil	21 d
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial	Seed	Soil	21 d
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial	Seed	Soil	21 d
Aquatox	2017		Rhodium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial	Seed	Soil	21 d
Schertzinger et al.	2017	Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium	Rhodium	NR	NR	HCl	NR	Caenorhabditis elegans	Nematode	Partial	Larvae	Exposure medium	96 hour
Schertzinger et al.	2017	Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium	Rhodium	NR	NR	HCl	NR	Caenorhabditis elegans	Nematode	Partial	Larvae	Exposure medium	96 hour
Schertzinger et al.	2017	Assessment of sublethal endpoints after chronic exposure of the nematode Caenorhabditis elegans to palladium, platinum and rhodium	Rhodium	NR	NR	HCl	NR	Caenorhabditis elegans	Nematode	Partial	Larvae	Exposure medium	96 hour

Results						CanNorth Team		Classification	
Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/kg dry soil)	Ranking of Study (Selected, Consulted, Not Acceptable)	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group
Mortality	LD50	> 107.5 mg/kg bw	Consulted	-	Intraperitoneal exposure	KJW	15/03/2017	Consulted	Laboratory Rodent
Mortality	LD50	> 400 mg/kg bw	Consulted	-	Intraperitoneal exposure	KJW	15/03/2017	Consulted	Laboratory Rodent
Mortality	LD50	144 mg/kg bw	Consulted	WHO EHC	Intraperitoneal exposure	KJW	28/02/2017	Consulted	Laboratory Rodent
Mortality	LD50	198 mg/kg	Consulted	-	Intravenous exposure	NT	10/04/2017	Consulted	Laboratory Rodent
Mortality	LD50	215 mg/kg	Consulted	-	Intravenous exposure	NT	10/04/2017	Consulted	Laboratory Mammal
Mortality	LD50	576 mg/kg bw	Consulted	WHO EHC	Not Scored	KJW	28/02/2017	Consulted	Insect
Renal Function (RBP)	LOAEC	0.1 mg/L	Not acceptable	Renal function not acceptable endpoint	Statistical tests completed, well described protocol	NT	10/04/2017	Unacceptable	Laboratory Rodent
Renal Function (RBP)	NOAEC	0.01 mg/L	Not acceptable	Renal function not acceptable endpoint	Statistical tests completed, well described protocol	NT	10/04/2017	Unacceptable	Laboratory Rodent
Renal Function (b2-microglobulin)	LOAEC	1 mg/L	Not acceptable	Renal function not acceptable endpoint	Statistical tests completed, well described protocol	NT	10/04/2017	Unacceptable	Laboratory Rodent
Renal Function (b2-microglobulin)	NOAEC	0.1 mg/L	Not acceptable	Renal function not acceptable endpoint	Statistical tests completed, well described protocol	NT	10/04/2017	Unacceptable	Laboratory Rodent
Survival	LC50	> 15 ug/g	Consulted	Other endpoints		KJW	21/02/2019	Consulted	Earthworm
Reproductive Success	IC25	6.64 ug/g	Selected			KJW	21/02/2019	Selected	Earthworm
Growth	IC25	<0.234 ug/g	Consulted	"<" and reproduction endpoint more relevant		KJW	21/02/2019	Consulted	Earthworm
Emergence	EC50	> 20 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Shoot Length	IC25	> 20 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Shoot Weight	IC25	> 20 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Root Length	IC25	7.3 ug/g	Selected			KJW	22/02/2019	Selected	Plant
Root Dry Weight	IC25	> 20 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Emergence	EC50	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Shoot Length	IC25	> 10 ug/g	Selected			KJW	22/02/2019	Selected	Plant
Shoot Weight	IC25	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Root Length	IC25	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Root Dry Weight	IC25	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Growth	EC50	>10000 ug/L	Consulted	aquatic toxicity test	14	NT	29/04/2019	Unacceptable	Nematode
Fertility	EC50	>10000 ug/L	Consulted	aquatic toxicity test	14	NT	29/04/2019	Unacceptable	Nematode
Reproduction	EC50	>10000 ug/L	Consulted	aquatic toxicity test	14	NT	29/04/2019	Unacceptable	Nematode

Literature Citation			Chemical Identity					Test Organism(s)		
Author(s)	Year	Journal/Report/Vol/Pages	Chemical Name	Chemical CAS	Formulation/ Form	Carrier Solvent	Background Concentration	Species Latin Name	Species Common Name	Life Stage Exposure (full, partial in vitro)
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Ruthenium chloride	NR	RuCl3	NR	NR	Sprague-Dawley	Rat	NR
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Ruthenium chloride	NR	RuCl3	NR	NR	Sprague-Dawley	Rat	NR
Holbrook et al.	1976	Assessment of Toxicity of Automotive Metallic Emissions, Volume 1. EPA-600/1-76-010a	Ruthenium chloride	NR	RuCl3	NR	NR	Sprague-Dawley	Rat	NR
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Eisenia andrei	Earthworm	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Eisenia andrei	Earthworm	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Eisenia andrei	Earthworm	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Hordeum vulgare	Barley	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial
Aquatox	2017		Ruthenium	NR	in 5% HCl	Autoclaved dilution water	NR	Medicago sativa	Alfalfa	Partial
Mello-Andrade	2018	Acute toxic effects of ruthenium (II)/amino acid/diphosphine complexes on Swiss mice and zebrafish embryos.Biomedicine & Pharmacotherapy 107 (2018) 1082–1092.	RuMet	NR	NR	NR	NR	NR	Swiss Albino Mice	Partial
Mello-Andrade	2018	Acute toxic effects of ruthenium (II)/amino acid/diphosphine complexes on Swiss mice and zebrafish embryos.Biomedicine & Pharmacotherapy 107 (2018) 1082–1092.	RuTrp	NR	NR	NR	NR	NR	Swiss Albino Mice	Partial

	Experimental Design		Results						CanNorth Team		Classification	
Life Cycle Stage (age)	Exposure	Duration	Observed Adverse Effect (% Growth Reduction, % Germination Success, Etc.)	Endpoint (EC10, EC50, etc.)	Effect Concentration (mg/kg dry soil)	Ranking of Study (Selected, Consulted, Not Acceptable)	Rational and Details for Ranking	Notes on Study	Evaluator	Evaluation Date	Data Categorization	Group
NR	oral	14 d	Mortality	LD50	310 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
NR	oral	14 d	Mortality	LD10	180 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
NR	oral	14 d	Mortality	LD90	550 mg/kg bw	Selected	WHO EHC	Not scored	KJW	28/02/2017	Selected	Laboratory Rodent
NR	Soil	28 day	Survival	LC50	> 15 ug/g	Consulted	Other endpoints		KJW	21/02/2019	Consulted	Earthworm
NR	Soil	56 day	Reproductive Success	IC25	10.4 ug/g	Consulted			KJW	21/02/2019	Consulted	Earthworm
NR	Soil	56 day	Growth	IC25	3.14 ug/g	Selected			KJW	21/02/2019	Selected	Earthworm
Seed	Soil	14 d	Emergence	EC50	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Seed	Soil	14 d	Shoot Length	IC25	> 10 ug/g	Selected			KJW	22/02/2019	Selected	Plant
Seed	Soil	14 d	Shoot Weight	IC25	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Seed	Soil	14 d	Root Length	IC25	< 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Seed	Soil	14 d	Root Dry Weight	IC25	< 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Seed	Soil	21 d	Emergence	EC50	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Seed	Soil	21 d	Shoot Length	IC25	> 10 ug/g	Selected			KJW	22/02/2019	Selected	Plant
Seed	Soil	21 d	Shoot Weight	IC25	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Seed	Soil	21 d	Root Length	IC25	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
Seed	Soil	21 d	Root Dry Weight	IC25	> 10 ug/g	Consulted			KJW	22/02/2019	Consulted	Plant
NR	Oral Gavage	Single dose	Survival	LD50	>2000	Not acceptable	for complex		NT	29/04/2019	Unacceptable	Laboratory Rodent
NR	Oral Gavage	Single dose	Survival	LD50	>2000	Not acceptable	for complex		NT	29/04/2019	Unacceptable	Laboratory Rodent

APPENDIX C.1: AQUATOX AQUATIC TOXICITY DATA

AquaTox Testing & Consulting Inc.
B-11 Nicholas Beaver Road
Puslinch, ON N0B 2J0
Tel. (519) 763-4412
Fax. (519) 763-4419

TOXICITY TEST REPORT

Ceriodaphnia dubia
EPS 1/RM/21

Work Order : 234749
Sample Number : 52860

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKCB9445
Test Item :	Ruthenium (1000 µg/mL Ru in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Date Tested :	2017-12-14
Test Item Description :	Dark brown liquid		

Test Method : Test of Reproduction and Survival using the Cladoceran *Ceriodaphnia dubia* . Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/21, 2nd ed. (February 2007), with deviation(s) as noted.

7-DAY TEST RESULTS

Effect	Endpoint	Value	Inhibition (% of Control)	Significantly Less than Control?	Calculation Method
Reproduction	IC25	>100 µg/L	6.46%	No (α= 0.05)	Wilcoxon Rank Sum Two-Sample Test [a]
Survival	LC50	>100 µg/L	0.0%	No (α= 0.05)	–

Results are based on nominal concentrations of the test item (v/v).
The results reported relate only to the item tested and as received.

SODIUM CHLORIDE REFERENCE TOXICANT DATA

Date Tested :	2018-01-03		
Test Duration :	6 days	Analyst(s) :	XD, JL, MA
IC25 Reproduction :	1.17 g/L	LC50 :	2.10 g/L
95% Confidence Limits :	1.11 - 1.22 g/L	95% Confidence Limits :	1.84 - 2.39 g/L
Statistical Method :	Linear Interpolation (CETIS)[a]	Statistical Method :	Spearman-Kärber (CETIS)[a]
Historical Mean IC25 :	1.34 g/L	Historical Mean LC50 :	2.22 g/L
Warning Limits (± 2SD) :	0.99 - 1.82 g/L	Warning Limits (± 2SD) :	1.86 - 2.65 g/L

The reference toxicity test was performed under the same experimental conditions as those used with the test sample.

TEST CONDITIONS

Sample Filtration :	None	Test Volume per Replicate :	15 mL
Test Aeration :	None	Test Vessel :	19 mL polystyrene vial
pH Adjustment :	None	Depth of Test Solution :	4.8 cm
Hardness Adjustment :	None	Organisms per Replicate :	1
Daily Renewal Method :	Transferred to fresh solutions	Number of Replicates :	10
Control/Dilution Water :	Well water (no chemicals added)	Test Method Deviation(s) :	See 'Comments'

COMMENTS

Noted Deviation(s) : According to the test method, a single sample may be used throughout the test if divided into at least 3 separate containers (i.e. three or more sub-samples) upon preparation. However, the test concentrations for this test were stored in a single container for the duration of the test.

Note: A single-concentration test was conducted.
•All test validity criteria as specified in the test method cited above were satisfied.
• The exposure concentration was confirmed analytically, although test endpoints were generated using the nominal test concentration. The total and dissolved Ru concentration was measured at test start, at first renewal and at test end. These results were provided separately to NWMO.

Work Order : 234749
Sample Number : 52860

TEST ORGANISMS

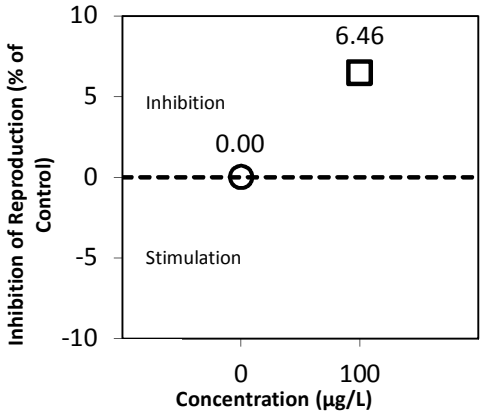
Test Organism : *Ceriodaphnia dubia*
Organism Batch : Cd17-12
Organism Origin : Single in-house mass culture
Test Organism Origin : Individual in-house cultures
Range of Age (at start of test) : 05:20 h - 08:50 h
Mean Brood Organism Mortality 1.7%
Ephippia in Culture : No

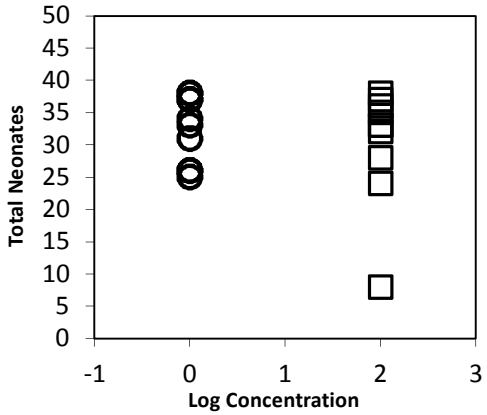
Brood Organism Neonate Production

Replicate :	1	2	3	4	5	6	7	8	9	10	Mean
Total (third or subsequent brood):	15	16	17	16	16	13	16	17	16	16	15.8
Total (first three broods):	25	27	25	28	24	24	26	27	26	25	25.7

No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

REPRODUCTION





PREPARATION OF TEST SOLUTIONS

Testing followed the general conditions of the cited test method. The test solution was prepared without the use of any solubilizing agent. A 10 mg/L (nominal) stock solution was prepared by thoroughly mixing 2 mL of 1000 mg/L ruthenium standard solution (in HCl) with reverse osmosis water for a total volume of 200 mL. The 10 mg/L stock solution was mixed with control/dilution water at a rate of 168 mL in 16.8 L in order to achieve a test solution of 100 µg/L (nominal). A sub-sample was removed for initiating the test. The remainder was stored in a sealed container, in complete darkness, with minimal head space, at 4±2 °C for the duration of the test. Sub-samples for test renewal were removed daily and warmed to test temperature. The Control consisted of control/dilution water which was stored and used in the same manner, but without the addition of ruthenium stock.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Date : 2019-03-08 *yyyy-mm-dd*

Approved By : *Project Manager*

AQUATOX

TOXICITY TEST REPORT
Ceriodaphnia dubia
EPS 1/RM/21

Work Order : 234749
Sample Number : 52860

SURVIVAL AND REPRODUCTION DATA

Test Initiation Date : 2017-12-14
Initiation Time : 14:50
Test Completion Date : 2017-12-21

Control	Date	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Mean Young (±SD)	Treatment Average Mortality (%)	Analyst(s)
	2017-12-15	**1**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0	RD
	2017-12-16	**2**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0	RD
	2017-12-17	**3**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0	RD
	2017-12-18	**4**	6	3	6	6	6	3	6	6	7	5	**5.4**	0.0	CZN
	2017-12-19	**5**	12	10	12	0	0	14	0	0	0	0	**4.8**	0.0	RD
	2017-12-20	**6**	0	0	0	15	16	0	17	12	15	14	**8.9**	0.0	RD
	2017-12-21	**7**	13	13	8	16	16	8	15	15	15	15	**13.4**	0.0	EJS
	Total	**31**	**26**	**26**	**37**	**38**	**25**	**38**	**33**	**37**	**34**	**32.5 (±5.2)**	**0.0**	

100 µg/L	Date	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Mean Young (±SD)	Treatment Average Mortality (%)
	2017-12-15	**1**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0
	2017-12-16	**2**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0
	2017-12-17	**3**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0
	2017-12-18	**4**	1	4	7	6	7	2	5	3	5	4	**4.4**	0.0
	2017-12-19	**5**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0
	2017-12-20	**6**	0	11	15	12	13	11	15	12	13	15	**11.7**	0.0
	2017-12-21	**7**	7	13	15	18	18	11	15	18	15	13	**14.3**	0.0
	Total	**8[2]**	**28**	**37**	**36**	**38**	**24**	**35**	**33**	**33**	**32**	**30.4 (±8.9)**	**0.0**	

NOTES : •All young produced by a test organism during its fourth and subsequent broods were discarded and not included in the above counts. The presence of two or more neonates in any test chamber, during any given day of the test, constitutes a brood.

•[2] Outlier according to Grubbs Test (CETIS)[a]. Outlying data points were not excluded from statistical analysis, since they could not be attributed to error.

"x"= test organism mortality
"*"= accidental test organism mortality
"–"=4th brood (see 'NOTES')

Data Reviewed By : JL
Date : 2018-04-23

AQUATOX

TOXICITY TEST REPORT

Ceriodaphnia dubia

EPS 1/RM/21

Work Order : 234749

Sample Number : 52860

INITIAL WATER CHEMISTRY DATA

	Day 0 - 1	Day 1 - 2	Day 2 - 3	Day 3 - 4	Day 4 - 5	Day 5 - 6	Day 6 - 7
Date :	2017-12-14	2017-12-15	2017-12-16	2017-12-17	2017-12-18	2017-12-19	2017-12-20
Sub-sample Used	1	1	1	1	1	1	1
Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Dissolved O_2 (mg/L)	8.1	8.0	8.2	8.9	8.9	9.0	8.9
Dissolved O_2 Saturation (%)[3]	100	100	100	108	108	109	109
pH	7.8	8.0	8.0	7.9	7.9	7.9	7.9
Pre-aeration Time (min)[4]	0	0	0	20	20	20	20

TEST WATER CHEMISTRY DATA

Analyst(s)	Initial	EJS	RD	RD	RD	CZN	RD	RD
	Final	RD	RD	RD	CZN	RD	RD	EJS
Control								
Temp. (°C)	Initial	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Final	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Dissolved O_2 Saturation (%)[3]	Initial	98	100	100	103	107	105	104
Dissolved O_2 (mg/L)	Initial	8.0	7.9	8.2	8.3	8.8	8.4	8.3
	Final	7.6	7.4	7.5	7.2	7.2	7.4	7.7
pH	Initial	8.3	8.3	8.3	8.3	8.2	8.2	8.2
	Final	8.2	8.2	8.3	8.2	8.2	8.1	8.1
Conductivity (µmhos/cm)	Initial	727	722	727	724	724	723	726
Hardness (mg/L as $CaCO_3$)		260	260	260	260	260	260	260
100 µg/L								
Temperature (°C)	Initial	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Final	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Dissolved O_2 (mg/L)	Initial	8.1	8.0	8.2	8.7	8.9	8.8	8.7
	Final	7.6	7.8	7.6	7.2	7.1	7.4	7.9
pH	Initial	7.8	8.0	8.0	8.0	7.9	7.9	7.9
	Final	8.2	8.2	8.3	8.1	8.1	8.1	8.1
Conductivity (µmhos/cm)	Initial	729	730	725	723	723	724	733

"–" = not measured

[3] % saturation (adjusted for actual temperature and barometric pressure)

[4] ≤100 bubbles/minute

Test Data Reviewed By : JL

Date : 2018-04-23

AquaTox Testing & Consulting Inc.
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TOXICITY TEST REPORT

Fathead minnow
EPS 1/RM/22

Work Order : 234749
Sample Number : 52860

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKCB9445
Test Item :	Ruthenium (1000 µg/mL Ru in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Date Tested :	2017-12-14
Test Item Description :	Dark brown liquid		

Test Method : Test of Larval Growth and Survival Using Fathead Minnows. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/22 , 2nd ed. (February 2011), with deviation(s) as noted.

7-DAY TEST RESULTS

Effect	Endpoint	Value	Inhibition (% of Control)	Significantly Less than Control?	Calculation Method
Growth (from Biomass)	IC25	>100 µg/L	4.76%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]
Survival	LC50	>100 µg/L	0.0%	No (α= 0.05)	–

Results are based on nominal concentrations of the test item (v/v).

The results reported relate only to the item tested and as received.

POTASSIUM CHLORIDE REFERENCE TOXICANT DATA

Date Tested :	2017-12-07	Analyst(s) :	XD, SEW, FS
Organism Batch :	Fm17-12	Test Duration :	7 days
IC25 Growth (from Biomass) :	1.00 g/L	LC50 :	1.19 g/L
95% Confidence Limits :	0.82 - 1.11 g/L	95% Confidence Limits :	1.13 - 1.26 g/L
Statistical Method :	Non-Linear Regression (CETIS)[a]	Statistical Method :	Spearman-Kärber (CETIS)[a]
Historical Mean IC25 :	0.97 g/L	Historical Mean LC50 :	1.14 g/L
Warning Limits (± 2SD) :	0.84 - 1.12 g/L	Warning Limits (± 2SD) :	1.01 - 1.28 g/L

The reference toxicity test was performed under the same experimental conditions as those used with the test sample.

TEST CONDITIONS

Test Organism :	*Pimephales promelas*	Test Type :	Static Renewal
Organism Batch :	Fm17-12	Control/Dilution Water :	Well water (no chemicals added
Organism Age :	~07:00 to ≤24 h at start of test	Test Volume / Replicate :	300 mL
Source :	In-house culture	Test Vessel :	420 mL polystyrene beaker
Culture Mortality/Diseased :	0.2 % (previous 7 days)	Depth of Test Solution :	8 cm
pH Adjustment :	None	Organisms per Replicate :	10
Sample Filtration :	None	Number of Replicates :	4
Hardness Adjustment :	None	Daily Renewal Method :	80-85% syphoned and replaced
Test Aeration :	None	Test Method Deviation(s)	See 'Comments'

COMMENTS

Noted Deviation(s) : According to the test method, a single sample may be used throughout the test if divided into at least 3 separate containers (i.e. three or more sub-samples) upon preparation. However, test concentrations for this test were stored in a single container for the duration of the test.

Note: A single-concentration test was conducted.

•All test validity criteria as specified in the test method cited above were satisfied.

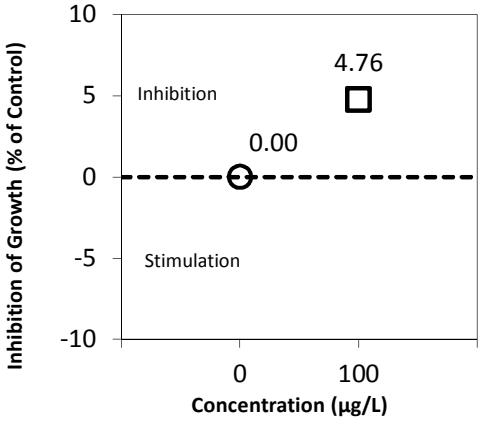
•No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

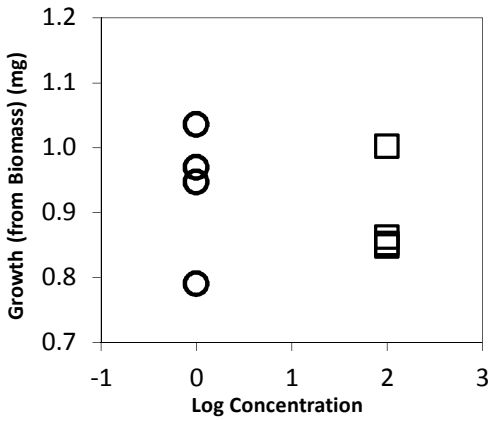
•Inflated swim bladders were confirmed in all test organisms used in this test.

• The exposure concentration was confirmed analytically, although test endpoints were generated using the nominal test concentration. The total and dissolved Ru concentration was measured at test start, at first renewal and at test end. These results were provided separately to NWMO. Analyses of test item concentration were conducted by SGS Canada Inc., 185 Concession Street PO Box 4300, Lakefield ON Canada K0L 2H0.

Work Order : 234749
Sample Number : 52860

GROWTH FROM BIOMASS





PREPARATION OF TEST SOLUTIONS

Testing followed the general conditions of the cited test method. The test solution was prepared without the use of any solubilizing agent. A 10 mg/L (nominal) stock solution was prepared by thoroughly mixing 2 mL of 1000 mg/L ruthenium standard solution (in HCl) with reverse osmosis water for a total volume of 200 mL. The 10 mg/L stock solution was mixed with control/dilution water at a rate of 168 mL in 16.8 L in order to achieve a test solution of 100 µg/L (nominal). A sub-sample was removed for initiating the test. The remainder was stored in a sealed container, in complete darkness, with minimal head space, at 4±2 °C for the duration of the test. Sub-samples for test renewal were removed daily and warmed to test temperature. The Control consisted of control/dilution water which was stored and used in the same manner, but without the addition of ruthenium stock.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Date : 2019-03-08 *yyyy-mm-dd*

Approved By : *Project Manager*

AQUATOX

TOXICITY TEST REPORT
Fathead minnow
EPS 1/RM/22

Work Order : 234749
Sample Number : 52860

CUMULATIVE DAILY CONTROL MORTALITY AND IMPAIRMENT

Date :	2017-12-14	2017-12-15	2017-12-16	2017-12-17	2017-12-18	2017-12-19	2017-12-20	2017-12-21
Dead and Impaired :	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Standard Deviation :	(±0.0)	(±0.0)	(±0.0)	(±0.0)	(±0.0)	(±0.0)	(±0.0)	(±0.0)

CUMULATIVE DAILY MORTALITY

Initiation Time : 13:20
Initiation Date : 2017-12-14
Completion Date : 2017-12-21

		Day 0		Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Treatment Mean Mortality (± SD)
	Date :	2017-12-14		2017-12-15		2017-12-16		2017-12-17		2017-12-18		2017-12-19		2017-12-20		2017-12-21		
	Analyst(s):	RD		RD		RD		RD		CZN		RD		RD		EJS		
	Replicate	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	%
Control	A	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**0.00 (±0.00)**
	B	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
	C	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
	D	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
100 µg/L	A	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**0.00 (±0.00)**
	B	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
	C	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
	D	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	

Aberrant behaviour or swimming impairment : None

DRY WEIGHT AND BIOMASS DATA

	Replicate	Number of Larvae Exposed	Replicate Mean Dry Weight (mg)	Treatment Mean Biomass (mg)	Standard Deviation
Control	A	10	0.947	0.936	0.104
	B	10	1.035		
	C	10	0.790		
	D	10	0.970		
100 µg/L	A	10	1.002	0.891	0.074
	B	10	0.862		
	C	10	0.848		
	D	10	0.852		

NOTES :
- No outlying data points were detected according to Grubbs Test (CETIS[a]).
- Control average dry weight per surviving organism = 0.936 mg

Data Reviewed By: JL
Date : 2018-04-26

AQUATOX

TOXICITY TEST REPORT
Fathead minnow
EPS 1/RM/22

Work Order : 234749
Sample Number: 52860

INITIAL WATER CHEMISTRY DATA

	Day 0 - 1 2017-12-14	Day 1 - 2 2017-12-15	Day 2 - 3 2017-12-16	Day 3 - 4 2017-12-17	Day 4 - 5 2017-12-18	Day 5 - 6 2017-12-19	Day 6 - 7 2017-12-20
Sub-sample Used	1	1	1	1	1	1	1
Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Dissolved O_2 (mg/L)	8.1	8.0	8.2	8.9	8.9	9.0	8.9
Dissolved O_2 Saturation (%)[2]	100	100	100	108	108	109	109
pH	7.8	8.0	8.0	7.9	7.9	7.9	7.9
Pre-aeration Time (min)[3]	0	0	0	20	20	20	20

TEST WATER CHEMISTRY DATA

Analyst(s) :	Initial	EJS	RD	RD	RD	CZN	RD	RD
	Final	RD	RD	RD	CZN	RD	RD	EJS
Control								
Temperature (°C)	Initial	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Final	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Dissolved O_2 Saturation (%)[2]	Initial	98	100	100	103	107	105	104
Dissolved O_2 (mg/L)	Initial	8.0	7.9	8.2	8.3	8.8	8.4	8.3
	Final	7.5	6.2	6.0	6.4	6.3	6.8	6.2
pH	Initial	8.3	8.3	8.3	8.3	8.2	8.2	8.2
	Final	8.2	7.9	7.9	7.9	7.8	7.8	7.8
Conductivity (µmhos/cm)	Initial	727	722	727	724	724	723	726
Hardness (mg/L as $CaCO_3$)		260	260	260	260	260	260	260
100 µg/L								
Temperature (°C)	Initial	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Final	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Dissolved O_2 (mg/L)	Initial	8.1	8.0	8.2	8.7	8.9	8.8	8.7
	Final	7.6	6.8	6.2	6.5	6.5	6.7	6.5
pH	Initial	7.8	8.0	8.0	8.0	7.9	7.9	7.9
	Final	8.1	7.8	7.8	7.8	7.9	7.8	7.8
Conductivity (µmhos/cm)	Initial	729	730	725	723	723	724	733

"–" = not measured

[2] % saturation (adjusted for actual temperature and barometric pressure)

AquaTox Testing & Consulting Inc.
B-11 Nicholas Beaver Road
Puslinch, ON N0B 2J0
Tel. (519) 763-4412
Fax. (519) 763-4419

TOXICITY TEST REPORT

Hyalella azteca
EPS 1/RM/33

Work Order : 234749
Sample Number : 52860

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKCB9445
Test Item :	Ruthenium (1000 µg/mL Ru in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Date Tested :	2018-03-21
Test Item Description :	Dark brown liquid		

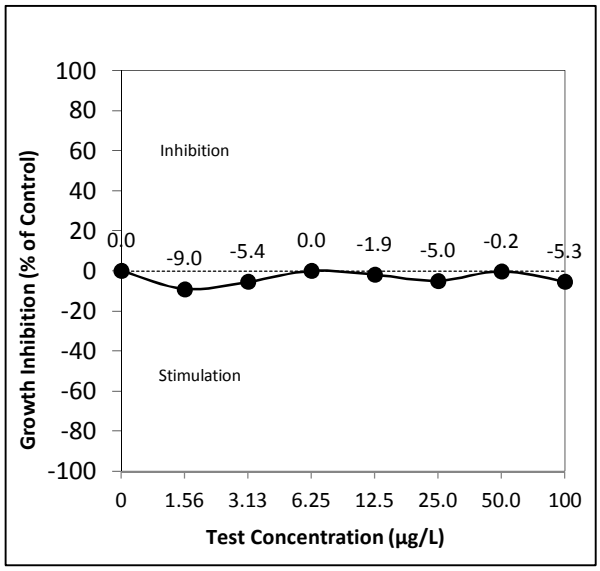
Test Method : Test for Survival and Growth in Sediment and Water Using the Freshwater Amphipod *Hyalella azteca*. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/33 (2nd ed.), January, 2013, with deviation(s) as noted.

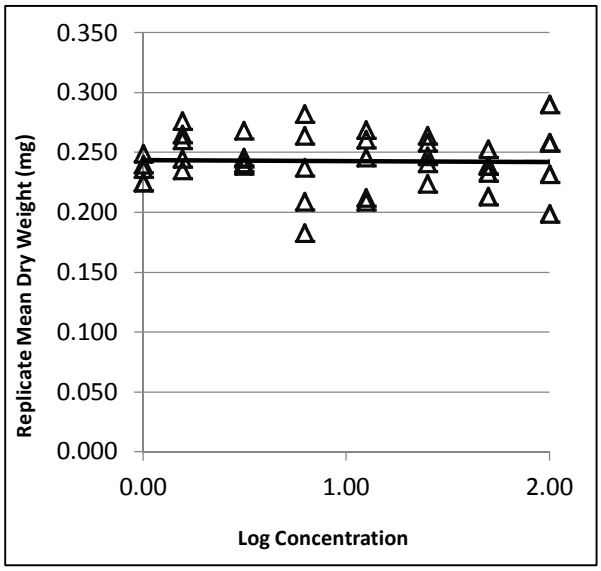
14-DAY TEST RESULTS

Effect	Endpoint	Value	95% Confidence Limits	Calculation Method
Growth	IC25	>100 µg/L	–	–
Survival	LC50	>100 µg/L	–	–

Results are based on nominal concentrations of the test item (v/v).

The results reported relate only to the item tested and as received.





REFERENCE TOXICANT DATA

Substance :	Copper (as Copper Sulphate)	LC50 :	239 µg/L
Organism Batch :	Ha18-03	95% Confidence Limits :	182 - 312 µg/L
Test Date :	2018-03-21	Historical Mean LC50 :	273 µg/L
Test Duration :	96 hours	Warning Limits (± 2 SD) :	194 - 384 µg/L
Analyst(s) :	CN, MR, MA	Statistical Method :	Linear Regression (MLE)[a]

The reference toxicity test was performed under the same experimental conditions as those used with the test sample.

Date : 2019-03-08
yyyy-mm-dd

Approved By : _____
Project Manager

Work Order : 234749
Sample Number : 52860

TEST ORGANISM

Species :	*Hyalella azteca*	Range of Age :	5 - 8 days old on day 0
Source :	In-house culture	Culture Mortality :	0% (preceding 48 h)

No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

TEST CONDITIONS

Test Type :	Static Renewal	Control/Dilution Water :	Well water (no chemicals added
Test Duration :	14 days	Depth of Test Solution :	Approx. 9.5 cm
Renewal Frequency :	Every other day	Test Vessel :	300 mL pyrex beaker
Renewal Method :	80-85% syphoned and replaced	Volume per Replicate	275 mL per replicate
Field Replicates :	Not applicable	Hardness Adjustment :	None
Test Replicates :	5	pH Adjustment :	None
Organisms per Replicate :	10	Sample Filtration :	None
Organisms per Test Level :	50	Test Aeration :	None
Feed Type :	YCT	Test Aeration Rate :	Not applicable
Feeding Frequency :	Once daily	Photoperiod (light/dark) :	16 h / 8 h
Food Ration (per replicate) :	~6.3 mg dry solids	Light Intensity :	651 - 839 lux
Substrate :	3 cm^2 Nytex mesh	Test Method Deviations :	Yes (see 'Comments')

PREPARATION OF TEST SOLUTIONS

Testing followed the general conditions of the cited test method. The test solution was prepared without the use of any solubilizing agent. A 10 mg/L (nominal) stock solution was prepared by thoroughly mixing 5 mL of 1000 mg/L ruthenium standard solution (in HCl) with reverse osmosis water for a total volume of 500 mL. The 10 mg/L stock solution was mixed thoroughly. Appropriate amounts of the 10 mg/L stock solution were mixed with control/dilution water to achieve the desired test concentrations. A sub-sample of each test concentration was removed for initiating the test. The remainder of each test concentration was stored in a sealed container, in complete darkness, with minimal head space, at 4 ±2 °C for the duration of the test. Sub-samples for test renewal were removed prior to renewal, and warmed to test temperature. The Control consisted of control/dilution water which was stored and used in the same manner, but without the addition of ruthenium stock.

COMMENTS

Noted Deviation(s) : According to the test method, a single sample may be used throughout the test if divided into at least 3 separate containers (i.e. three or more sub-samples) upon preparation. However, test concentrations for this test were stored in a single container for the duration of the test.

•All test validity criteria as specified in the test method cited above were satisfied.

•A negative value for inhibition (%) indicates stimulation compared to the control.

• The lowest, middle and highest exposure concentrations were confirmed analytically, although test endpoints were generated using nominal test concentrations. The total and dissolved Ru concentrations were measured at test start, at first renewal and at test end. These results were provided separately to NWMO.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Work Order : 234749
Sample Number : 52860

MORTALITY DATA

Initiation Time : 10:10
Initiation Date : 2018-03-21
Completion Date : 2018-04-04

Test Day :	**0**	**2**	**3**	**6**	**8**	**10**	**12**	**14**
Date :	2018-03-21	2018-03-23	2018-03-24	2018-03-27	2018-03-29	2018-03-31	2018-04-02	2018-04-04
Analyst(s) :	MA	MA	MR	MA	MA	MA	MA	CN

Concentration (µg/L)	Replicate	CUMULATIVE DAILY MORTALITY							Mortality (%)	Average Mortality (%)	Standard Deviation
	A	0	0	0	0	0	0	0	**0**	**0**	0.00
Control	B	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	**0**	**0**	0.00
1.56	B	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	**0**	**0**	0.00
3.13	B	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	**0**	**0**	0.00
6.25	B	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	**0**	**0**	0.00
12.5	B	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	**0**	**0**	0.00
25.0	B	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	**0**	**0**	0.00
50.0	B	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	**0**	**0**	0.00
100	B	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	**0**		

Test Data Reviewed By: JL
Date : 2018-06-26

Work Order : 234749
Sample Number : 52860

TEST ORGANISM DRY WEIGHT DATA

Concentration (µg/L)	Replicate	Average Weight per Organism (mg)	Treatment Average Weight per Organism (mg)	Standard Deviation
Control	A	0.249	0.235	0.01
	B	0.240		
	C	0.236		
	D	0.225		
	E	0.225		
1.56	A	0.265	0.256	0.02
	B	0.260		
	C	0.276		
	D	0.235		
	E	0.245		
3.13	A	0.245	0.248	0.01
	B	0.241		
	C	0.246		
	D	0.239		
	E	0.268		
6.25	A	0.237	0.235	0.04
	B	0.183		
	C	0.209		
	D	0.282		
	E	0.264		
12.5	A	0.269	0.239	0.03
	B	0.246		
	C	0.209		
	D	0.261		
	E	0.212		
25.0	A	0.247	0.247	0.02
	B	0.241		
	C	0.258		
	D	0.264		
	E	0.224		
50.0	A	0.213	0.235	0.01
	B	0.233		
	C	0.239		
	D	0.239		
	E	0.253		
100	A	0.199	0.247	0.03
	B	0.258		
	C	0.232		
	D	0.290		
	E	0.258		

Test Data Reviewed By : JL
Date : 2018-06-26

Work Order : 234749
Sample Number : 52860

INITIAL WATER CHEMISTRY DATA

Test Day :	Day 0 - 2	Day 2 - 4	Day 4 - 6	Day 6 - 8	Day 8 - 10	Day 10 - 12	Day 12 - 14
Analyst(s)	MA	MA	MR	MA	MA	MA	MA
Date :	2018-03-21	2018-03-23	2018-03-25	2018-03-27	2018-03-29	2018-03-31	2018-04-02
Sub-sample Used :	1	1	1	1	1	1	1
Control							
Temperature (°C)	23.0	24.0	24.0	24.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	8.2	8.8	9.2	9.8	9.7	10.0	9.2
Dissolved O_2 Saturation (%)[3]	97	105	109	117	116	120	109
pH	8.4	8.2	8.3	8.2	8.2	8.2	8.2
Conductivity (µmhos/cm)	741	733	734	729	729	732	731
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
1.56							
Temperature (°C)	23.0	24.0	24.0	24.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	8.2	8.8	9.6	9.7	9.7	10.0	9.5
Dissolved O_2 Saturation (%)[3]	–	105	113	116	116	119	112
pH	8.4	8.2	8.3	8.2	8.2	8.2	8.2
Conductivity (µmhos/cm)	748	735	739	735	736	737	742
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
3.13							
Temperature (°C)	23.0	24.0	24.0	24.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	8.3	8.8	9.4	9.5	9.7	10.3	9.3
Dissolved O_2 Saturation (%)[3]	–	105	111	114	116	122	110
pH	8.4	8.2	8.3	8.2	8.2	8.2	8.2
Conductivity (µmhos/cm)	742	734	735	735	736	736	741
Pre-aeration Time (min)[4]	0	20	200	20	20	20	20
6.25							
Temperature (°C)	23.0	24.0	24.0	24.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	8.3	8.9	9.9	9.6	10.0	9.9	9.5
Dissolved O_2 Saturation (%)[3]	–	107	112	114	119	117	112
pH	8.4	8.2	8.2	8.2	8.2	8.2	8.2
Conductivity (µmhos/cm)	744	734	728	735	736	736	741
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
12.5							
Temperature (°C)	23.0	24.0	24.0	24.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	8.3	8.8	9.6	9.8	9.7	10.1	9.5
Dissolved O_2 Saturation (%)[3]	–	105	113	116	116	119	113
pH	8.4	8.2	8.2	8.2	8.2	8.2	8.2
Conductivity (µmhos/cm)	743	734	736	736	737	736	739
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
25.0							
Temperature (°C)	23.0	24.0	24.0	24.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	8.4	8.8	9.6	9.6	10.0	10.1	9.4
Dissolved O_2 Saturation (%)[3]	–	106	111	114	119	120	111
pH	8.3	8.1	8.2	8.2	8.2	8.1	8.2
Conductivity (µmhos/cm)	742	736	736	736	736	738	740
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
50.0							
Temperature (°C)	23.0	24.0	24.0	24.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	8.4	8.8	9.3	9.4	10.0	10.2	9.5
Dissolved O_2 Saturation (%)[3]	–	105	110	112	120	121	112
pH	8.3	8.0	8.1	8.1	8.1	8.1	8.1
Conductivity (µmhos/cm)	744	734	736	736	736	739	740
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
100							
Temperature (°C)	23.0	24.0	24.0	24.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	8.4	8.8	9.4	9.5	10.1	10.3	9.5
Dissolved O_2 Saturation (%)[3]	–	105	108	113	121	121	112
pH	8.2	7.9	8.0	8.0	8.0	8.0	8.1
Conductivity (µmhos/cm)	742	735	739	742	739	742	740
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20

"–" = not measured
[3] % saturation (adjusted for actual temperature and barometric pressure)
[4] ≤100 bubbles/minute

Test Data Reviewed By : JL
Date : 2018-06-27

Work Order : 234749
Sample Number : 52860

WATER CHEMISTRY DATA

Test Day :		Day 0 - 2	Day 2 - 4	Day 4 - 6	Day 6 - 8	Day 8 - 10	Day 10 - 12	Day 12 - 14
Date :		2018-03-21	2018-03-23	2018-03-25	2018-03-27	2018-03-29	2018-03-31	2018-04-02
Analyst(s)	Initial	MA	MA	MR	MA	MA	MA	MA
	Final	MA	MR	MA	MA	MA	MA	CN
Control								
Temperature (°C)	Initial	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	Final	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Dissolved O_2 Saturation (%)[3]	Initial	97	103	105	115	116	118	108
Dissolved O2 (mg/L)	Initial	8.2	8.7	8.8	9.7	9.7	10.0	9.2
	Final	6.1	4.8	4.4	4.4	4.3	4.9	4.7
pH	Initial	8.4	8.3	8.3	8.2	8.2	8.2	8.2
	Final	8.0	7.9	7.8	7.8	7.8	7.9	7.9
Conductivity (µmhos/cm)	Initial	741	734	733	730	728	735	737
1.56								
Temperature (°C)	Initial	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	Final	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.2	8.7	8.7	9.6	9.7	10.0	9.4
	Final	6.6	4.3	4.9	4.4	4.0	4.9	4.8
pH	Initial	8.4	8.3	8.3	8.2	8.2	8.2	8.2
	Final	8.1	7.8	7.8	7.8	7.8	7.9	7.9
Conductivity (µmhos/cm)	Initial	748	732	733	734	729	736	737
3.13								
Temperature (°C)	Initial	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	Final	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.3	8.7	8.8	9.5	9.7	10.0	9.3
	Final	6.1	4.6	5.7	4.7	4.6	4.8	4.9
pH	Initial	8.4	8.3	8.3	8.2	8.2	8.2	8.2
	Final	8.0	7.9	7.9	7.8	7.8	7.8	7.8
Conductivity (µmhos/cm)	Initial	742	734	735	734	735	736	737
6.25								
Temperature (°C)	Initial	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	Final	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.3	8.8	8.9	9.6	9.7	9.7	9.5
	Final	5.9	4.8	5.0	4.6	4.3	4.8	5.0
pH	Initial	8.4	8.3	8.3	8.2	8.2	8.2	8.2
	Final	8.0	7.9	7.9	7.8	7.9	7.8	7.9
Conductivity (µmhos/cm)	Initial	744	734	734	735	736	737	737
12.5								
Temperature (°C)	Initial	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	Final	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.3	8.7	8.9	9.5	9.7	10.1	9.4
	Final	6.3	4.9	4.9	4.8	3.9	4.5	4.7
pH	Initial	8.4	8.3	8.2	8.2	8.2	8.2	8.2
	Final	8.0	7.9	7.9	7.8	7.7	7.8	7.8
Conductivity (µmhos/cm)	Initial	743	734	736	736	736	737	739
25.0								
Temperature (°C)	Initial	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	Final	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.4	8.7	8.8	9.5	9.9	10.0	9.4
	Final	5.7	5.1	5.1	4.9	4.2	4.8	4.8
pH	Initial	8.3	8.1	8.2	8.2	8.2	8.1	8.1
	Final	8.0	7.8	7.8	7.8	7.8	7.8	7.8
Conductivity (µmhos/cm)	Initial	742	736	737	736	736	737	737
50.0								
Temperature (°C)	Initial	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	Final	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.4	8.7	8.9	9.4	9.9	10.1	9.4
	Final	5.6	5.2	4.8	4.7	4.8	4.9	5.1
pH	Initial	8.3	8.1	8.1	8.1	8.1	8.1	8.1
	Final	8.0	7.9	7.8	7.8	7.8	7.8	7.9
Conductivity (µmhos/cm)	Initial	744	735	737	735	736	737	738
100								
Temperature (°C)	Initial	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	Final	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.4	8.7	9.0	9.4	10.0	10.1	9.4
	Final	5.5	5.4	5.1	4.8	4.2	4.5	4.7
pH	Initial	8.2	8.0	8.1	8.0	8.0	8.0	8.0
	Final	7.9	7.8	7.8	7.8	7.7	7.8	7.8
Conductivity (µmhos/cm)	Initial	742	735	738	735	735	736	737

"–" = not measured

[3] % saturation (adjusted for actual temperature and barometric pressure)

Test Data Reviewed By : JL
Date : 2018-06-27

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TOXICITY TEST REPORT

Salmonid E Test
EPS 1/RM/28

Work Order : 234749
Sample Number : 52860

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKCB9445
Test Item :	Ruthenium (1000 µg/mL Ru in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Initiation Date :	2018-12-13
Test Item Description :	Dark brown liquid	Completion Date :	2018-12-20

Test Method : Biological Test Method : Toxicity Tests Using Early Life Stages of Salmonid Fish (Rainbow Trout). Environment Canada EPS 1/RM/28 (Second Edition, July 1998).

7-DAY TEST RESULTS

Effect	Value	95% Confidence Limits	Calculation Method
EC10	86.8 µg/L	–[1]	Linear Regression (MLE)(CETIS)[a]
EC10[2]	>100 µg/L	50.8 - 810[3]	Linear Regression (MLE)(CETIS)[a]
EC10	79.3 µg/L	43.0 - 116[3]	Non-Linear Regression[4, 5] (CETIS)[a]
EC25	>100 µg/L	–	–
EC50	>100 µg/L	–	–

The results reported relate only to the item tested and as received.

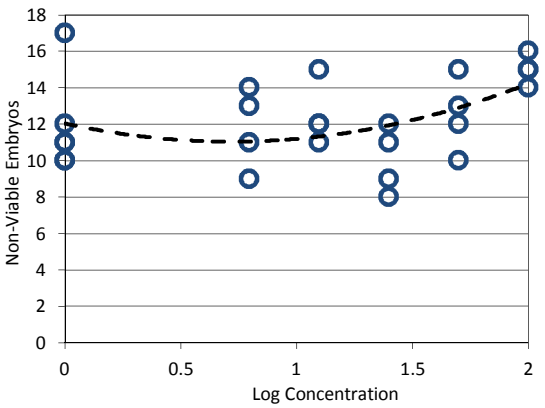
[1] Statistically valid 95% confidence limits could not be generated.

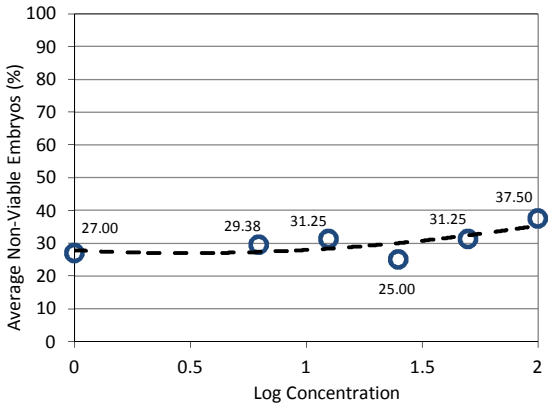
[2] After application of Abbott's Formula (Environment Canada, 2005)[b], for correction of control effects.

[3] An upper 95% confidence limit greater than the highest test concentration (100 µg/L) is statistically valid.

[4] Binomial weighting was applied

[5] The model was a 2P linear with binomial weighting: $\mu=\alpha + \beta \cdot x$ where $\alpha= 0.7274$ and $\beta= -0.000917$.





COMMENTS

Noted Deviation(s) : •A reference toxicant test was not conducted in conjunction with this test, as required by the test method. The client has declined the option to include a positive control.

• The exposure concentrations were confirmed analytically, although test endpoints were generated using the nominal test concentrations. Total and dissolved Ru concentrations were measured at test start, at the final renewal, and at test end. These results were provided separately to NWMO.

•All test validity criteria as specified in the test method (the average percentage of non-viable control embryos must be ≤30%) were satisfied.

Work Order : 234749
Sample Number : 52860

TEST ORGANISM

Test Organism :	Rainbow Trout (gamete/embryo)	Confirmation of Sperm Motility	Magnified observation
Species :	*Oncorhynchus mykiss*	Fertilization Procedure :	Dry mixing (15 min)
Gamete Source :	Lyndon Fish Hatcheries Inc.	Embryo Distribution :	Within 15 min of fertilization
Location :	New Dundee ON N0B 2E0	Female Broodstock used :	5
		Male Broodstock used :	6

No gametes or embryos exhibiting unusual appearance, or undergoing unusual treatment were used in the test.

TEST CONDITIONS

Test Type :	Static Renewal E-test	Control/Dilution Water :	Well water (no chemicals added)
Renewal Method :	80% syphoned and replaced	pH Adjustment :	None
Renewal Frequency :	≤ 24 hours	Sample Filtration :	None
Test Levels :	5 + 1 Control	Hardness Adjustment :	None
Control Replicates :	6	Volume per Replicate :	2500 mL
Test Replicates :	4	Test Chamber :	4 L plastic pail
Test Aeration :	Yes	Depth of Test Solution :	8 cm
Pre-Aeration Rate :	6.5 ± 1 mL/min/L	Organisms per Replicate :	40
Aeration Rate :	≤100 bubbles/min/chamber	Organisms per Test Level :	160
		Test Method Deviation(s):	See 'Comments'

PREPARATION OF TEST SOLUTIONS

Testing followed the general conditions of the cited test method. The test solution was prepared without the use of any solubilizing agent. A 20 mg/L (nominal) stock solution was prepared by thoroughly mixing 20 mL of 1000 mg/L ruthenium standard solution (in HCl) with reverse osmosis water for a total volume of 1000 mL. Appropriate volumes of the 20 mg/L stock solution were mixed with control/dilution water to achieve the desired test concentrations. Sub-samples of each test solution were removed for initiating the test. The remaining test solutions were stored in a sealed containers, in complete darkness, with minimal head space, at 4±2 °C for the duration of the test. Sub-samples for test renewal were removed daily and warmed to test temperature. The Control consisted of control/dilution water which was stored and used in the same manner, bu without the addition of ruthenium stock.

REFERENCES

[a] CETIS™, © 2000-2018. V.1.9.4.7. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

[b] Environment Canada, 2005. Guidance Document on Statistical Methods for Environmental Toxicity Tests. Environmental Protection Series, Ottawa, Ont., Rept. EPS 1/RM/46.

Date : 2019-03-08 *yyyy-mm-dd*

Approved By : *Project Manager*

Work Order : 234749
Sample Number : 52860

DAY 7 VIABILITY DATA

Completion Date : 2018-12-20
Analyst(s) : FS/AS/SK/MR

Concentration µg/L	Replicate	Day 0 Viable	Day 7 Viable	Day 7 Non-Viable	Average Non-Viable	Non-Viable (%)	Average Non-Viable (%)	Standard Deviation
Control	A	40	23	17[6]	10.80	42.50	27.00	2.09
	B	40	28	12		30.00		
	C	40	29	11		27.50		
	D	40	29	11		27.50		
	E	40	30	10		25.00		
	F	40	30	10		25.00		
6.25	A	40	31	9	11.75	22.50	29.38	5.54
	B	40	27	13		32.50		
	C	40	29	11		27.50		
	D	40	26	14		35.00		
12.5	A	40	29	11	12.50	27.50	31.25	4.33
	B	40	28	12		30.00		
	C	40	28	12		30.00		
	D	40	25	15		37.50		
25	A	40	31	9	10.00	22.50	25.00	4.56
	B	40	29	11		27.50		
	C	40	32	8		20.00		
	D	40	28	12		30.00		
50	A	40	28	12	12.50	30.00	31.25	5.20
	B	40	27	13		32.50		
	C	40	30	10		25.00		
	D	40	25	15		37.50		
100	A	40	24	16	15.00	40.00	37.50	2.04
	B	40	26	14		35.00		
	C	40	25	15		37.50		
	D	40	25	15		37.50		

• [6]Outlier according to Grubbs Test [b]. The outlying data point was excluded from statistical analysis.

Test Data Reviewed By : JL
Date : 2019-02-01

Work Order : 234749
Sample Number : 52860

WATER CHEMISTRY DATA

Test Day		**Day 0-1**	**Day 1-2**	**Day 2-3**	**Day 3-4**	**Day 4-5**	**Day 5-6**	**Day 6-7**
Date :		2018-12-13	2018-12-14	2018-12-15	2018-12-16	2018-12-17	2018-12-18	2018-12-19
Sub-sample Used		1	1	1	2	2	3	3
Temperature (°C)		14.0	14.0	14.0	14.0	14.0	14.0	14.0
Dissolved O_2 (mg/L)		9.6	9.6	9.6	9.5	9.5	9.6	9.6
Dissolved O_2 Saturation (%)[7]		100	100	100	100	100	100	100
Pre-aeration Time (hh:mm)		00:30	00:30	00:30	00:30	00:30	00:30	00:30
Analyst(s) :		FS	FS	FS	FS	FS	FS	AS
Control								
Temperature (°C)	Initial	15.0	15.0	15.0	14.5	14.0	14.0	14.0
	Final	15.0	15.0	15.0	14.5	14.5	14.5	14.5
Dissolved O_2 Saturation (%)[7]	Initial	100	100	99	99	100	100	100
Dissolved O_2 (mg/L)	Initial	9.7	9.6	9.5	9.5	9.6	9.6	9.6
	Final	8.7	9.2	9.3	9.2	9.3	9.2	9.3
pH	Initial	8.1	8.1	8.1	8.1	8.1	8.1	8.1
	Final	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Conductivity (µmhos/cm)	Initial	825	824	799	759	755	742	779
6.25 µg/L								
Temperature (°C)	Initial	15.0	15.0	15.0	14.5	14.0	14.0	14.0
	Final	15.0	15.0	15.0	14.5	14.5	14.5	14.5
Dissolved O_2 (mg/L)	Initial	9.7	9.6	9.5	9.4	9.5	9.5	9.4
	Final	8.7	9.1	9.2	9.1	9.2	9.0	9.4
pH	Initial	8.0	8.0	8.1	8.1	8.1	8.1	8.0
	Final	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Cond. (µmhos)	Initial	824	821	815	809	807	809	807
12.5 µg/L								
Temperature (°C)	Initial	15.0	15.0	15.0	14.5	14.0	14.0	14.0
	Final	15.0	15.0	15.0	14.5	14.5	14.5	14.5
Dissolved O_2 (mg/L)	Initial	9.7	9.5	9.5	9.5	9.5	9.6	9.5
	Final	9.1	9.2	9.1	9.0	9.0	9.2	9.4
pH	Initial	8.0	8.0	8.1	8.0	8.0	8.0	8.0
	Final	8.1	8.1	8.1	8.2	8.1	8.1	8.3
Conductivity (µmhos/cm)	Initial	825	824	817	814	811	809	807
25 µg/L								
Temperature (°C)	Initial	15.0	15.0	15.0	14.5	14.0	14.0	14.0
	Final	15.0	15.0	15.0	14.5	14.5	14.5	14.5
Dissolved O_2 (mg/L)	Initial	9.7	9.6	9.6	9.6	9.5	9.6	9.5
	Final	8.9	9.2	9.0	8.9	8.9	9.0	9.3
pH	Initial	7.9	8.0	8.0	8.0	7.9	7.9	7.9
	Final	8.1	8.1	8.1	8.2	8.0	8.1	8.3
Cond. (µmhos)	Initial	822	824	821	811	809	811	809
50 µg/L								
Temperature (°C)	Initial	15.0	15.0	15.0	14.5	14.0	14.0	14.0
	Final	15.0	15.0	15.0	14.5	14.5	14.5	14.5
Dissolved O_2 (mg/L)	Initial	9.6	9.6	9.6	9.6	9.5	9.5	9.4
	Final	9.0	9.2	8.9	9.2	9.2	9.1	9.3
pH	Initial	7.8	7.9	7.9	8.0	7.9	7.9	7.9
	Final	8.1	8.2	8.2	8.2	8.2	8.2	8.2
Conductivity (µmhos/cm)	Initial	820	818	810	805	807	807	805
100 µg/L								
Temperature (°C)	Initial	15.0	15.0	15.0	14.5	14.0	14.0	14.0
	Final	15.0	15.0	15.0	14.5	14.5	14.5	14.5
Dissolved O_2 (mg/L)	Initial	9.7	9.6	9.6	9.6	9.6	9.6	9.5
	Final	8.9	9.3	9.0	9.2	9.2	9.0	9.3
pH	Initial	7.8	7.8	8.0	8.0	7.9	8.0	7.8
	Final	8.1	8.2	8.3	8.3	8.3	8.3	8.2
Conductivity (µmhos/cm)	Initial	812	814	809	804	805	808	807

"–" = not measured/not required

[7] % saturation (adjusted for temperature and barometric pressure)

Test Data Reviewed By : JL
Date : 2019-02-12

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TOXICITY TEST REPORT

Ceriodaphnia dubia
EPS 1/RM/21

Work Order : 234748
Sample Number : 52859

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKBW7418V
Test Item :	Rhodium (1000 µg/mL Rh in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Date Tested :	2017-12-14
Test Item Description :	Dark pink liquid		

Test Method : Test of Reproduction and Survival using the Cladoceran *Ceriodaphnia dubia* . Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/21, 2nd ed. (February 2007), with deviation(s) as noted.

7-DAY TEST RESULTS

Effect	Endpoint	Value	Inhibition (% of Control)	Significantly Less than Control?	Calculation Method
Reproduction	IC25	>100 µg/L	-14.50%	No (α= 0.05)	–
Survival	LC50	>100 µg/L	0.0%	No (α= 0.05)	–

Results are based on nominal concentrations of the test item (v/v).
The results reported relate only to the item tested and as received.

SODIUM CHLORIDE REFERENCE TOXICANT DATA

Date Tested :	2018-01-03		
Test Duration :	6 days	Analyst(s) :	XD, JL, MA
IC25 Reproduction :	1.17 g/L	LC50 :	2.10 g/L
95% Confidence Limits :	1.11 - 1.22 g/L	95% Confidence Limits :	1.84 - 2.39 g/L
Statistical Method :	Linear Interpolation (CETIS)[a]	Statistical Method :	Spearman-Kärber (CETIS)[a]
Historical Mean IC25 :	1.34 g/L	Historical Mean LC50 :	2.22 g/L
Warning Limits (± 2SD) :	0.99 - 1.82 g/L	Warning Limits (± 2SD) :	1.86 - 2.65 g/L

The reference toxicity test was performed under the same experimental conditions as those used with the test sample.

TEST CONDITIONS

Sample Filtration :	None	Test Volume per Replicate :	15 mL
Test Aeration :	None	Test Vessel :	19 mL polystyrene vial
pH Adjustment :	None	Depth of Test Solution :	4.8 cm
Hardness Adjustment :	None	Organisms per Replicate :	1
Daily Renewal Method :	Transferred to fresh solutions	Number of Replicates :	10
Control/Dilution Water :	Well water (no chemicals added)	Test Method Deviation(s) :	See 'Comments'

COMMENTS

Noted Deviation(s) : According to the test method, a single sample may be used throughout the test if divided into at least 3 separate containers (i.e. three or more sub-samples) upon preparation. However, test concentrations for this test were stored in a single container for the duration of the test.

Note: A single-concentration test was conducted.

•All test validity criteria as specified in the test method cited above were satisfied.

•A negative value for Inhibition (%) indicates stimulation compared to the Control.

• The exposure concentration was confirmed analytically, although test endpoints were generated using the nominal test concentration. The total and dissolved Rh concentration was measured at test start, at first renewal and at test end. These results were provided separately to NWMO.

Work Order : 234748
Sample Number : 52859

TEST ORGANISMS

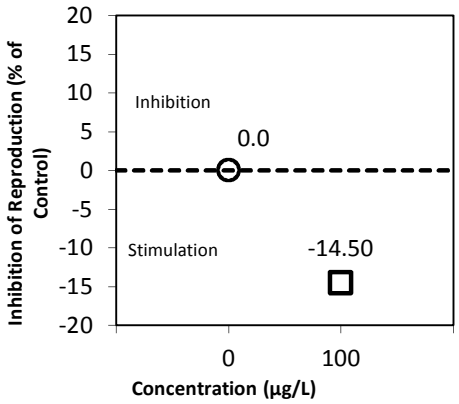
Test Organism :	*Ceriodaphnia dubia*	Range of Age (at start of test) :	05:00 h - 08:30 h
Organism Batch :	Cd17-12	Mean Brood Organism Mortality :	5%
Organism Origin :	Single in-house mass culture	Ephippia in Culture :	No
Test Organism Origin :	Individual in-house cultures		

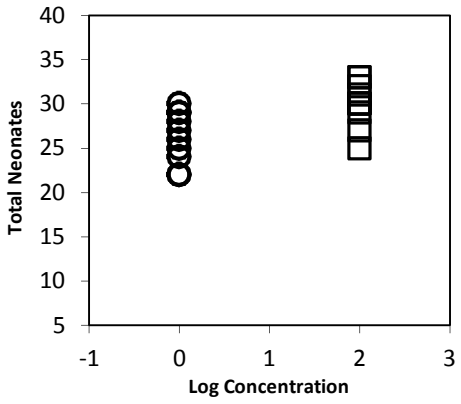
Brood Organism Neonate Production

Replicate :	1	2	3	4	5	6	7	8	9	10	Mean
Total (third or subsequent brood):	25	13	15	13	15	17	14	15	16	17	16.0
Total (first three broods):	29	29	23	28	25	30	24	24	26	26	26.4

No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

REPRODUCTION





PREPARATION OF TEST SOLUTIONS

Testing followed the general conditions of the cited test method. The test solution was prepared without the use of any solubilizing agent. A 10 mg/L (nominal) stock solution was prepared by thoroughly mixing 2 mL of 1000 mg/L rhodium standard solution (in HCl) with reverse osmosis water for a total volume of 200 mL. The 10 mg/L stock solution was mixed with control/dilution water at a rate of 168 mL in 16.8 L in order to achieve a test solution of 100 µg/L (nominal). A sub-sample was removed for initiating the test. The remainder was stored in a sealed container, in complete darkness, with minimal head space, at 4±2 °C for the duration of the test. Sub-samples for test renewal were removed daily and warmed to test temperature. The Control consisted of control/dilution water which was stored and used in the same manner, but without the addition of rhodium stock.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

[b]Grubbs, F.E., 1969. Procedures for detecting outlying observations in samples. Technometrics, 11:1-21.

Date : 2019-03-08 *yyyy-mm-dd*

Approved By : *Project Manager*

AQUATOX

TOXICITY TEST REPORT
Ceriodaphnia dubia
EPS 1/RM/21

Work Order : 234748
Sample Number : 52859

SURVIVAL AND REPRODUCTION DATA

Test Initiation Date : 2017-12-14
Initiation Time : 14:30
Test Completion Date : 2017-12-21

Control			Replicate										Mean Young (±SD)	Treatment Average Mortality (%)	Analyst(s)
	Date	Day	1	2	3	4	5	6	7	8	9	10			
	2017-12-15	**1**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0	RD
	2017-12-16	**2**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0	RD
	2017-12-17	**3**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0	RD
	2017-12-18	**4**	7	4	3	6	4	4	3	2	3	4	**4.0**	0.0	CZN
	2017-12-19	**5**	0	0	0	0	11	10	0	0	14	14	**4.9**	0.0	RD
	2017-12-20	**6**	4	5	9	9	0	0	12	14	0	0	**5.3**	0.0	RD
	2017-12-21	**7**	15	13	10	15	13	10	10	11	12	11	**12.0**	0.0	EJS
		Total	**26**	**22**	**22**	**30**	**28**	**24**	**25**	**27**	**29**	**29**	**26.2 (±2.9)**	**0.0**	

100 µg/L			Replicate										Mean Young (±SD)	Treatment Average Mortality (%)
	Date	Day	1	2	3	4	5	6	7	8	9	10		
	2017-12-15	**1**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0
	2017-12-16	**2**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0
	2017-12-17	**3**	0	0	0	0	0	0	0	0	0	0	**0.0**	0.0
	2017-12-18	**4**	4	4	5	7	5	1	4	5	6	6	**4.7**	0.0
	2017-12-19	**5**	10	13	0	0	10	14	0	0	0	0	**4.7**	0.0
	2017-12-20	**6**	0	0	13	15	0	0	11	13	12	14	**7.8**	0.0
	2017-12-21	**7**	11	13	12	10	12	14	16	12	15	13	**12.8**	0.0
		Total	**25**	**30**	**30**	**32**	**27**	**29**	**31**	**30**	**33**	**33**	**30.0 (±2.5)**	**0.0**

NOTES :
- All young produced by a test organism during its fourth and subsequent broods were discarded and not included in the above counts. The presence of two or more neonates in any test chamber, during any given day of the test, constitutes a brood.
- No outlying data points were detected according to Grubbs Test[b].

"x"= test organism mortality
"*"= accidental test organism mortality
"–"=4th brood (see 'NOTES')

Data Reviewed By : JL
Date : 2018-04-23

AQUATOX

TOXICITY TEST REPORT

Ceriodaphnia dubia

EPS 1/RM/21

Work Order : 234748

Sample Number : 52859

INITIAL WATER CHEMISTRY DATA

	Day 0 - 1	Day 1 - 2	Day 2 - 3	Day 3 - 4	Day 4 - 5	Day 5 - 6	Day 6 - 7
Date :	2017-12-14	2017-12-15	2017-12-16	2017-12-17	2017-12-18	2017-12-19	2017-12-20
Sub-sample Used	1	1	1	1	1	1	1
Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Dissolved Oxygen (mg/L)	8.1	8.0	8.1	8.6	8.9	9.0	9.0
Dissolved Oxygen % Sat.[3]	100	100	100	105	109	110	110
pH	7.9	7.9	7.9	7.9	7.9	7.9	7.9
Pre-aeration Time (min)[4]	0	0	0	20	20	20	20

TEST WATER CHEMISTRY DATA

Analyst(s)	Initial	EJS	RD	RD	RD	CZN	RD	RD
	Final	RD	RD	RD	CZN	RD	RD	EJS
Control								
Temperature (°C)	Initial	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Final	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Dissolved O_2 Saturation (%)[3]	Initial	98	100	100	103	103	105	105
Dissolved O_2 (mg/L)	Initial	8.0	7.9	8.2	8.3	8.4	8.4	8.4
	Final	7.6	7.6	7.8	7.3	7.0	6.8	7.7
pH	Initial	8.3	8.3	8.3	8.3	8.2	8.2	8.2
	Final	8.2	8.2	8.3	8.2	8.2	8.1	8.2
Conductivity (µmhos/cm)	Initial	727	722	727	722	724	722	728
Hardness (mg/L as $CaCO_3$)		260	260	260	260	260	260	260
100 µg/L								
Temperature (°C)	Initial	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Final	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Dissolved O_2 (mg/L)	Initial	8.1	8.0	8.1	8.4	8.8	8.6	8.8
	Final	7.6	7.4	7.6	7.3	7.1	7.2	7.8
pH	Initial	7.9	7.9	7.9	7.9	7.9	7.9	7.9
	Final	8.2	8.2	8.3	8.1	8.1	8.0	8.2
Conductivity (µmhos/cm)	Initial	731	726	724	724	723	724	728

"–" = not measured

[3] % saturation (adjusted for actual temperature and barometric pressure)

[4] ≤100 bubbles/minute

Test Data Reviewed By : JL

Date : 2018-04-26

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TOXICITY TEST REPORT

Fathead minnow
EPS 1/RM/22

Work Order : 234748
Sample Number : 52859

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKBW7418V
Test Item :	Rhodium (1000 µg/mL Rh in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Date Tested :	2017-12-14
Test Item Description :	Dark pink liquid		
Test Method :	Test of Larval Growth and Survival Using Fathead Minnows. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/22 , 2nd ed. (February 2011), with deviation(s) as noted.		

7-DAY TEST RESULTS

Effect	Endpoint	Value	Inhibition (% of Control)	Significantly Less than Control?	Calculation Method
Growth (from Biomass)	IC25	>100 µg/L	-9.12%	No (α= 0.05)	–
Survival	LC50	>100 µg/L	0.0%	No (α= 0.05)	–

Results are based on nominal concentrations of the test item (v/v).

The results reported relate only to the item tested and as received.

POTASSIUM CHLORIDE REFERENCE TOXICANT DATA

Date Tested :	2017-12-07	Analyst(s) :	XD, SEW, FS
Organism Batch :	Fm17-12	Test Duration :	7 days
IC25 Growth (from Biomass) :	1.00 g/L	LC50 :	1.19 g/L
95% Confidence Limits :	0.82 - 1.11 g/L	95% Confidence Limits :	1.13 - 1.26 g/L
Statistical Method :	Non-Linear Regression (CETIS)[a]	Statistical Method :	Spearman-Kärber (CETIS)[a]
Historical Mean IC25 :	0.97 g/L	Historical Mean LC50 :	1.14 g/L
Warning Limits (± 2SD) :	0.84 - 1.12 g/L	Warning Limits (± 2SD) :	1.01 - 1.28 g/L

The reference toxicity test was performed under the same experimental conditions as those used with the test sample.

TEST CONDITIONS

Test Organism :	*Pimephales promelas*	Test Type :	Static Renewal
Organism Batch :	Fm17-12	Control/Dilution Water :	Well water (no chemicals added)
Organism Age :	~07:00 to ≤24 h at start of test	Test Volume / Replicate :	300 mL
Source :	In-house culture	Test Vessel :	420 mL polystyrene beaker
Culture Mortality/Diseased :	0.2 % (previous 7 days)	Depth of Test Solution :	8 cm
pH Adjustment :	None	Organisms per Replicate :	10
Sample Filtration :	None	Number of Replicates :	4
Hardness Adjustment :	None	Daily Renewal Method :	80-85% syphoned and replaced
Test Aeration :	None	Test Method Deviation(s):	See 'Comments'

COMMENTS

Noted Deviation(s) : According to the test method, a single sample may be used throughout the test if divided into at least 3 separate containers (i.e. three or more sub-samples) upon preparation. However, test concentrations for this test were stored in a single container for the duration of the test.

Note: A single-concentration test was conducted.

•All test validity criteria as specified in the test method cited above were satisfied.

•No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

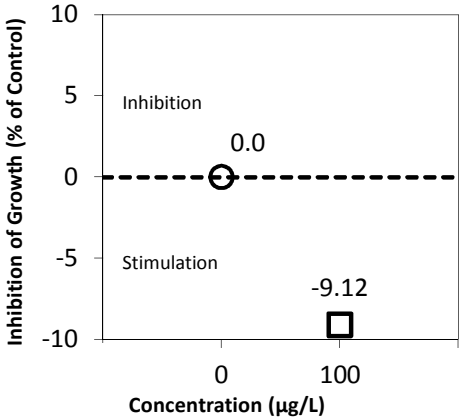
•Inflated swim bladders were confirmed in all test organisms used in this test.

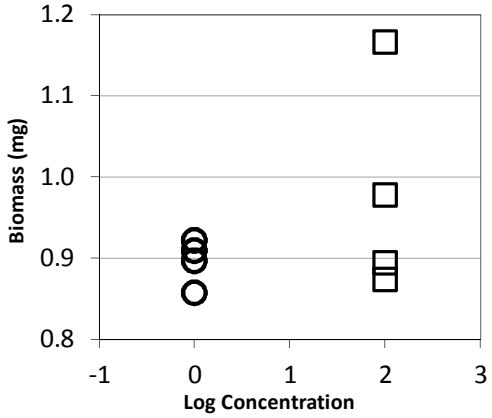
•A negative value for Inhibition (%) indicates stimulation compared to the Control.

• The exposure concentration was confirmed analytically, although test endpoints were generated using the nominal test concentration. The total and dissolved Rh concentration was measured at test start, at first renewal and at test end. These results were provided separately to NWMO.

Work Order : 234748
Sample Number : 52859

GROWTH FROM BIOMASS





PREPARATION OF TEST SOLUTIONS

Testing followed the general conditions of the cited test method. The test solution was prepared without the use of any solubilizing agent. A 10 mg/L (nominal) stock solution was prepared by thoroughly mixing 2 mL of 1000 mg/L rhodium standard solution (in HCl) with reverse osmosis water for a total volume of 200 mL. The 10 mg/L stock solution was mixed with control/dilution water at a rate of 168 mL in 16.8 L in order to achieve a tes solution of 100 µg/L. A sub-sample was removed for initiating the test. The remainder was stored in a sealed container, in complete darkness, with minimal head space, at 4±2 °C for the duration of the test. Sub-samples for test renewal were removed daily and warmed to test temperature. The Control consisted of control/dilution water which was stored and used in the same manner, but without the addition of rhodium stock.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

[b] Grubbs, F.E., 1969. Procedures for detecting outlying observations in samples. Technometrics, 11:1-21.

Date : 2019-03-08
yyyy-mm-dd

Approved By : _____
Project Manager

AQUATOX

TOXICITY TEST REPORT
Fathead minnow
EPS 1/RM/22

Work Order : 234748
Sample Number : 52859

CUMULATIVE DAILY CONTROL MORTALITY AND IMPAIRMENT

Date :	2017-12-14	2017-12-15	2017-12-16	2017-12-17	2017-12-18	2017-12-19	2017-12-20	2017-12-21
Dead and Impaired :	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Standard Deviation :	(±0.0)	(±0.0)	(±0.0)	(±0.0)	(±0.0)	(±0.0)	(±0.0)	(±0.0)

CUMULATIVE DAILY MORTALITY

Initiation Time : 13:10
Initiation Date : 2017-12-14
Completion Date : 2017-12-21

		Day 0		Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Treatment Mean Mortality (± SD)
Date :		2017-12-14		2017-12-15		2017-12-16		2017-12-17		2017-12-18		2017-12-19		2017-12-20		2017-12-21		
Analyst(s):		RD		RD		RD		RD		CZN		RD		RD		EJS		
	Replicate	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	Number Dead	% Dead	%
Control	A	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**0.00 (±0.00)**
	B	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
	C	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
	D	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
100 µg/L	A	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**0.00 (±0.00)**
	B	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
	C	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	
	D	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	

Aberrant behaviour or swimming impairment : None

DRY WEIGHT AND BIOMASS DATA

	Replicate	Number of Larvae Exposed	Replicate Mean Dry Weight (mg)	Treatment Mean Biomass (mg)	Standard Deviation
Control	A	10	0.897	0.896	0.028
	B	10	0.909		
	C	10	0.857		
	D	10	0.922		
100 µg/L	A	10	1.166	0.978	0.133
	B	10	0.874		
	C	10	0.894		
	D	10	0.978		

NOTES :
- No outlying data points were detected according to Grubbs Test[b].
- Control average dry weight per surviving organism = 0.896 mg

Data Reviewed By: JL
Date : 2018-04-23

AQUATOX

TOXICITY TEST REPORT
Fathead minnow
EPS 1/RM/22

Work Order : 234748
Sample Number : 52859

INITIAL WATER CHEMISTRY DATA

	Day 0 - 1 2017-12-14	Day 1 - 2 2017-12-15	Day 2 - 3 2017-12-16	Day 3 - 4 2017-12-17	Day 4 - 5 2017-12-18	Day 5 - 6 2017-12-19	Day 6 - 7 2017-12-20
Sub-sample Used	1	1	1	1	1	1	1
Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Dissolved Oxygen (mg/L)	8.1	8.0	8.1	8.6	8.9	9.0	9.0
Dissolved Oxygen % Sat.[2]	100	100	100	105	109	110	110
pH	7.9	7.9	7.9	7.9	7.9	7.9	7.9
Pre-aeration Time (min)[3]	0	0	0	20	20	20	20

TEST WATER CHEMISTRY DATA

Analyst(s) :	Initial	EJS	RD	RD	RD	CZN	RD	RD
	Final	RD	RD	RD	CZN	RD	RD	EJS
Control								
Temperature (°C)	Initial	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Final	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Dissolved O_2 Saturation (%)[2]	Initial	98	100	100	103	103	105	105
Dissolved O_2 (mg/L)	Initial	8.0	7.9	8.2	8.3	8.4	8.4	8.4
	Final	7.6	6.5	6.5	6.5	6.5	6.7	6.7
pH	Initial	8.3	8.3	8.3	8.3	8.2	8.2	8.2
	Final	8.2	8.0	8.0	7.9	8.0	7.9	7.9
Conductivity (µmhos/cm)	Initial	727	722	727	722	724	722	728
Hardness (mg/L as $CaCO_3$)		260	260	260	260	260	260	260
100 µg/L								
Temperature (°C)	Initial	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Final	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Dissolved O_2 (mg/L)	Initial	8.1	8.0	8.1	8.4	8.8	8.6	8.8
	Final	7.8	6.4	6.1	6.5	6.7	6.5	6.6
pH	Initial	7.9	7.9	7.9	7.9	7.9	7.9	7.9
	Final	8.1	7.7	7.8	7.9	7.9	7.8	7.8
Conductivity (µmhos/cm)	Initial	731	726	724	724	723	724	728

"–" = not measured

[2] % saturation (adjusted for actual temperature and barometric pressure)

[3] ≤100 bubbles/minute

Test Data Reviewed By : JL
Date : 2018-04-26

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TOXICITY TEST REPORT
Hyalella azteca
EPS 1/RM/33

Work Order : 234748
Sample Number : 52859

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organizatior	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKBW7418V
Test Item :	Rhodium (1000 µg/mL Rh in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Date Tested :	2018-02-28
Test Item Description :	Dark pink liquid		

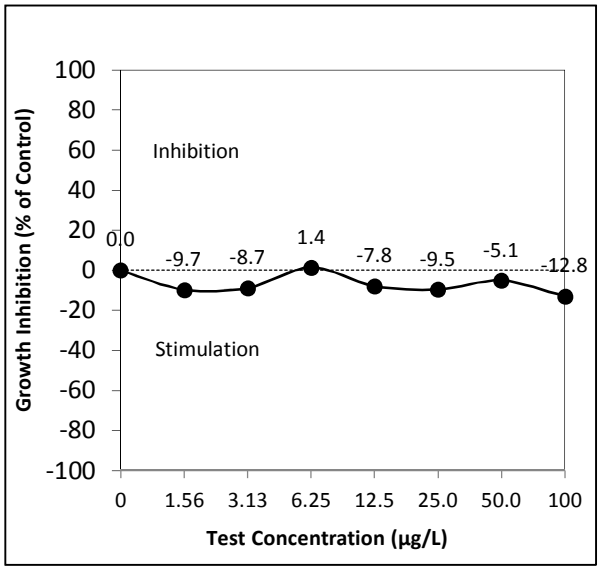
Test Method : Test for Survival and Growth in Sediment and Water Using the Freshwater Amphipod *Hyalella azteca* . Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/33 (2nd ed.), January, 2013, with deviation(s) as noted.

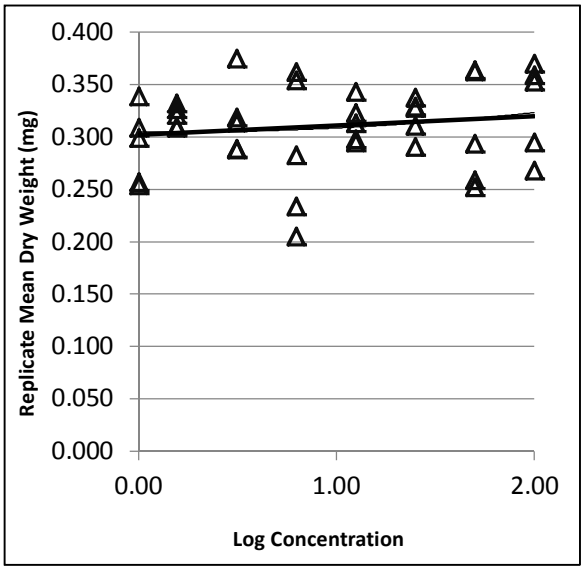
14-DAY TEST RESULTS

Effect	Endpoint	Value	95% Confidence Limits	Calculation Method
Growth	IC25	>100 µg/L	–	–
Survival	LC50	>100 µg/L	–	–

Results are based on nominal concentrations of the test item (v/v).

The results reported relate only to the item tested and as received.





REFERENCE TOXICANT DATA

Substance :	Copper (as Copper Sulphate)	LC50 :	308 µg/L
Organism Batch :	Ha18-02	95% Confidence Limits :	258 - 367 µg/L
Test Date :	2018-02-01	Historical Mean LC50 :	258 µg/L
Test Duration :	96 hours	Warning Limits (± 2 SD) :	161 - 412 µg/L
Analyst(s) :	CN, RD	Statistical Method :	Spearman-Kärber (CETIS)[a]

The reference toxicity test was performed under the same experimental conditions as those used with the test sample.

Date : 2019-03-08
yyyy-mm-dd

Approved By : _____
Project Manager

Work Order : 234748
Sample Number : 52859

TEST ORGANISM

Species :	*Hyalella azteca*	Range of Age :	5 - 8 days old on day 0
Source :	In-house culture	Culture Mortality :	0% (preceding 48 h)

No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

TEST CONDITIONS

Test Type :	Water only (static renewal)	Control/Dilution Water :	Well water (no chemicals added
Test Duration :	14 days	Depth of Test Solution :	Approx. 9.5 cm
Renewal Frequency :	Every other day	Test Vessel :	300 mL pyrex beaker
Renewal Method :	80-85% syphoned and replaced	Volume per Replicate	275 mL per replicate
Field Replicates :	Not applicable	Hardness Adjustment :	None
Test Replicates :	5	pH Adjustment :	None
Organisms per Replicate :	10	Sample Filtration :	None
Organisms per Test Level :	50	Test Aeration :	None
Feed Type :	YCT	Test Aeration Rate :	Not applicable
Feeding Frequency :	daily	Photoperiod (light/dark) :	16 h / 8 h
Food Ration (per replicate) :	~6.3 mg dry solids	Light Intensity :	520 - 751 lux
Substrate :	3 cm^2 Nytex mesh	Test Method Deviations :	Yes (see 'Comments')

PREPARATION OF TEST SOLUTIONS

Testing followed the general conditions of the cited test method. The test solution was prepared without the use of any solubilizing agent. A 10 mg/L (nominal) stock solution was prepared by thoroughly mixing 5 mL of 1000 mg/L rhodium standard solution (in HCl) with reverse osmosis water for a total volume of 500 mL. The 10 mg/L stock solution was mixed thoroughly. Appropriate amounts of the 10 mg/L stock solution were mixed with control/dilution water to achieve the desired test concentrations. A sub-sample of each test concentration was removed for initiating the test. The remainder of each test concentration was stored in a sealed container, in complete darkness, with minimal head space, at 4 ±2 °C for the duration of the test. Sub-samples for test renewal were removed prior to renewal, and warmed to test temperature. The Control consisted of control/dilution water which was stored and used in the same manner, but without the addition of rhodium stock.

COMMENTS

Noted Deviation(s) : According to the test method, a single sample may be used throughout the test if divided into at least 3 separate containers (i.e. three or more sub-samples) upon preparation. However, test concentrations for this test were stored in a single container for the duration of the test.

•All test validity criteria as specified in the test method cited above were satisfied.

•A negative value for inhibition (%) indicates stimulation compared to the control.

• The lowest, middle and highest exposure concentrations were confirmed analytically, although test endpoints were generated using nominal test concentrations. The total and dissolved Rh concentrations were measured at test start, at first renewal and at test end. These results were provided separately to NWMO. Analyses of test item concentration were conducted by SGS Canada Inc., 185 Concession Street PO Box 4300, Lakefield ON Canada K0L 2H0.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Work Order : 234748
Sample Number : 52859

MORTALITY DATA

Initiation Time : 12:40
Initiation Date : 2018-02-28
Completion Date : 2018-03-14

Test Day :	**0**	**2**	**3**	**4**	**6**	**8**	**10**	**12**	**14**
Date :	2018-02-28	2018-03-02	2018-03-03	2018-03-04	2018-03-06	2018-03-08	2018-03-10	2018-03-12	2018-03-14
Analyst(s) :	MA	MA	MR	MR	MR	MA	MA	MR	MA

Concentration (µg/L)	Replicate	CUMULATIVE DAILY MORTALITY								Mortality (%)	Average Mortality (%)	Standard Deviation
	A	0	0	0	0	0	0	0	0	**0**	**0**	0
Control	B	0	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	0	**0**	**0**	0
1.56	B	0	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	0	**0**	**0**	0
3.13	B	0	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	0	**0**	**0**	0
6.25	B	0	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	0	**0**	**0**	0
12.5	B	0	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	0	**0**	**0**	0.00
25.0	B	0	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	0	**0**	**0**	0.00
50.0	B	0	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	0	**0**		
	A	0	0	0	0	0	0	0	0	**0**	**0**	0.00
100	B	0	0	0	0	0	0	0	0	**0**		
	C	0	0	0	0	0	0	0	0	**0**		
	D	0	0	0	0	0	0	0	0	**0**		
	E	0	0	0	0	0	0	0	0	**0**		

Test Data Reviewed By: JL
Date : 2018-06-27

Work Order : 234748
Sample Number : 52859

TEST ORGANISM DRY WEIGHT DATA

Concentration (µg/L)	Replicate	Average Weight per Organism (mg)	Treatment Average Weight per Organism (mg)	Standard Deviation
Control	A	0.254	0.292	0.04
	B	0.309		
	C	0.339		
	D	0.299		
	E	0.257		
1.56	A	0.310	0.320	0.01
	B	0.309		
	C	0.321		
	D	0.327		
	E	0.332		
3.13	A	0.375	0.317	0.04
	B	0.288		
	C	0.314		
	D	0.319		
	E	0.289		
6.25	A	0.362	0.288	0.07
	B	0.354		
	C	0.234		
	D	0.283		
	E	0.205		
12.5	A	0.295	0.314	0.02
	B	0.323		
	C	0.313		
	D	0.298		
	E	0.343		
25.0	A	0.311	0.319	0.02
	B	0.328		
	C	0.338		
	D	0.329		
	E	0.291		
50.0	A	0.363	0.306	0.05
	B	0.259		
	C	0.294		
	D	0.364		
	E	0.252		
100	A	0.268	0.329	0.04
	B	0.295		
	C	0.370		
	D	0.353		
	E	0.359		

Test Data Reviewed By : JL
Date : 2018-06-27

Work Order : 234748
Sample Number : 52859

INITIAL WATER CHEMISTRY DATA

Test Day :	**Day 0 - 2**	**Day 2 - 4**	**Day 4 - 6**	**Day 6 - 8**	**Day 8 - 10**	**Day 10 - 12**	**Day 12 - 14**
Analyst(s)	MA	MA	MR	MA	MA	MA	MR
Date :	2018-02-28	2018-03-02	2018-03-04	2018-03-06	2018-03-08	2018-03-10	2018-03-12
Sub-sample Used :	1	1	1	1	1	1	1
Control							
Temperature (°C)	23.0	23.5	23.5	24.0	24.0	23.0	23.0
Dissolved O_2 (mg/L)	8.1	8.8	9.3	9.4	9.5	9.4	9.8
Dissolved O_2 Saturation (%)[3]	98	105	111	114	115	112	118
pH	8.1	8.2	8.3	8.1	8.1	8.1	8.1
Conductivity (µmhos/cm)	794	786	794	789	786	780	801
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
1.56							
Temperature (°C)	23.0	23.5	23.5	24.0	24.0	23.0	23.0
Dissolved O_2 (mg/L)	8.2	8.8	9.2	9.5	9.5	9.4	9.7
Dissolved O_2 Saturation (%)[3]	–	105	109	115	115	112	117
pH	8.4	8.2	8.3	8.2	8.1	8.2	8.1
Conductivity (µmhos/cm)	799	793	797	792	792	788	797
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
3.13							
Temperature (°C)	23.0	23.5	23.5	24.0	24.0	23.0	23.0
Dissolved O_2 (mg/L)	8.2	8.8	9.2	9.5	9.8	9.4	9.8
Dissolved O_2 Saturation (%)[3]	–	106	109	115	118	113	119
pH	8.4	8.2	8.2	8.2	8.1	8.2	8.1
Conductivity (µmhos/cm)	798	794	795	793	792	789	798
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
6.25							
Temperature (°C)	23.0	23.5	23.5	24.0	24.0	23.0	23.0
Dissolved O_2 (mg/L)	8.3	8.8	9.2	9.4	9.6	9.4	9.7
Dissolved O_2 Saturation (%)[3]	–	105	109	113	116	113	117
pH	8.4	8.2	8.3	8.2	8.1	8.2	8.1
Conductivity (µmhos/cm)	800	795	797	794	792	791	800
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
12.5							
Temperature (°C)	23.0	23.5	23.5	24.0	24.0	23.0	23.0
Dissolved O_2 (mg/L)	8.2	8.8	9.2	9.4	9.5	9.4	10.3
Dissolved O_2 Saturation (%)[3]	–	105	109	114	114	113	122
pH	8.4	8.2	8.2	8.2	8.2	8.2	8.1
Conductivity (µmhos/cm)	802	795	798	795	797	793	803
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
25.0							
Temperature (°C)	23.0	23.5	23.5	24.0	24.0	23.0	23.0
Dissolved O_2 (mg/L)	8.3	8.8	9.3	9.5	9.4	9.4	9.6
Dissolved O_2 Saturation (%)[3]	–	104	110	114	114	113	115
pH	8.2	8.2	8.3	8.2	8.2	8.2	8.1
Conductivity (µmhos/cm)	802	795	798	797	800	796	808
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
50.0							
Temperature (°C)	23.0	23.5	23.5	24.0	24.0	23.0	23.0
Dissolved O_2 (mg/L)	8.3	8.7	9.2	9.5	9.5	9.3	10.2
Dissolved O_2 Saturation (%)[3]	–	105	107	114	115	111	122
pH	8.2	8.1	8.2	8.1	8.1	8.2	8.1
Conductivity (µmhos/cm)	803	795	797	798	799	797	807
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20
100							
Temperature (°C)	23.0	23.5	23.5	24.0	24.0	23.0	23.0
Dissolved O_2 (mg/L)	8.3	8.8	9.2	9.4	9.5	9.3	9.4
Dissolved O_2 Saturation (%)[3]	–	105	107	113	115	111	112
pH	8.3	7.9	8.1	8.0	8.1	8.2	8.0
Conductivity (µmhos/cm)	805	797	805	804	804	802	812
Pre-aeration Time (min)[4]	0	20	20	20	20	20	20

"–" = not measured

[3] % saturation (adjusted for actual temperature and barometric pressure)

[4] ≤100 bubbles/minute

Test Data Reviewed By : JL
Date : 2018-06-27

Work Order : 234748
Sample Number : 52859

WATER CHEMISTRY DATA

Test Day :		Day 0 - 2	Day 2 - 4	Day 4 - 6	Day 6 - 8	Day 8 - 10	Day 10 - 12	Day 12 - 14
Date :		2018-02-28	2018-03-02	2018-03-04	2018-03-06	2018-03-08	2018-03-10	2018-03-12
Analyst(s)	Initial	MA	MA	MR	MA	MA	MA	MR
	Final	MA	MR	MR	MA	MA	MR	MA
Control								
Temperature (°C)	Initial	23.0	23.5	23.5	23.0	23.0	23.0	23.0
	Final	24.0	24.0	24.0	23.0	23.0	23.0	23.0
Dissolved O_2 Saturation (%)[3]	Initial	98	102	100	111	114	112	116
Dissolved O_2 (mg/L)	Initial	8.1	8.4	8.4	9.4	9.4	9.4	9.8
	Final	7.6	5.6	4.7	6.4	6.4	5.2	5.7
pH	Initial	8.4	8.2	8.3	8.1	8.1	8.1	8.0
	Final	8.2	8.1	7.9	8.0	8.1	7.8	8.0
Conductivity (µmhos/cm)	Initial	794	795	793	792	785	787	799
1.56								
Temperature (°C)	Initial	23.0	23.5	23.5	23.0	23.0	23.0	23.0
	Final	24.0	24.0	24.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.2	8.5	8.7	9.3	9.4	9.4	10.0
	Final	7.7	5.2	4.9	6.3	6.4	5.2	5.8
pH	Initial	8.4	8.2	8.3	8.1	8.1	8.2	8.1
	Final	8.2	8.1	7.9	8.0	8.0	7.9	8.0
Conductivity (µmhos/cm)	Initial	799	797	795	793	791	789	799
3.13								
Temperature (°C)	Initial	23.0	23.5	23.5	23.0	23.0	23.0	23.0
	Final	24.0	24.0	24.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.2	8.4	8.7	9.3	9.6	9.4	9.7
	Final	7.6	5.1	4.7	6.3	6.3	5.3	5.6
pH	Initial	8.4	8.2	8.3	8.2	8.1	8.2	8.1
	Final	8.2	8.1	7.9	8.0	8.0	8.0	8.1
Conductivity (µmhos/cm)	Initial	798	799	795	793	791	790	800
6.25								
Temperature (°C)	Initial	23.0	23.5	23.5	23.0	23.0	23.0	23.0
	Final	24.0	24.0	24.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.3	8.5	8.8	9.3	9.5	9.3	9.9
	Final	7.6	5.0	4.9	6.3	6.3	5.1	5.7
pH	Initial	8.4	8.2	8.3	8.2	8.2	8.2	8.1
	Final	8.2	8.1	7.9	8.0	8.0	8.0	8.0
Conductivity (µmhos/cm)	Initial	800	793	796	796	792	793	802
12.5								
Temperature (°C)	Initial	23.0	23.5	23.5	23.0	23.0	23.0	23.0
	Final	24.0	24.0	24.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.2	8.6	8.8	9.3	9.4	9.3	9.7
	Final	7.6	5.0	4.8	6.4	6.4	5.1	5.7
pH	Initial	8.4	8.2	8.3	8.2	8.2	8.2	8.1
	Final	8.2	8.1	7.9	8.0	8.0	7.9	8.0
Conductivity (µmhos/cm)	Initial	802	797	799	797	794	795	806
25.0								
Temperature (°C)	Initial	23.0	23.5	23.5	23.0	23.0	23.0	23.0
	Final	24.0	24.0	24.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.3	8.4	8.8	9.3	9.3	9.3	9.7
	Final	7.5	5.1	5.1	6.4	6.2	5.4	6.7
pH	Initial	8.4	8.2	8.3	8.2	8.2	8.2	8.1
	Final	8.2	8.1	7.9	8.0	8.0	7.9	8.0
Conductivity (µmhos/cm)	Initial	802	799	797	800	798	797	810
50.0								
Temperature (°C)	Initial	23.0	23.5	23.5	23.0	23.0	23.0	23.0
	Final	24.0	24.0	24.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.3	8.4	8.9	9.2	9.4	9.3	9.4
	Final	7.6	5.0	5.3	5.6	6.0	5.5	5.6
pH	Initial	8.4	8.1	8.2	8.1	8.2	8.2	8.1
	Final	8.2	8.1	7.9	7.9	8.0	7.9	8.0
Conductivity (µmhos/cm)	Initial	803	801	801	800	797	797	810
100								
Temperature (°C)	Initial	23.0	23.5	23.5	23.0	23.0	23.0	23.0
	Final	24.0	24.0	24.0	23.0	23.0	23.0	23.0
Dissolved O_2 (mg/L)	Initial	8.3	8.4	8.8	9.2	9.4	9.2	10.0
	Final	7.6	4.8	5.1	5.6	5.9	5.4	5.5
pH	Initial	8.3	8.0	8.1	8.0	8.1	8.2	8.0
	Final	8.2	8.1	8.1	7.9	8.0	7.9	8.0
Conductivity (µmhos/cm)	Initial	805	801	796	798	797	797	805

"–" = not measured
[3] % saturation (adjusted for actual temperature and barometric pressure)

Test Data Reviewed By : JL
Date : 2018-06-27

AquaTox Testing & Consulting Inc.
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TOXICITY TEST REPORT
Salmonid E Test
EPS 1/RM/28

Work Order : 234748
Sample Number : 52859

SAMPLE IDENTIFICATION

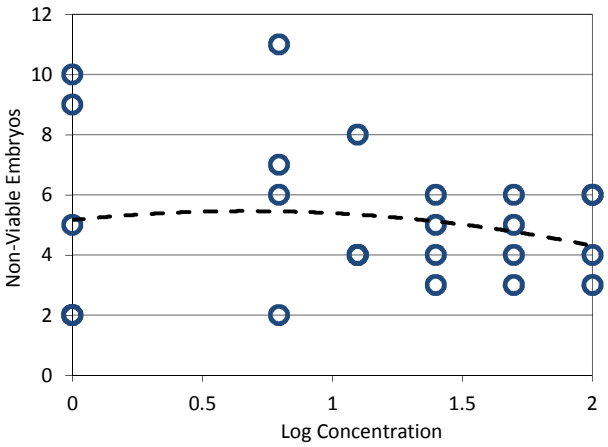
Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKBW7418V
Test Item :	Rhodium (1000 µg/mL Rh in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Initiation Date :	2018-11-28
Test Item Description :	Dark pink liquid	Completion Date :	2018-12-05

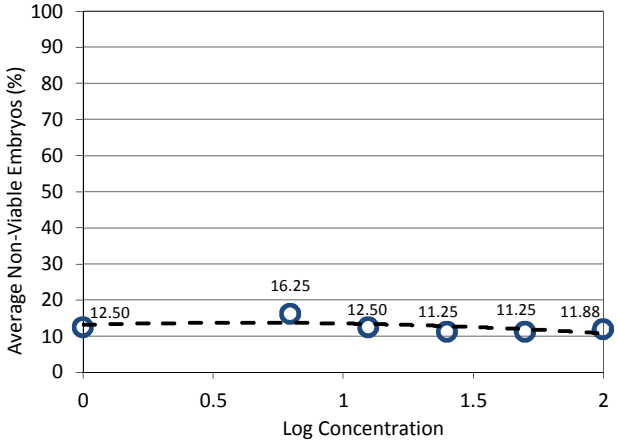
Test Method : Biological Test Method : Toxicity Tests Using Early Life Stages of Salmonid Fish (Rainbow Trout). Environment Canada EPS 1/RM/28 (Second Edition, July 1998).

7-DAY TEST RESULTS

Effect	Value	95% Confidence Limits	Calculation Method
EC25	>100 µg/L	–	–
EC50	>100 µg/L	–	–

The results reported relate only to the sample tested and as received.





COMMENTS

Noted Deviation(s) : •A reference toxicant test was not conducted in conjunction with this test, as required by the test method. The client has declined the option to include a positive control.

• The exposure concentrations were confirmed analytically, although test endpoints were generated using the nominal test concentrations. Total and dissolved Rh concentrations were measured at test start, at the final renewal, and at test end. These results were provided separately to NWMO.

• Abbott's Formula for correction of control effects was not applied to the test data, since statistical analysis was not required (i.e. results were intuitively based on inhibition values).

•All test validity criteria as specified in the test method (the average percentage of non-viable control embryos must be ≤30%) were satisfied.

Work Order : 234748
Sample Number : 52859

TEST ORGANISM

Test Organism :	Rainbow Trout (gamete/embryo)	Confirmation of Sperm Motility	Magnified observation
Species :	*Oncorhynchus mykiss*	Fertilization Procedure :	Dry mixing (5 min)
Gamete Source :	Lyndon Fish Hatcheries Inc.	Embryo Distribution :	Within 30 min of fertilization
Location :	New Dundee ON N0B 2E0	Female Broodstock used :	5
		Male Broodstock used :	5

No gametes or embryos exhibiting unusual appearance, or undergoing unusual treatment were used in the test.

TEST CONDITIONS

Test Type :	Static Renewal E-test	Control/Dilution Water :	Well water (no chemicals added)
Renewal Method :	80% syphoned and replaced	pH Adjustment :	None
Renewal Frequency :	≤ 24 hours	Sample Filtration :	None
Test Levels :	5 + 1 Control	Hardness Adjustment :	None
Control Replicates :	6	Volume per Replicate :	2500 mL
Test Replicates :	4	Test Chamber :	4 L plastic pail
Test Aeration :	Yes	Depth of Test Solution :	8 cm
Pre-Aeration Rate :	6.5 ± 1 mL/min/L	Organisms per Replicate :	40
Aeration Rate :	≤100 bubbles/min/chamber	Organisms per Test Level :	160
		Test Method Deviation(s):	See 'Comments'

PREPARATION OF TEST SOLUTIONS

Testing followed the general conditions of the cited test method. The test solution was prepared without the use of any solubilizing agent. A 20 mg/L (nominal) stock solution was prepared by thoroughly mixing 20 mL of 1000 mg/L rhodium standard solution (in HCl) with reverse osmosis water for a total volume of 1000 mL. Appropriate volumes of the 20 mg/L stock solution were mixed with control/dilution water to achieve the desired test concentrations. Sub-samples of each test solution were removed for initiating the test. The remaining test solutions were stored in a sealed containers, in complete darkness, with minimal head space, at 4±2 °C for the duration of the test. Sub-samples for test renewal were removed daily and warmed to test temperature. The Control consisted of control/dilution water which was stored and used in the same manner, but without the addition of rhodium stock.

REFERENCES

CETIS™, © 2000-2018. V.1.9.4.7. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Date : 2019-03-08 *yyyy-mm-dd*

Approved By :  *Project Manager*

Work Order : 234748
Sample Number : 52859

DAY 7 VIABILITY DATA

Completion Date : 2018-12-05
Analyst(s) : FS/RD/MR/LN

Concentration µg/L	Replicate	Day 0 Viable	Day 7 Viable	Day 7 Non-Viable	Average Non-Viable	Non-Viable (%)	Average Non-Viable (%)	Standard Deviation
Control	A	40	38	2	5.00	5.00	12.50	9.22
	B	40	38	2		5.00		
	C	40	35	5		12.50		
	D	40	38	2		5.00		
	E	40	30	10		25.00		
	F	40	31	9		22.50		
6.25	A	40	33	7	6.50	17.50	16.25	9.24
	B	40	34	6		15.00		
	C	40	38	2		5.00		
	D	40	29	11		27.50		
12.5	A	40	36	4	5.00	10.00	12.50	5.00
	B	40	32	8		20.00		
	C	40	36	4		10.00		
	D	40	36	4		10.00		
25	A	40	34	6	4.50	15.00	11.25	3.23
	B	40	37	3		7.50		
	C	40	36	4		10.00		
	D	40	35	5		12.50		
50	A	40	36	4	4.50	10.00	11.25	3.23
	B	40	37	3		7.50		
	C	40	34	6		15.00		
	D	40	35	5		12.50		
100	A	40	36	4	4.75	10.00	11.88	3.75
	B	40	34	6		15.00		
	C	40	37	3		7.50		
	D	40	34	6		15.00		

Test Data Reviewed By : JL
Date : 2019-02-01

Work Order : 234748
Sample Number : 52859

WATER CHEMISTRY DATA

Test Day		**Day 0-1**	**Day 1-2**	**Day 2-3**	**Day 3-4**	**Day 4-5**	**Day 5-6**	**Day 6-7**
Date :		2018-11-28	2018-11-29	2018-11-30	2018-12-01	2018-12-02	2018-12-03	2018-12-04
Sub-sample Used		1	1	1	2	2	3	3
Temperature (°C)		15.0	14.0	14.0	14.0	14.0	14.0	14.0
Dissolved O_2 (mg/L)		9.8	10.2	10.3	10.3	10.2	10.2	10.2
Dissolved O_2 Saturation (%)[2]		100	102	104	105	105	105	104
Pre-aeration Time (hh:mm)		00:30	02:00	02:00	02:00	02:00	02:00	02:00
Analyst(s) :		FS	CN	CN	CN	RD/RK	FS	CN
Control								
Temperature (°C)	Initial	15.0	14.0	14.0	14.0	14.0	14.0	14.0
	Final	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Dissolved O_2 Saturation (%)[2]	Initial	100	100	100	100	100	100	100
Dissolved O_2 (mg/L)	Initial	9.6	9.9	9.9	9.8	9.8	9.8	9.9
	Final	9.6	9.7	9.8	9.6	9.6	9.7	9.7
pH	Initial	8.0	8.0	7.9	7.9	7.9	7.9	7.9
	Final	8.2	8.2	8.2	8.3	8.2	8.2	8.2
Conductivity (µmhos/cm)	Initial	753	745	743	741	740	741	739
6.25 µg/L								
Temperature (°C)	Initial	15.0	14.0	14.0	14.0	14.0	14.0	14.0
	Final	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Dissolved O_2 (mg/L)	Initial	9.6	9.9	9.9	9.8	9.8	9.8	9.9
	Final	9.8	9.8	9.9	9.6	9.6	9.7	9.6
pH	Initial	8.0	8.0	7.9	7.9	8.0	8.0	7.9
	Final	8.3	8.2	8.3	8.3	8.2	8.2	8.2
Cond. (µmhos)	Initial	750	747	745	743	740	740	742
12.5								
Temperature (°C)	Initial	15.0	14.0	14.0	14.0	14.0	14.0	14.0
	Final	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Dissolved O_2 (mg/L)	Initial	9.6	9.9	9.9	9.9	9.8	9.8	9.9
	Final	9.8	9.7	9.9	9.6	9.7	9.7	9.6
pH	Initial	8.0	8.0	7.9	7.9	8.0	8.1	7.9
	Final	8.3	8.2	8.3	8.3	8.3	8.2	8.2
Conductivity (µmhos/cm)	Initial	750	751	750	750	750	750	748
25 µg/L								
Temperature (°C)	Initial	15.0	14.0	14.0	14.0	14.0	14.0	14.0
	Final	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Dissolved O_2 (mg/L)	Initial	9.6	9.9	9.9	9.9	9.8	9.8	9.9
	Final	9.9	9.7	9.8	9.6	9.6	9.8	9.7
pH	Initial	8.0	8.0	7.9	7.9	8.0	8.0	7.9
	Final	8.3	8.2	8.3	8.3	8.2	8.1	8.2
Cond. (µmhos)	Initial	753	754	754	753	751	750	751
50 µg/L								
Temperature (°C)	Initial	15.0	14.0	14.0	14.0	14.0	14.0	14.0
	Final	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Dissolved O_2 (mg/L)	Initial	9.6	9.9	10.0	10.0	9.8	9.7	9.9
	Final	9.9	9.8	9.9	9.6	9.5	9.8	9.7
pH	Initial	8.0	8.0	7.9	7.9	8.0	8.0	7.9
	Final	8.3	8.2	8.3	8.3	8.2	8.2	8.2
Conductivity (µmhos/cm)	Initial	756	758	760	758	754	752	758
100 µg/L								
Temperature (°C)	Initial	15.0	14.0	14.0	14.0	14.0	14.0	14.0
	Final	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Dissolved O_2 (mg/L)	Initial	9.6	9.9	10.0	10.0	9.7	9.7	9.9
	Final	9.9	9.8	9.9	9.6	9.6	9.8	9.6
pH	Initial	7.9	7.9	7.8	7.9	8.0	8.0	7.9
	Final	8.3	8.2	8.3	8.3	8.2	8.2	8.2
Conductivity (µmhos/cm)	Initial	759	761	761	760	760	760	760

"–" = not measured/not required
[2] % saturation (adjusted for temperature and barometric pressure)

Test Data Reviewed By : JL
Date : 2019-02-12

APPENDIX C.2: AQUATOX TERRESTRIAL TOXICITY DATA

AquaTox Testing & Consulting Inc.
B-11 Nicholas Beaver Road
Puslinch, ON N0B 2J0
Tel. (519) 763-4412
Fax. (519) 763-4419

TOXICITY TEST REPORT

Alfalfa
EPS 1/RM/45

Work Order : 234749
Sample Number : 52860

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKCB9445
Test Item :	Ruthenium (1000 µg/mL Ru in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Initiation Date :	2018-02-14
Test Item Description :	Dark brown liquid	Completion Date :	2018-03-07

Test Method : Test for Measuring Emergence and Growth of Terrestrial Plants Exposed to Contaminants in Soil. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/45, February 2005 (with June 2007 amendments), with deviation(s) as noted.

21-DAY TEST RESULTS

Effect	Endpoint	Value	Inhibition (% of Control)	Significant Difference from Control?	Calculation Method
Emergence	EC50	>10.0 µg/g	2.00%	No (α= 0.05)	Fisher Exact Test [a]
Shoot Length	IC25	>10.0 µg/g	1.87%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]
Shoot Weight	IC25	>10.0 µg/g	-7.14%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]
Root Length	IC25	>10.0 µg/g	9.32%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]
Root Dry Weight	IC25	>10.0 µg/g	-3.03%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]

•A negative value for inhibition (%) indicates stimulation compared to the control.

Results are based on nominal concentrations of the test item (µg/g).
The results reported relate only to the item tested and as received.

TEST ORGANISM

Species :	*Medicago sativa*	Seed Variety :	N/A (tap-rooted, farm-saved)
Seed Source :	Mumm's Sprouting Seeds[1]	Lot Number :	A5L

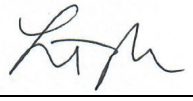
No seeds exhibiting unusual appearance or undergoing unusual treatment were used in the test.

[1]Box 80, 118 1st Ave W, Parkside SK, S0J 2A0; 306-747-2935

TEST CONDITIONS

Test Type :	Static	Light Intensity (at soil surface) :	15280 - 16530 lux
Test Duration :	21 days	Photoperiod (light/dark) :	16 h / 8 h
Control/Test Soil :	Artificial Soil	Average Temperature (Range) :	23.8 °C (22 - 27 °C)
Sample Type :	Chemical-Spiked Soil	Emergence Observations :	Days 7 and 21
Samples per Treatment :	1	Shoot/Root Length Observations:	Day 21
Replicates per Treatment :	5	Shoot/Root Weight Observations:	Day 21
Number of Treatments :	1 + 1 (Negative) Control	Conductivity Measurements :	Days 0 and 21
Soil per Replicate :	~350 mL (dry)	pH Measurements :	Days 0 and 21
Seeds per Replicate :	10	Soil Moisture Determinations :	Days 0 and 21
Seeds per Treatment :	50	Test Method Deviations :	Yes (see 'Comments')

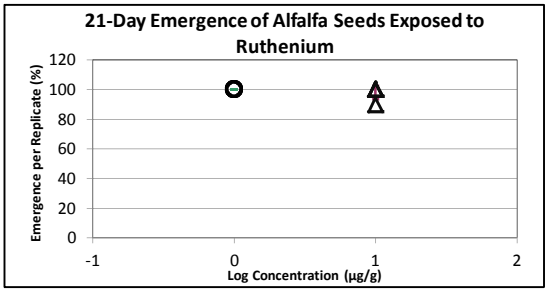
Date : 2019-03-08
yyyy-mm-dd

Approved By : 
Project Manager

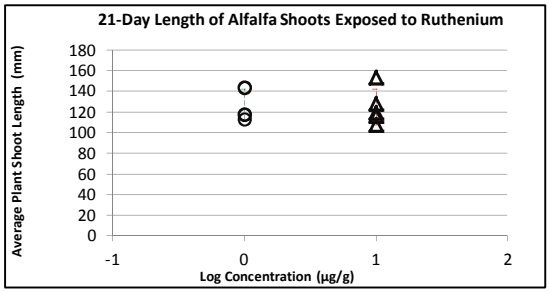
Work Order : 234749
Sample Number : 52860

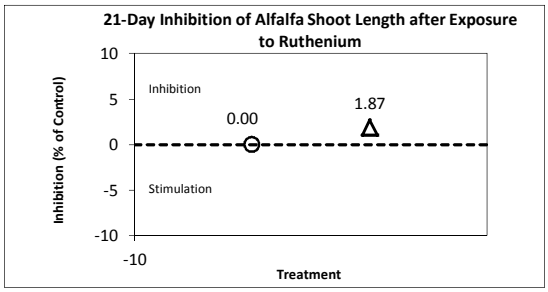
RESULTS (cont.)

EMERGENCE

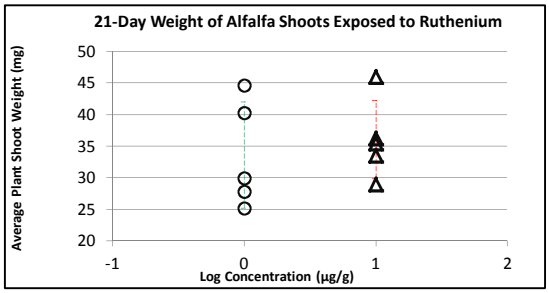


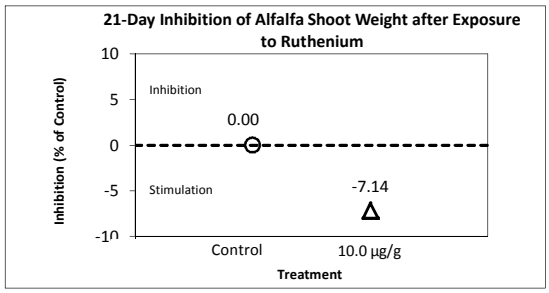
SHOOT LENGTH



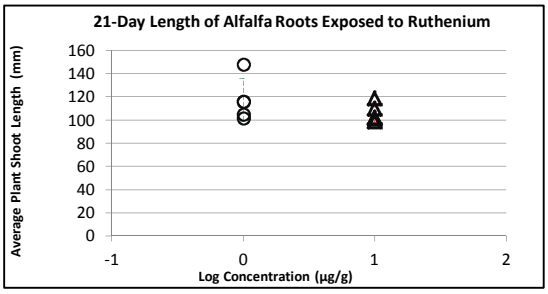


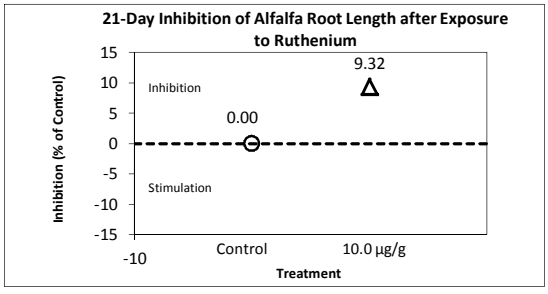
SHOOT WEIGHT



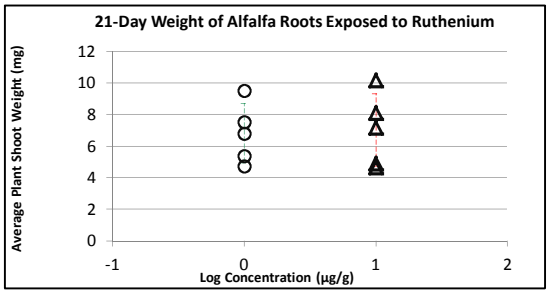


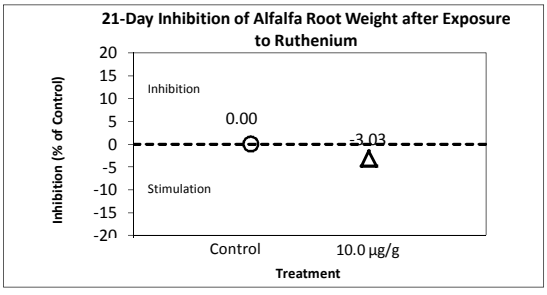
ROOT LENGTH





ROOT WEIGHT





•A negative value for inhibition (%) indicates stimulation compared to the control.

Work Order : 234749
Sample Number : 52860

PREPARATION OF TEST MEDIUM

Artificial Soil was formulated in the laboratory following procedures described in AquaTox SOP #364 (AquaTox, 2015c). The ingredients of Artificial Soil included 70% silica sand, 20% kaolinite clay, 10% Sphagnum spp. fine grind peat, and calcium carbonate ($CaCO_3$). The Artificial Soil was allowed to stabilize for a minimum of three days prior to test initiation.

Testing followed the general conditions of the cited test method. Solutions used for soil spiking were prepared without the use of any solubilizing agent. A 1008 µg/L (nominal, w/v) stock solution was prepared by thoroughly mixing the test item with distilled water. Appropriate volumes of the stock solution were added to individual portions of Artificial Soil to achieve each desired nominal test concentration. The stock solution was added by pouring the solution over the soil surface. Each soil was mixed using a hand-held mechanical mixer for 10 minutes to ensure homogeneity. Additional distilled water was added to the each soil in order to achieve the required moisture content. The soil was then mixed with the hand-held mechanical mixer for 5 minutes. Once homogenized, the spiked soils were dispensed into the appropriate test vessels. Control treatments were prepared in the same manner, but without the addition of stock solution.

The exposure concentration was confirmed analytically, although test endpoints were generated using the nominal test concentration. The total Ru concentration was measured at test start, day 7, 14 and at test end (day 21). These results were provided separately to NWMO.

SOIL CHARACTERISTICS

Treatment	Initial pH[2]	Final pH[2]	Initial Conductivity[2] (µS/cm)	Final Conductivity[2] (µS/cm)	Initial Soil Moisture (% WHC)	Final Soil Moisture (% WHC)
Control	7.47	7.60	175	231	79	83
10.0 µg/g	6.81	7.00	739	695	82	88

[2] pH and conductivity were measured using a 2:1 water:soil slurry

ARTIFICIAL SOIL COMPOSITION[3]

Sand (%)	Silt (%)	Clay (%)	Organic Matter (mg/kg)	Organic Carbon (mg/kg)	Nitrogen (%)	Plant Available Phosphorus (µg/g dry)
76	3.8	21	27000	16000	0.080	150

[3] Analysis conducted by Maxxam Analytics, 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700

COMMENTS

Noted Deviation(s) :

•The Control organisms satisfied the emergence, survival, and the shoot length validity criteria; however, the validity criterion for root length was not satisfied. The Control did however pass the recommended root weight validity criterion. According to Environment and Climate Change Canada (the author of the standardized plant test method), the test validity criteria were established from tests that did not use a weak nutrient solution for watering. As a weak nutrient solution was used for watering, as is allowed by the method, we observed that the roots were more branched horizontally (i.e., filamentous). Since the roots had access to nutrients in the soil, the plants were able to direct growth to their shoots rather than the root length. This phenomenon is not atypical when a weak nutrient solution is applied and did not warrant repeating the test.

•A reference toxicant test was not conducted in conjunction with this test, as required by the test method. The client has declined the option to include a positive control as part of the terrestrial testing.

Work Order : 234749
Sample Number : 52860

EMERGENCE DATA - DAY 7

Treatment	Replicate	Emergence	Emergence (%)	Treatment Average	Standard Deviation	Notes	Analyst(s)
Control	1	10	100	100.00	0.00	Healthy	RD
	2	10	100			Healthy	RD
	3	10	100			Healthy	RD
	4	10	100			Healthy	RD
	5	10	100			Healthy	RD
10.0 µg/g	1	10	100	98.00	4.47	Healthy	RD
	2	10	100			Healthy	RD
	3	9	90			Healthy	RD
	4	10	100			Healthy	RD
	5	10	100			Healthy	RD

EMERGENCE DATA - DAY 21

Treatment	Replicate	Emergence	Emergence (%)	Treatment Average	SD	Notes	Analyst(s)
Control	1	10	100	100.00	0.00	Healthy	EJS
	2	10	100			Healthy	EJS
	3	10	100			Healthy	EJS
	4	10	100			Healthy	EJS
	5	10	100			Healthy	EJS
10.0 µg/g	1	10	100	98.00	4.47	Healthy, 1 wilted and browning	EJS
	2	10	100			Healthy	EJS
	3	9	90			Healthy	EJS
	4	10	100			Healthy, 1 very chlorotic	EJS
	5	10	100			Healthy	EJS

NOTES : 2018-03-07: Algal growth was observed in the soil in all replicates in all concentrations (EJS).

Test Data Reviewed By : JL
Date : 2018-06-18

Work Order : 234749
Sample Number : 52860

SHOOT AND ROOT LENGTH DATA - DAY 21

Treatment	Replicate	Plant	Shoot Length (mm)	Average Shoot Length per Plant (mm)	Treatment Average	Standard Deviation	Root Length (mm)	Treatment Average Root Length (mm)	Treatment Average	SD	Notes	Analyst(s)
Control	1	1	215	117.9	127.18	15.1	146	101.6	117.22	18.3	Healthy	CZN
		2	83				89				Healthy	
		3	130				115				Healthy	
		4	102				92				Healthy	
		5	111				91				Healthy	
		6	68				105				Healthy	
		7	104				119				Healthy	
		8	169				98				Healthy	
		9	168				141				Healthy	
		10	29				20				Wilted, slightly chlorotic.	
	2	1	159	113.3			135	115.8			Healthy	RD
		2	156				131				Healthy	
		3	120				128				Healthy	
		4	133				119				Healthy	
		5	132				94				Healthy	
		6	158				155				Healthy	
		7	135				156				Healthy	
		8	74				108				Healthy	
		9	20				80				Healthy	
		10	46				52				Healthy	
	3	1	206	144.0			139	116.0			Healthy	CZN
		2	184				120				Healthy	
		3	131				135				Healthy	
		4	145				93				Healthy	
		5	155				123				Healthy	
		6	150				136				Healthy	
		7	195				115				Healthy	
		8	169				156				Healthy	
		9	64				84				Healthy	
		10	41				59				Healthy	
	4	1	210	143.3			206	147.9[4]			Healthy	RD
		2	172				260				Healthy	
		3	163				126				Healthy	
		4	76				113				Healthy	
		5	116				124				Healthy	
		6	125				140				Healthy	
		7	153				136				Healthy	
		8	169				154				Healthy	
		9	159				158				Healthy	
		10	90				62				Healthy	
	5	1	120	117.4			96	104.8			Healthy	CZN
		2	157				143				Healthy	
		3	143				105				Healthy	
		4	145				76				Healthy	
		5	96				120				Healthy	
		6	115				126				Healthy	
		7	92				76				Healthy	
		8	105				130				Healthy	
		9	145				96				Healthy	
		10	56				80				Healthy	
10.0 µg/g	1	1	93	127.7	124.81	17.4	100	101.7	106.30	8.2	Healthy	RD
		2	15				25				Wilted plant.	
		3	181				132				Healthy	
		4	152				124				Healthy	
		5	131				111				Healthy	
		6	220				140				Healthy	
		7	185				114				Healthy	
		8	140				121				Healthy	
		9	46				66				Healthy	
		10	114				84				Healthy	
	2	1	161	153.1			164	118.9			Healthy	CZN
		2	144				90				Healthy	
		3	171				151				Healthy	
		4	162				111				Healthy	
		5	218				145				Healthy	
		6	201				141				Healthy	
		7	125				98				Healthy	
		8	99				124				Some leaves have yellow spots.	
		9	135				108				Healthy	
		10	115				57				Healthy	
	3	1	159	119.3			120	102.0			Healthy	RD
		2	92				103				Healthy	
		3	151				108				Healthy	
		4	168				96				Healthy	
		5	178				104				Healthy	
		6	158				91				Healthy	
		7	62				92				Healthy	
		8	54				116				Healthy	
		9	52				88				Healthy	
		10	-				-				Healthy	
	4	1	99	107.6			101	110.0			Healthy	CZN
		2	169				135				Healthy	
		3	160				142				Healthy	
		4	136				115				Healthy	
		5	125				115				Healthy	
		6	136				128				Healthy	
		7	88				99				Healthy	
		8	95				99				Healthy	
		9	50				72				Some leaves have yellow spots.	
		10	18				94				Wilted, completely chlorotic.	
	5	1	164	116.3			93	98.9			Healthy	RD
		2	193				143				Healthy	
		3	152				114				Healthy	
		4	86				76				Healthy	
		5	141				113				Healthy	
		6	163				151				Healthy	
		7	104				74				Healthy	
		8	78				72				Healthy	
		9	50				59				Healthy	
		10	32				94				Healthy	

•[4] Outlier according to Grubbs Test (CETIS). Outlying data points were not excluded from statistical analysis, since they could not be attributed to error.

Test Data Reviewed By : JL
Date : 2018-07-16

Work Order : 234749
Sample Number : 52860

SHOOT WEIGHT DATA - DAY 21

Treatment	Replicate	Weigh Boat (g)	Weigh Boat + Dry (g)	Dry Weight (mg)	Number of Plants	Dry Weight/Individual Plant (mg)	Treatment Average Weight (mg)	Standard Deviation
Control	1	0.9335	1.1857	252.23	10	25.223	33.608	8.4
	2	0.9736	1.2734	299.79	10	29.979		
	3	0.9320	1.3354	403.40	10	40.340		
	4	0.9818	1.4282	446.42	10	44.642		
	5	0.9516	1.2301	278.54	10	27.854		
10	1	0.9530	1.4122	459.22	10	45.922	36.008	6.2
	2	0.9292	1.2918	362.63	10	36.263		
	3	0.9465	1.2068	260.33	9	28.926		
	4	0.9266	1.2806	354.01	10	35.401		
	5	0.9660	1.3013	335.29	10	33.529		

ROOT WEIGHT DATA - DAY 21

Treatment	Replicate	Weigh Boat (g)	Weigh Boat + Dry (g)	Dry Weight (mg)	Number of Plants	Dry Weight/Individual Plant (mg)	Treatment Average Weight (mg)	Standard Deviation
Control (0)	1	1.2638	1.3113	47.50	10	4.750	6.814	1.9
	2	1.2716	1.3396	68.02	10	6.802		
	3	1.2732	1.3488	75.59	10	7.559		
	4	1.2775	1.3729	95.43	10	9.543		
	5	1.2811	1.3353	54.15	10	5.415		
10	1	1.2779	1.3797	101.86	10	10.186	7.020	2.3
	2	1.2719	1.3439	71.98	10	7.198		
	3	1.2665	1.3085	42.00	9	4.667		
	4	1.2847	1.3659	81.19	10	8.119		
	5	1.2824	1.3317	49.31	10	4.931		

•No outlying data points were detected according to Grubbs Test (CETIS)[a].

DEFINITIONS

IC*x* : The concentration of test item estimated to cause x% inhibition compared to the Control.
LC50 : The concentration of test item estimated to cause mortality in 50% of the test organisms.
WHC : Water-holding capacity of the soil.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Softwa LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Test Data Reviewed By : JL
Date : 2018-07-16

AquaTox Testing & Consulting Inc.
B-11 Nicholas Beaver Road
Puslinch, ON N0B 2J0
Tel. (519) 763-4412
Fax. (519) 763-4419

TOXICITY TEST REPORT
Barley
EPS 1/RM/45

Work Order : 234749
Sample Number : 52860

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKCB9445
Test Item :	Ruthenium (1000 µg/mL Ru in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Initiation Date :	2018-02-14
Test Item Description :	Dark brown liquid	Completion Date :	2018-02-28
Test Method :	Test for Measuring Emergence and Growth of Terrestrial Plants Exposed to Contaminants in Soil. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/45, February 2005 (with June 2007 amendments), with deviation(s) as noted.		

14-DAY TEST RESULTS

Effect	Endpoint	Value	Inhibition (% of Control)	Significant Difference from Control?	Calculation Method
Emergence	EC50	>10.0 µg/g	0.00%	No (α= 0.05)	–
Shoot Length	IC25	>10.0 µg/g	2.22%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]
Shoot Weight	IC25	>10.0 µg/g	-12.14%	Yes (α= 0.05)	Equal Variance t Two-Sample Test [a]
Root Length	IC25	<10.0 µg/g	29.19%	Yes (α= 0.05)	Equal Variance t Two-Sample Test [a]
Root Weight	IC25	<10.0 µg/g	25.65%	Yes (α= 0.05)	Equal Variance t Two-Sample Test [a]

•A negative value for inhibition (%) indicates stimulation compared to the control.

Results are based on nominal concentrations of the test item (µg/g).
The results reported relate only to the item tested and as received.

TEST ORGANISM

Species :	*Hordeum vulgare*	Seed Variety :	Dignity
Seed Source :	Rosebank Seed Farms Ltd.[1]	Lot Number :	Spring Six Row - Home Back

No seeds exhibiting unusual appearance or undergoing unusual treatment were used in the test.

[1]7340 Perth Line 24, RR #2, Staffa ON, CA N0K 1Y0

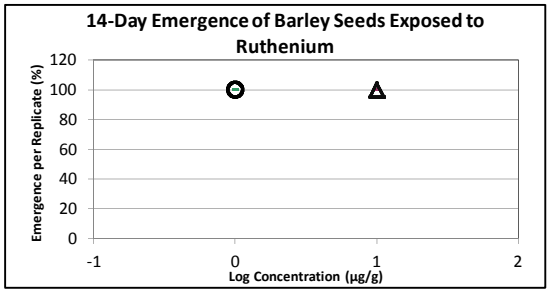
TEST CONDITIONS

Test Type :	Static	Light Intensity (at soil surface) :	14370 - 15930 lux
Test Duration :	14 days	Photoperiod (light/dark) :	16 h / 8 h
Control/Test Soil :	Artificial Soil	Average Temperature (Range) :	23.7 °C (22 - 25 °C)
Sample Type :	Chemical-Spiked Soil	Emergence Observations :	Days 7 and 14
Samples per Treatment :	1	Shoot/Root Length Observations:	Day 14
Replicates per Treatment :	5	Shoot/Root Weight Observations:	Day 14
Number of Treatments :	1 + 1 (Negative) Control	Conductivity Measurements :	Days 0 and 14
Soil per Replicate :	~350 mL (dry)	pH Measurements :	Days 0 and 14
Seeds per Replicate :	5	Soil Moisture Determinations :	Days 0 and 14
Seeds per Treatment :	25	Test Method Deviations :	Yes (see 'Comments')

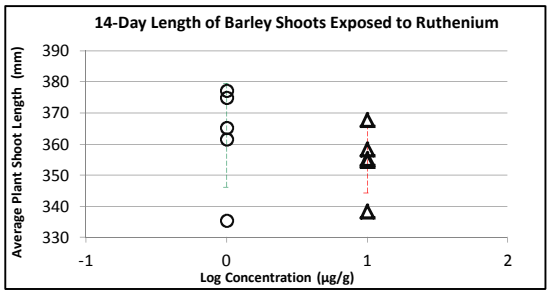
Work Order : 234749
Sample Number : 52860

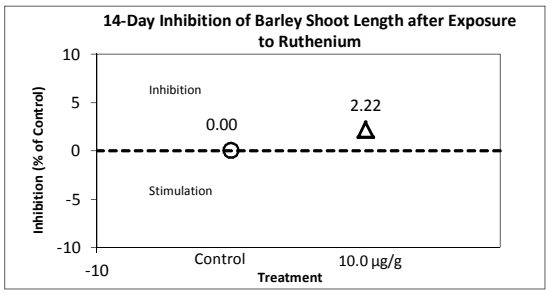
RESULTS (cont.)

EMERGENCE

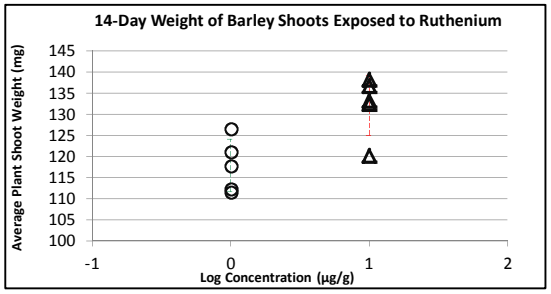


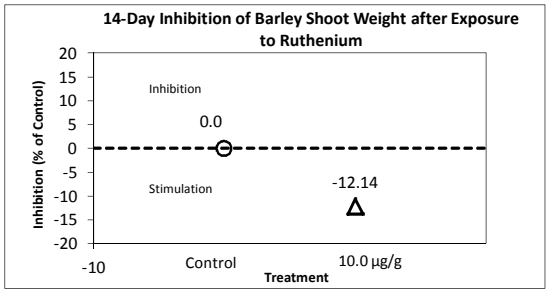
SHOOT LENGTH



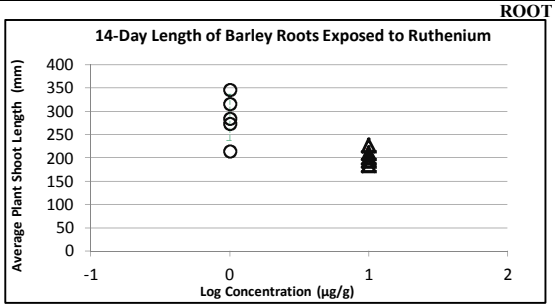


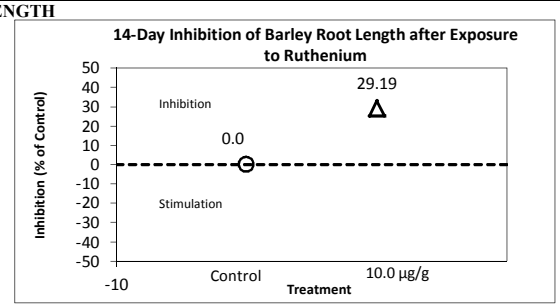
SHOOT WEIGHT



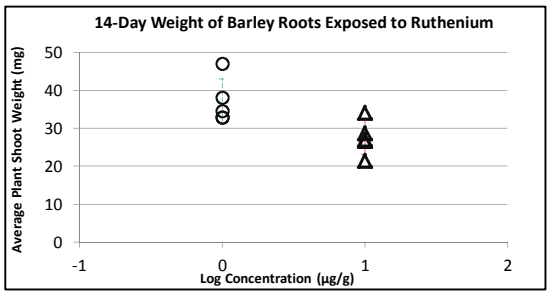


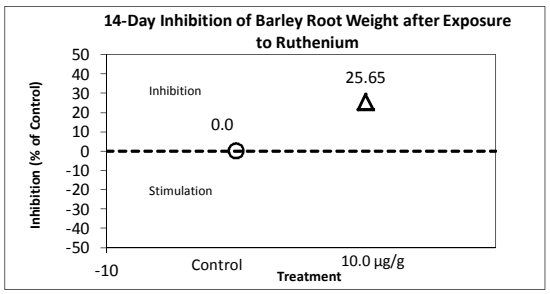
ROOT LENGTH





ROOT WEIGHT





•A negative value for inhibition (%) indicates stimulation compared to the control.

Work Order : 234749
Sample Number : 52860

PREPARATION OF TEST MEDIUM

Artificial Soil was formulated in the laboratory following procedures described in AquaTox SOP #364 (AquaTox, 2015c). The ingredients of Artificial Soil included 70% silica sand, 20% kaolinite clay, 10% Sphagnum spp. fine grind peat, and calcium carbonate ($CaCO_3$). The Artificial Soil was allowed to stabilize for a minimum of three days prior to test initiation.

Testing followed the general conditions of the cited test method. The solution used for soil spiking were prepared without the use of any solubilizing agent. A 1008 mg/L (nominal, w/v) stock solution was prepared by thoroughly mixing the test item with distilled water. An appropriate volume of the stock solution was added to Artificial Soil to achieve the desired nominal test concentration (10.0 µg/g). The stock solution was added by pouring the solution over the soil surface. The soil was mixed using a hand-held mechanical mixer for 10 minutes to ensure homogeneity. Additional distilled water was added to the soil in order to achieve the required moisture content. The soil was then mixed with the hand-held mechanical mixer for 5 minutes. Once homogenized, the spiked soil was dispensed into the appropriate test vessels. The Control treatment was prepared in the same manner, but without the addition of stock solution.

The exposure concentration was confirmed analytically, although test endpoints were generated using the nominal test concentration. The total Ru concentration was measured at test start, day 7 and at test end (day 14). These results were provided separately to NWMO.

SOIL CHARACTERISTICS

Treatment	Initial pH[2]	Final pH[2]	Initial Conductivity[2] (µS/cm)	Final Conductivity[2] (µS/cm)	Initial Soil Moisture (% WHC)	Final Soil Moisture (% WHC)
Control	7.47	7.40	180	171	78	58
10.0 µg/g	6.76	6.84	758	708	83	61

[2] pH and conductivity were measured using a 2:1 water:soil slurry

ARTIFICIAL SOIL COMPOSITION[3]

Sand (%)	Silt (%)	Clay (%)	Organic Matter (mg/kg)	Organic Carbon (mg/kg)	Nitrogen (%)	Plant Available Phosphorus (µg/g dry)
76	3.8	21	27000	16000	0.080	150

[3] Analysis conducted by Maxxam Analytics, 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700

COMMENTS

Noted Deviation(s) : •A reference toxicant test was not conducted in conjunction with this test, as required by the test method. The client has declined the option to include a positive control as part of the terrestrial testing.

Date : 2019-03-08 ***Approved By :***
yyyy-mm-dd *Project Manager*

Work Order : 234749
Sample Number : 52860

EMERGENCE DATA - DAY 7

Treatment	Replicate	Emergence	Emergence (%)	Treatment Average	Standard Deviation	Notes	Analyst(s)
Control	1	5	100	100.00	0.00	Healthy	EJS
	2	5	100			Healthy	RD
	3	5	100			Healthy, 1 short	RD
	4	5	100			Healthy	RD
	5	5	100			Healthy	RD
10.0 µg/g	1	5	100	100.00	0.00	Healthy	RD
	2	5	100			Healthy	RD
	3	5	100			Healthy	RD
	4	5	100			Healthy	RD
	5	5	100			Healthy	RD

EMERGENCE DATA - DAY 14

Treatment	Replicate	Emergence	Emergence (%)	Treatment Average	SD	Notes	Analyst(s)
Control	1	5	100	100.00	0.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	5	100			Healthy, 1 short	EJS
	4	5	100			Healthy	EJS
	5	5	100			Healthy	EJS
10.0 µg/g	1	5	100	100.00	0.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	5	100			Healthy	EJS
	4	5	100			Healthy	EJS
	5	5	100			Healthy	EJS

Test Data Reviewed By : JL
Date : 2018-06-22

Work Order : 234749
Sample Number : 52860

SHOOT AND ROOT LENGTH DATA - DAY 14

Treatment	Replicate	Average Shoot Length per Plant (mm)	Treatment Average	Standard Deviation	Treatment Average Root Length (mm)	Treatment Average	SD	Notes	Analyst(s)
Control	1	361.6	362.88	16.7	316.0	287.12	49.6	Healthy	EJS
								Healthy	
								Healthy	
								Healthy	
								Healthy	
	2	375.0			273.2			Healthy	DK
								Healthy	
								Healthy	
								Healthy	
								Healthy	
	3	335.4			284.6			Healthy	EJS
								Healthy	
								Healthy	
								Healthy	
								Healthy	
	4	365.2			214.8			Healthy	DK
								Healthy	
								Healthy	
								Healthy	
								Healthy	
	5	377.2			347.0			Healthy	EJS
								Healthy	
								Healthy	
								Healthy	
								Healthy	
10.0 µg/g	1	367.8	354.84	10.6	210.0	203.32	15.9	Healthy	DK
								Healthy	
								Healthy	
								Healthy	
								Healthy	
	2	354.6			226.4			Healthy	EJS
								Healthy	
								Healthy	
								Healthy	
								Healthy	
	3	355.2			184.8			Healthy	DK
								Healthy	
								Healthy	
								Healthy	
								Healthy	
	4	338.4			201.2			Healthy	EJS
								Healthy	
								Healthy	
								Healthy	
								Healthy	
	5	358.2			194.2			Healthy	DK
								Healthy	
								Healthy	
								Healthy	
								Healthy	

•No outlying data points were detected according to Grubbs Test (CETIS®)

Test Data Reviewed By : JL
Date : 2018-06-22

Work Order : 234749
Sample Number : 52860

SHOOT WEIGHT DATA - DAY 14

Treatment	Replicate	Weigh Boat (g)	Weigh Boat + Dry (g)	Dry Weight (mg)	Number of Plants	Dry Weight/Individual Plant (mg)	Treatment Average Weight (mg)	Standard Deviation
Control	1	0.9480	1.5369	588.96	5	117.792	117.848	6.2
	2	0.9940	1.5555	561.48	5	112.296		
	3	0.9269	1.5320	605.15	5	121.030		
	4	0.9517	1.5097	557.96	5	111.592		
	5	0.9202	1.5528	632.65	5	126.530		
10	1	0.9289	1.6125	683.57	5	136.714	132.155	7.1
	2	0.9556	1.6216	665.94	5	133.188		
	3	0.9461	1.6374	691.38	5	138.276		
	4	0.9299	1.5305	600.58	5	120.116		
	5	0.9072	1.5696	662.40	5	132.480		

ROOT WEIGHT DATA - DAY 14

Treatment	Replicate	Weigh Boat (g)	Weigh Boat + Dry (g)	Dry Weight (mg)	Number of Plants	Dry Weight/Individual Plant (mg)	Treatment Average Weight (mg)	Standard Deviation
Control (0)	1	1.2887	1.5241	235.44	5	47.088	37.150	5.9
	2	1.2690	1.4420	172.99	5	34.598		
	3	1.2819	1.4467	164.79	5	32.958		
	4	1.2652	1.4300	164.77	5	32.954		
	5	1.2792	1.4699	190.77	5	38.154		
10	1	1.2839	1.4280	144.05	5	28.810	27.620	4.6
	2	1.2712	1.4043	133.19	5	26.638		
	3	1.2738	1.4449	171.07	5	34.214		
	4	1.2720	1.3792	107.28	5	21.456		
	5	1.2811	1.4160	134.90	5	26.980		

•No outlying data points were detected according to Grubbs Test (CETIS[a])

DEFINITIONS

IC*x* : The concentration of test item estimated to cause x% inhibition compared to the Control.
LC50 : The concentration of test item estimated to cause mortality in 50% of the test organisms.
WHC : Water-holding capacity of the soil.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Test Data Reviewed By : JL
Date : 2018-07-16

AquaTox Testing & Consulting Inc.
B-11 Nicholas Beaver Road
Puslinch, ON N0B 2J0
Tel. (519) 763-4412
Fax. (519) 763-4419

TOXICITY TEST REPORT

Eisenia andrei
EPS 1/RM/43

Work Order : 234749
Sample Number : 52860

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKCB9445
Test Item :	Ruthenium (1000 µg/mL Ru in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Date Initiated :	2018-02-08
Test Item Description :	Dark brown liquid	Date Completed :	2018-04-05

Test Method : Tests for Toxicity of Contaminated Soil to Earthworms (*Eisenia andrei* , *Eisenia fetida* , or *Lumbricus terrestris*). Report EPS 1/RM/43, June 2004 with June 2007 amendments, with deviation(s) as noted.

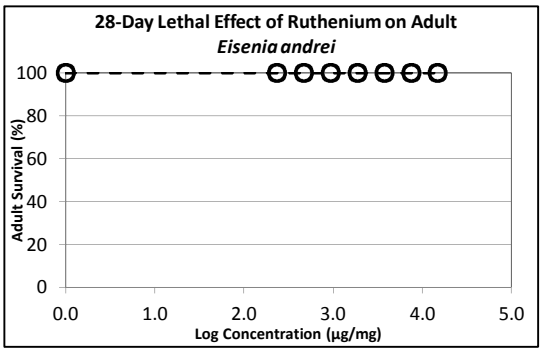
TEST RESULTS

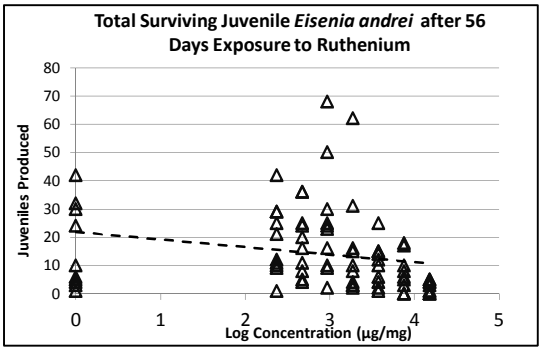
Effect	Endpoint	Value	95% Confidence Limits	Calculation Method
Survival	28-day LC50	>15.0 µg/g	–	–
Reproductive Success	56-day IC25	10.4 µg/g	0.206* - 14.3 µg/g	Linear Interpolation (CETIS)[a]
Growth	56-day IC25	3.14 µg/g	0.181* - 4.96 µg/g	Linear Interpolation (CETIS)[a]

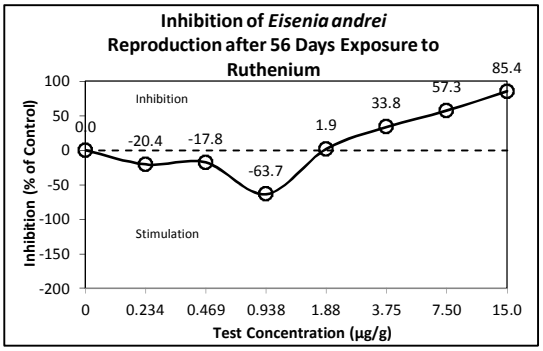
*The lower 95% confidence limit is less than the lowest concentration tested.

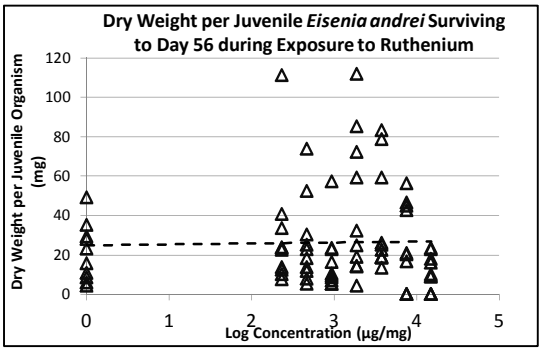
Results are based on nominal concentrations of the test item (µg/g).

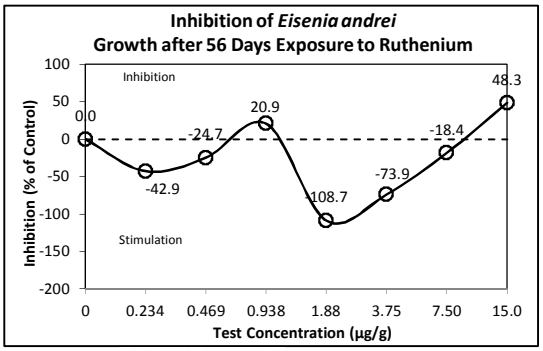
The results reported relate only to the item tested and as received.











Date : 2019-03-08
yyyy-mm-dd

Approved By : _____
Project Manager

Work Order : 234749
Sample Number : 52860

TEST ORGANISM

Test Organism :	*Eisenia andrei*
Culture Origin :	Environment Canada (Ottawa, ON)
Test Organism Source :	In-house culture
Average Wet Weight (±SD) :	453 mg (± 82) at start of test

•No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

TEST CONDITIONS

Test Type :	Prolonged exposure (static)	Soil Type :	Artificial Soil
Test Duration :	56 days	Test Chamber :	500 mL glass jar
Number of Treatments :	7 + 1 Control	Test Chamber Covering :	Perforated cover
Discrete Samples per Treatment :	1	Soil per Replicate :	270 g wet weight
Replicates per Treatment :	10	Test Temperature :	20 ± 2 °C
Test Organisms per Replicate :	2	Test Photoperiod :	16 h light : 8 h dark
Test Organisms per Treatment :	20	Light Quality :	Cool white fluorescent
Test/Dilution/Misting Water :	Autoclaved dilution water	Test Method Deviation(s) :	Yes (see 'Comments')

FOOD PREPARATION AND FEEDING

Date	Test Day	Food Type	Ration (per Replicate)
2018-02-08	0	Un-cooked oatmeal + Magic® Worm Food	~4 mL
2018-02-22	14	Un-cooked oatmeal + Magic® Worm Food	~4 mL
2018-03-08	28	Un-cooked oatmeal + Magic® Worm Food	~4 mL
2018-03-22	42	Un-cooked oatmeal + Magic® Worm Food	~4 mL

For each feeding event, a fresh batch of food was prepared. Dry un-cooked oatmeal (250 mL) was mixed thoroughly with 75 mL of Magic® Worm Food. The food mixture was added to each test replicate, and hydrated by spraying 10 times with distilled water.

PREPARATION OF TEST MEDIUM

Artificial Soil was formulated in the laboratory following procedures described in AquaTox SOP #364 (AquaTox, 2015c). The ingredients of Artificial Soil included 70% silica sand, 20% kaolinite clay, 10% Sphagnum spp. fine grind peat, and calcium carbonate ($CaCO_3$). The Artificial Soil was allowed to stabilize for a minimum of three days prior to test initiation.

Testing followed the general conditions of the cited test method. Solutions used for soil spiking were prepared without the use of any solubilizing agent. A 991µg/L (nominal, w/v) stock solution was prepared by thoroughly mixing the test item with distilled water. Appropriate volumes of the stock solution were added to individual portions of Artificial Soil to achieve each desired nominal test concentration. The stock solution was added by pouring the solution over the soil surface. Each soil was mixed using a hand-held mechanical mixer for 10 minutes to ensure homogeneity. Additional distilled water was added to the each soil in order to achieve the required moisture content. The soil was then mixed with the hand-held mechanical mixer for 5 minutes. Once homogenized, the spiked soils were dispensed into the appropriate test vessels. Control treatments were prepared in the same manner, but without the addition of stock solution.

The lowest, middle and highest exposure concentrations were confirmed analytically, although test endpoints were generated using nominal test concentrations. The total Ru concentrations were measured at test start, day 14, 28, 42 and at test end (day 56). These results were provided separately to NWMO.

Work Order : 234749
Sample Number : 52860

ADULT SURVIVAL (DAY 28)

Date : 2018-03-08
Analyst(s) : EJS, RD, AS

Concentration (µg/g)	Replicate	Number of Live Adults	Number of Healthy Adults	Comments	Adult Survival (%)	Average Survival (%)	Standard Deviation
Control	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
0.234	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
0.469	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
0.938	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
1.88	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
3.75	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
7.50	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
15.0	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	0	Test organisms appear pale.	100		
	8	2	0	Test organisms lethargic	100		
	9	2	0	Test organisms lethargic	100		
	10	2	0	Test organisms lethargic	100		

Test Data Reviewed By : JL
Date : 2018-07-16

Work Order : 234749
Sample Number : 52860

SURVIVING JUVENILES (DAY 56)

Date : 2018-04-05
Analyst(s) : EJS, RD, CZN, CG, AS, JL, SEW

Concentration (µg/g)	Replicate	Comments	Surviving Juveniles	Average Surviving Juveniles	Standard Deviation
Control	1	–	1	15.7	14.86
	2	–	32		
	3	–	24		
	4	–	5		
	5	–	42		
	6	–	30		
	7	–	6		
	8	–	10		
	9	–	3		
	10	–	4		
0.234	1	–	25	18.9	12.41
	2		10		
	3	–	29		
	4	–	1		
	5	–	42		
	6	–	9		
	7	–	11		
	8	–	29		
	9	–	12		
	10	–	21		
0.469	1	–	16	18.5	11.80
	2	–	11		
	3	–	36		
	4	–	8		
	5	–	36		
	6	–	20		
	7	–	5		
	8	–	24		
	9	–	25		
	10	–	4		
0.938	1	–	25	25.7	19.97
	2	–	2		
	3	–	9		
	4	–	50		
	5	–	68[1]		
	6	–	10		
	7	–	16		
	8	–	24		
	9	–	30		
	10	–	23		
1.88	1	–	3	15.4	18.61
	2	–	16		
	3	–	3		
	4	–	8		
	5	–	10		
	6	–	31		
	7	–	62[1]		
	8	–	2		
	9	–	4		
	10	–	15		
3.75	1	–	10	10.4	7.38
	2	–	4		
	3	–	15		
	4	–	15		
	5	–	12		
	6	–	2		
	7	–	1		
	8	–	6		
	9	–	14		
	10	–	25		
7.50	1	–	18	6.7	6.65
	2	–	10		
	3	Large amount of uneaten food	0		
	4	–	6		
	5	–	5		
	6	Some uneaten food - foul odour.	0		
	7	Large amount of uneaten food	0		
	8	–	8		
	9	–	17		
	10	–	3		
15.0	1	Some uneaten food	1	2.3	2.11
	2	–	5		
	3	–	4		
	4	–	3		
	5	–	0		
	6	–	4		
	7	Some uneaten food - mild odour.	0		
	8	–	0		
	9	–	1		
	10	–	5		

•[1] Outlier according to Grubbs Test (CETIS)[a]. Outlying data points were not excluded from statistical analysis, since they could not be attributed to error.

Test Data Reviewed By : JL
Date : 2018-07-16

Work Order : 234749
Sample Number : 52860

SURVIVING JUVENILE WEIGHT DATA (DAY 56)

Analyst(s) : EJS, RD, CZN, CG, AS, JL, SEW

Concentration (µg/g)	Replicate	Number of Surviving Juveniles	Total Wet Weight of Juveniles (mg)	Total Dry Weight of Juveniles (mg)	Dry Weight per Juvenile (mg)	Average Dry Weight per Juvenile (mg)	Standard Deviation
Control	1	1	249.59	48.95	48.95	20.92	14.50
	2	32	1000.10	191.96	6.00		
	3	24	1157.48	203.09	8.46		
	4	5	798.36	140.08	28.02		
	5	42	920.52	181.84	4.33		
	6	30	1477.04	320.83	10.69		
	7	6	1031.12	210.09	35.02		
	8	10	831.54	156.36	15.64		
	9	3	447.90	69.03	23.01		
	10	4	534.62	116.53	29.13		
0.234	1	25	1703.72	341.75	13.67	29.90	30.45
	2	10	1267.96	238.67	23.87		
	3	29	1676.12	357.23	12.32		
	4	1	541.58	111.28	111.28[1]		
	5	42	1624.64	316.01	7.52		
	6	9	1633.08	301.78	33.53		
	7	11	1981.78	447.20	40.65		
	8	29	1620.02	296.70	10.23		
	9	12	1582.91	280.19	23.35		
	10	21	2113.81	474.24	22.58		
0.469	1	16	1778.85	364.71	22.79	26.10	21.61
	2	11	1265.41	276.00	25.09		
	3	36	1451.10	280.52	7.79		
	4	8	1117.15	242.44	30.31		
	5	36	1063.90	183.04	5.08		
	6	20	1207.79	235.44	11.77		
	7	5	2001.89	369.57	73.91		
	8	24	2110.13	441.37	18.39		
	9	25	1717.93	338.63	13.55		
	10	4	1025.53	209.23	52.31		
0.938	1	25	891.64	168.36	6.73	16.54	15.82
	2	2	519.49	114.63	57.32		
	3	9	1021.31	210.53	23.39		
	4	50	1680.28	257.93	5.16		
	5	68	1736.10	358.95	5.28		
	6	10	1064.75	227.29	22.73		
	7	16	1539.54	262.62	16.41		
	8	24	1323.66	248.94	10.37		
	9	30	1332.05	256.47	8.55		
	10	23	1157.75	218.25	9.49		
1.88	1	3	920.36	216.09	72.03	43.68	36.14
	2	16	1114.45	225.67	14.10		
	3	3	1231.21	255.16	85.05		
	4	8	1384.08	258.30	32.29		
	5	10	1262.44	248.90	24.89		
	6	31	2106.94	448.61	14.47		
	7	62	1420.89	263.28	4.25		
	8	2	909.27	223.46	111.73[1]		
	9	4	1072.13	236.03	59.01		
	10	15	1238.11	284.59	18.97		
3.75	1	10	1129.03	250.07	25.01	36.38	26.62
	2	4	1116.67	236.02	59.01		
	3	15	1300.66	280.33	18.69		
	4	15	1510.99	280.75	18.72		
	5	12	1134.92	226.32	18.86		
	6	2	846.22	157.09	78.55		
	7	1	387.36	83.20	83.20		
	8	6	811.98	135.45	22.58		
	9	14	1738.77	363.11	25.94		
	10	25	1460.52	331.87	13.27		
7.50	1	18	1491.65	297.02	16.50	24.78	21.43
	2	10	1980.25	449.09	44.91		
	3	0	–	–	0.00		
	4	6	1137.34	255.89	42.65		
	5	5	1142.88	232.43	46.49		
	6	0	–	–	0.00		
	7	0	–	–	0.00		
	8	8	888.91	165.59	20.70		
	9	17	1671.86	345.58	20.33		
	10	3	878.84	168.73	56.24		
15.0	1	1	68.25	9.15	9.15	10.81	9.05
	2	5	792.47	113.20	22.64		
	3	4	172.75	34.89	8.72		
	4	3	444.51	70.70	23.57		
	5	0	–	–	0.00		
	6	4	467.07	71.48	17.87		
	7	0	–	–	0.00		
	8	0	–	–	0.00		
	9	1	63.75	10.18	10.18		
	10	5	501.89	80.03	16.01		

• [1] Outlier according to Grubbs Test (CETIS)[a]. Outlying data points were not excluded from statistical analysis, since they could not be attributed to error.

Test Data Reviewed By : JL
Date : 2018-07-16

SOIL CHARACTERISTICS

Concentration (µg/g)	Initial pH[2]	Final pH[2]	Initial Conductivity[2] (µS/cm)	Final Conductivity[2] (µS/cm)	Initial Soil Moisture (% WHC)	Final Soil Moisture (% WHC)
Control	7.40	7.42	183	249	76	103
0.234	7.43	7.49	189	290	78	110
0.469	7.48	7.52	199	299	78	109
0.938	7.39	7.44	217	343	72	99
1.88	7.40	7.44	270	345	73	102
3.75	7.21	7.28	399	437	74	105
7.50	7.14	7.20	595	610	86	108
15.0	6.62	6.68	1089	996	82	112

[2] pH and conductivity were measured using a 2:1 water:soil slurry

ARTIFICIAL SOIL COMPOSITION[3]

Sand (%)	Silt (%)	Clay (%)	Organic Matter (mg/kg)	Organic Carbon (mg/kg)	Nitrogen (%)	Plant Available Phosphorus (µg/g dry)
76	3.8	21	27000	16000	0.080	150

[3] Analysis conducted by Maxxam Analytics, 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700

COMMENTS

Noted Deviation(s) : A reference toxicant test was not conducted in conjunction with this test, as required by the test method. The client has declined the option to include a positive control as part of the terrestrial testing.

•Statistical analyses for IC25 endpoints could not be conducted using Non-Linear Regression, since none of the available models were able to successfully describe the concentration - response relationships. Therefore, test results were calculated using Linear Interpolation (CETIS)[a]. Data for test concentrations where reproduction/growth was stimulated (greater than the control), data were replaced with the control values for the purposes of statistical analysis, as recommended by Environment Canada (2005).

•All test validity criteria as specified in the test method were satisfied.

DEFINITIONS

IC*x* : The concentration of test item estimated to cause x% inhibition compared to the Control.

LC50 : The concentration of test item estimated to cause mortality in 50% of the test organisms.

WHC : water-holding capacity of the soil

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Softwa LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Environment Canada, 2005. Guidance Document on Statistical Methods for Environmental Toxicity Tests. Environmental Protection Series, Ottawa, Ont., Rept. EPS 1/RM/46.

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Fax. (519) 763-4419

TOXICITY TEST REPORT

Alfalfa
EPS 1/RM/45

Work Order : 234748
Sample Number : 52859

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKBW7418V
Test Item :	Rhodium (1000 µg/mL Rh in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Initiation Date :	2018-02-13
Test Item Description :	Dark pink liquid	Completion Date :	2018-03-06

Test Method : Test for Measuring Emergence and Growth of Terrestrial Plants Exposed to Contaminants in Soil. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/45, February 2005 (with June 2007 amendments), with deviation(s) as noted.

21-DAY TEST RESULTS

Effect	Endpoint	Value	95% Confidence Limits	Inhibition (% of Control)	Significant Difference from Control?	Calculation Method
Emergence	EC50	>10.0 µg/g	–	4.08%	No (α= 0.05)	Fisher Exact Test [a]
Shoot Length	IC25	>10.0 µg/g	–	2.65%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]
Shoot Weight	IC25	>10.0 µg/g	–	3.04%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]
Root Length	IC25	>10.0 µg/g	–	-7.55%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]
Root Dry Weight	IC25	>10.0 µg/g	–	12.86%	No (α= 0.05)	Equal Variance t Two-Sample Test [a]

•A negative value for inhibition (%) indicates stimulation compared to the control.

Results are based on nominal concentrations of the test item (µg/g).
The results reported relate only to the item tested and as received.

TEST ORGANISM

Species :	*Medicago sativa*	Seed Variety :	N/A (tap-rooted, farm-saved)
Seed Source :	Mumm's Sprouting Seeds[1]	Lot Number :	A5L

No seeds exhibiting unusual appearance or undergoing unusual treatment were used in the test.

[1]Box 80, 118 1st Ave W, Parkside SK, S0J 2A0; 306-747-2935

TEST CONDITIONS

Test Type :	Static	Light Intensity (at soil surface) :	18340 - 19190 lux
Test Duration :	21 days	Photoperiod (light/dark) :	16 h / 8 h
Control/Test Soil :	Artificial Soil	Average Temperature (Range) :	23.9 °C (22 - 27 °C)
Sample Type :	Chemical-Spiked Soil	Emergence Observations :	Days 7 and 21
Samples per Treatment :	1	Shoot/Root Length Observations:	Day 21
Replicates per Treatment :	5	Shoot/Root Weight Observations:	Day 21
Number of Treatments :	1 + 1 (Negative) Control	Conductivity Measurements :	Days 0 and 21
Soil per Replicate :	~350 mL (dry)	pH Measurements :	Days 0 and 21
Seeds per Replicate :	10	Soil Moisture Determinations :	Days 0 and 21
Seeds per Treatment :	50	Test Method Deviations :	Yes (see 'Comments')

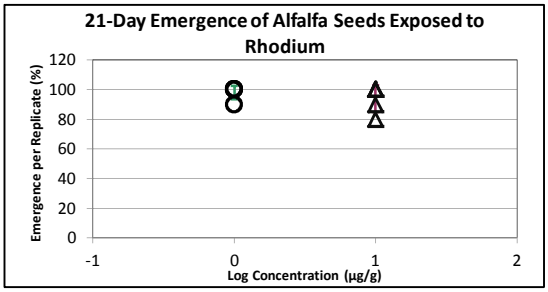
Date : 2019-03-08
yyyy-mm-dd

Approved By : _____
Project Manager

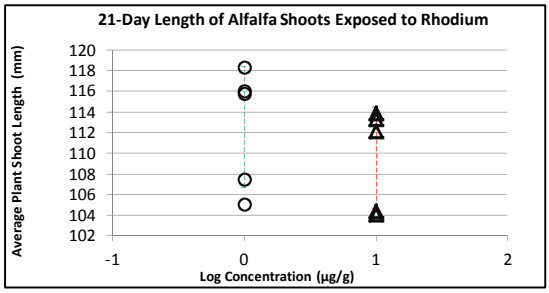
Work Order : 234748
Sample Number : 52859

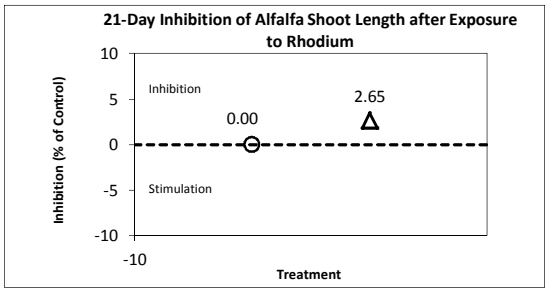
RESULTS (cont.)

EMERGENCE

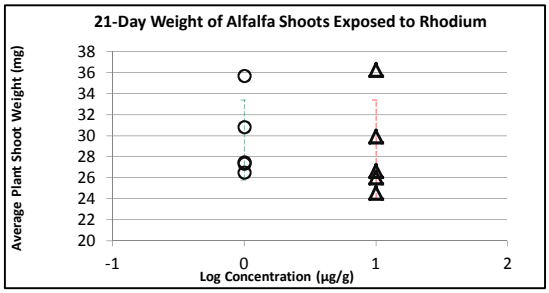


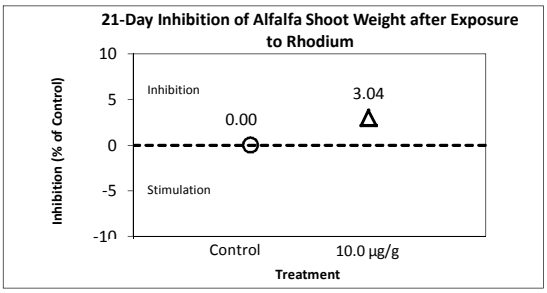
SHOOT LENGTH



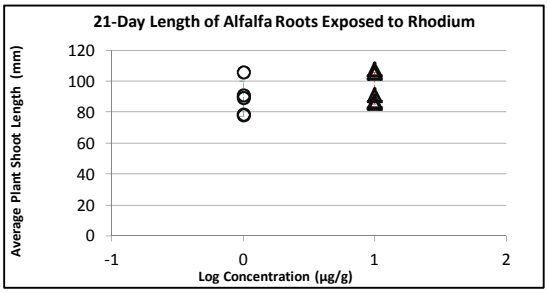


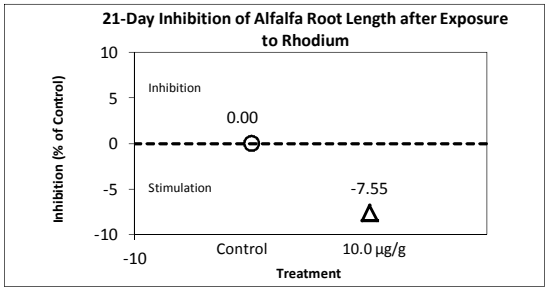
SHOOT WEIGHT



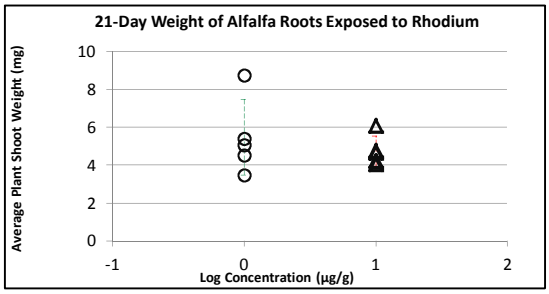


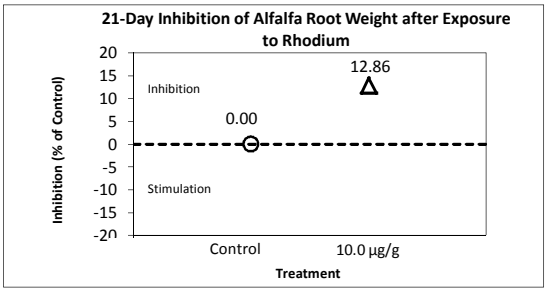
ROOT LENGTH





ROOT WEIGHT





•A negative value for inhibition (%) indicates stimulation compared to the control.

Work Order : 234748
Sample Number : 52859

PREPARATION OF TEST MEDIUM

Artificial Soil was formulated in the laboratory following procedures described in AquaTox SOP #364 (AquaTox, 2015c). The ingredients of Artificial Soil included 70% silica sand, 20% kaolinite clay, 10% Sphagnum spp. fine grind peat, and calcium carbonate ($CaCO_3$). The Artificial Soil was allowed to stabilize for a minimum of three days prior to test initiation.

Testing followed the general conditions of the cited test method. Solutions used for soil spiking were prepared without the use of any solubilizing agent. A 991 µg/L (nominal, w/v) stock solution was prepared by thoroughly mixing the test item with distilled water. Appropriate volumes of the stock solution were added to individual portions of Artificial Soil to achieve each desired nominal test concentration. The stock solution was added by pouring the solution over the soil surface. Each soil was mixed using a hand-held mechanical mixer for 10 minutes to ensure homogeneity. Additional distilled water was added to the each soil in order to achieve the required moisture content. The soil was then mixed with the hand-held mechanical mixer for 5 minutes. Once homogenized, the spiked soils were dispensed into the appropriate test vessels. Control treatments were prepared in the same manner, but without the addition of stock solution.

The exposure concentration was confirmed analytically, although test endpoints were generated using the nominal test concentration. The total Rh concentration was measured at test start, day 7, 14 and at test end (day 21). These results were provided separately to NWMO.

SOIL CHARACTERISTICS

Treatment	Initial pH[2]	Final pH[2]	Initial Conductivity[2] (µS/cm)	Final Conductivity[2] (µS/cm)	Initial Soil Moisture (% WHC)	Final Soil Moisture (% WHC)
Control	7.50	7.50	165	225	76	82
10.0 µg/g	6.82	6.77	855	817	79	94

[2] pH and conductivity were measured using a 2:1 water:soil slurry

ARTIFICIAL SOIL COMPOSITION[3]

Sand (%)	Silt (%)	Clay (%)	Organic Matter (mg/kg)	Organic Carbon (mg/kg)	Nitrogen (%)	Plant Available Phosphorus (µg/g dry)
76	3.8	21	27000	16000	0.080	150

[3] Analysis conducted by Maxxam Analytics, 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700

COMMENTS

Noted Deviation(s) :

•The Control organisms satisfied the emergence, survival, and the shoot length validity criteria; however, the validity criterion for root length was not satisfied. The Control did however pass the recommended root weight validity criterion. According to Environment and Climate Change Canada (the author of the standardized plant test method), the test validity criteria were established from tests that did not use a weak nutrient solution for watering. As a weak nutrient solution was used for watering, as is allowed by the method, we observed that the roots were more branched horizontally (i.e., filamentous). Since the roots had access to nutrients in the soil, the plants were able to direct growth to their shoots rather than the root length. This phenomenon is not atypical when a weak nutrient solution is applied and did not warrant repeating the test.

•A reference toxicant test was not conducted in conjunction with this test, as required by the test method. The client has declined the option to include a positive control as part of the terrestrial testing.

Work Order : 234748
Sample Number : 52859

EMERGENCE DATA - DAY 7

Treatment	Replicate	Emergence	Emergence (%)	Treatment Average	Standard Deviation	Notes	Analyst(s)
Control	1	10	100	98.00	4.47	Healthy	EJS
	2	10	100			Healthy	EJS
	3	10	100			Healthy	EJS
	4	9	90			Healthy	EJS
	5	10	100			Healthy	EJS
10.0 µg/g	1	8	80	94.00	8.94	Healthy	EJS
	2	10	100			Healthy	EJS
	3	10	100			Healthy	EJS
	4	9	90			Healthy	EJS
	5	10	100			Healthy	EJS

EMERGENCE DATA - DAY 21

Treatment	Replicate	Emergence	Emergence (%)	Treatment Average	SD	Notes	Analyst(s)
Control	1	10	100	98.00	4.47	Healthy, 1 very short plant	EJS
	2	10	100			Healthy	EJS
	3	10	100			Healthy	EJS
	4	9	90			Healthy	EJS
	5	10	100			Healthy	EJS
10.0 µg/g	1	8	80	94.00	8.94	Healthy	EJS
	2	10	100			Healthy	EJS
	3	10	100			Healthy	EJS
	4	9	90			Healthy	EJS
	5	10	100			Healthy	EJS

NOTES : 2018-03-06: Algal growth was observed in the soil in all replicates in all concentrations (EJS).

Test Data Reviewed By : JL
Date : 2018-06-14

Work Order : 234748
Sample Number : 52859

SHOOT AND ROOT LENGTH DATA - DAY 21

Treatment	Replicate	Plant	Shoot Length (mm)	Average Shoot Length per Plant (mm)	Treatment Average	Standard Deviation	Root Length (mm)	Treatment Average Root Length (mm)	Treatment Average	SD	Notes	Analyst(s)
Control	1	1	80	107.50	112.54	5.84	78	78.80	88.64	11.36	Healthy	CZN
		2	137				75				Healthy	
		3	221				130				Healthy	
		4	135				75				Healthy	
		5	145				115				Healthy	
		6	85				80				Healthy	
		7	134				98				Healthy	
		8	95				85				Healthy	
		9	24				45				Wilted/small	
		10	19				7				Wilted/chlorotic	
	2	1	138	118.30			131	89.20			Healthy	EJS
		2	161				121				Healthy	
		3	96				82				Healthy	
		4	80				78				Healthy	
		5	159				83				Healthy	
		6	205				143				Healthy	
		7	134				105				Healthy	
		8	91				37				Healthy	
		9	75				63				Healthy	
		10	44				49				Healthy	
	3	1	130	105.10			80	78.20			Healthy	CZN
		2	173				120				Healthy	
		3	172				85				Healthy	
		4	165				100				Healthy	
		5	85				80				Healthy	
		6	90				101				Healthy	
		7	48				70				Healthy	
		8	99				81				Healthy	
		9	53				39				Wilted	
		10	36				26				Wilted	
	4	1	158	116.00			116	106.11			Healthy	EJS
		2	132				121				Healthy	
		3	76				109				Healthy	
		4	72				130				Healthy	
		5	155				117				Healthy	
		6	186				123				Healthy	
		7	22				23				Healthy	
		8	99				88				Healthy	
		9	144				128				Healthy	
		10	–				–				–	
	5	1	165	115.80			127	90.90			Healthy	CZN
		2	123				110				Healthy	
		3	138				86				Healthy	
		4	87				91				Healthy	
		5	113				67				Healthy	
		6	92				57				Healthy	
		7	144				120				Healthy	
		8	109				94				Healthy	
		9	94				75				Healthy	
		10	93				82				Healthy	
10.0 µg/g	1	1	166	113.88	109.56	4.89	93	107.38	95.34	10.24	Healthy	EJS
		2	63				72				Healthy, leaves have chlorotic spots	
		3	147				79				Healthy	
		4	105				172				Healthy	
		5	139				137				Healthy	
		6	129				115				Healthy	
		7	90				118				Healthy	
		8	72				73				Healthy	
		9	–				–				–	
		10	–				–				–	
	2	1	179	104.40			131	91.00			Healthy	CZN
		2	166				112				Healthy	
		3	140				109				Healthy	
		4	116				91				Healthy	
		5	80				128				Healthy	
		6	111				103				Healthy	
		7	111				72				Healthy	
		8	59				40				Healthy	
		9	62				95				Healthy	
		10	20				29				Wilted	
	3	1	89	104.10			67	86.00			Healthy	EJS
		2	153				95				Healthy	
		3	108				89				Healthy	
		4	74				77				Healthy	
		5	138				90				Healthy	
		6	35				37				Healthy	
		7	78				74				Healthy	
		8	109				114				Healthy	
		9	105				63				Healthy	
		10	152				154				Healthy	
	4	1	145	112.11			90	87.00			Healthy	CZN
		2	112				86				Healthy	
		3	119				110				Healthy	
		4	107				97				Healthy	
		5	143				102				Healthy	
		6	150				85				Healthy	
		7	138				82				Healthy	
		8	47				83				Wilted	
		9	48				48				Wilted	
		10	–				–				–	
	5	1	140	113.30			118	105.30			Healthy	EJS
		2	118				101				Healthy	
		3	131				132				Healthy	
		4	93				39				Healthy	
		5	122				99				Healthy	
		6	123				161				Healthy	
		7	77				69				Healthy	
		8	93				132				Healthy	
		9	123				108				Healthy	
		10	113				94				Healthy	

•No outlying data points were detected according to Grubbs Test (CETIS).

Test Data Reviewed By : JL
Date : 2018-06-14

Work Order : 234748
Sample Number : 52859

SHOOT WEIGHT DATA - DAY 21

Treatment	Replicate	Weigh Boat (g)	Weigh Boat + Dry (g)	Dry Weight (mg)	Number of Plants	Dry Weight/Individual Plant (mg)	Treatment Average Weight (mg)	Standard Deviation
Control	1	0.9509	1.2258	274.9200	10	27.4920	29.5827	3.8155
	2	0.8469	1.1554	308.5000	10	30.8500		
	3	0.8663	1.1313	265.0300	10	26.5030		
	4	0.9196	1.2411	321.5400	9	35.7267		
	5	0.9675	1.2410	273.4200	10	27.3420		
10.0 µg/g	1	0.9289	1.1418	212.9400	8	26.6175	28.6848	4.6684
	2	0.9594	1.2588	299.3800	10	29.9380		
	3	0.8633	1.1092	245.8900	10	24.5890		
	4	0.8935	1.2198	326.3700	9	36.2633		
	5	0.9455	1.2057	260.1600	10	26.0160		

ROOT WEIGHT DATA - DAY 21

Treatment	Replicate	Weigh Boat (g)	Weigh Boat + Dry (g)	Dry Weight (mg)	Number of Plants	Dry Weight/Individual Plant (mg)	Treatment Average Weight (mg)	Standard Deviation
Control	1	1.2758	1.3211	45.2300	10	4.5230	5.4540	1.9947
	2	1.2759	1.3301	54.1900	10	5.4190		
	3	1.2726	1.3074	34.7600	10	3.4760		
	4	1.2889	1.3678	78.9300	9	8.7700[1]		
	5	1.2670	1.3178	50.8200	10	5.0820		
10.0 µg/g	1	1.2689	1.3062	37.2900	8	4.6613	4.7528	0.7953
	2	1.2763	1.3185	42.1500	10	4.2150		
	3	1.2894	1.3300	40.5800	10	4.0580		
	4	1.2713	1.3260	54.6800	9	6.0756		
	5	1.2724	1.3199	47.5400	10	4.7540		

• [1] Outlier according to Grubbs Test (CETIS[a]). Outlying data points were not excluded from statistical analysis, since they could not be attributed to error.

DEFINITIONS

IC*x* : The concentration of test item estimated to cause x% inhibition compared to the Control.
LC50 : The concentration of test item estimated to cause mortality in 50% of the test organisms.
WHC : Water-holding capacity of the soil.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Test Data Reviewed By : JL
Date : 2018-06-14

AquaTox Testing & Consulting Inc.
B-11 Nicholas Beaver Road
Puslinch, ON N0B 2J0
Tel. (519) 763-4412
Fax. (519) 763-4419

TOXICITY TEST REPORT
Barley
EPS 1/RM/45
REVISION 1

Work Order : 234748
Sample Number : 52859

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKBW7418V
Test Item :	Rhodium (1000 µg/mL Rh in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Initiation Date :	2018-02-13
Test Item Description :	Dark pink liquid	Completion Date :	2018-02-27
Test Method :	Test for Measuring Emergence and Growth of Terrestrial Plants Exposed to Contaminants in Soil. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/45, February 2005 (with June 2007 amendments), with deviation(s) as noted.		

14-DAY TEST RESULTS

Effect	Endpoint	Value	95% Confidence Limits	Calculation Method
Emergence	EC50	>20.0 µg/g	–	–
Shoot Length	IC25	>20.0 µg/g	–	–
Shoot Weight	IC25	>20.0 µg/g	–	–
Root Length	IC25	7.30 µg/g	5.55 - 9.18 µg/g	Non-Linear Regression[a,b]
Root Dry Weight	IC25	>20.0 µg/g	–	Non-Linear Regression[a]

Results are based on nominal concentrations of the test item (µg/g).
The results reported relate only to the item tested and as received.

[b]The model was a 2P exponential: $\mu=\alpha\cdot\exp[\log[0.5]\cdot x/\delta]$ where α= 256.9 and δ=17.59.

TEST ORGANISM

Species :	*Hordeum vulgare*	Seed Variety :	Dignity
Seed Source :	Rosebank Seed Farms Ltd.[1]	Lot Number :	Spring Six Row - Home Back

No seeds exhibiting unusual appearance or undergoing unusual treatment were used in the test.

[1]7340 Perth Line 24, RR #2, Staffa ON, CA N0K 1Y0

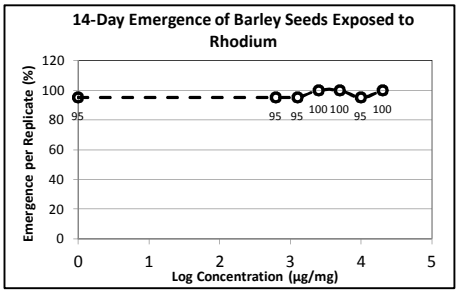
TEST CONDITIONS

Test Type :	Static	Light Intensity (at soil surface) :	17860 - 18480 lux
Test Duration :	14 days	Photoperiod (light/dark) :	16 h / 8 h
Control/Test Soil :	Artificial Soil	Average Temperature (Range) :	23.9 °C (22 - 26 °C)
Sample Type :	Chemical-Spiked Soil	Emergence Observations :	Days 7 and 14
Samples per Treatment :	1	Shoot/Root Length Observations:	Day 14
Replicates per Treatment :	4	Shoot/Root Weight Observations:	Day 14
Number of Treatments :	6 + 1 (Negative) Control	Conductivity Measurements :	Days 0 and 14
Soil per Replicate :	~350 mL (dry)	pH Measurements :	Days 0 and 14
Seeds per Replicate :	5	Soil Moisture Determinations :	Days 0 and 14
Seeds per Treatment :	20	Test Method Deviations :	Yes (see 'Comments')

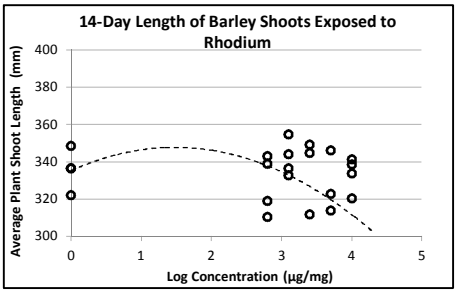
Work Order : 234748
Sample Number : 52859

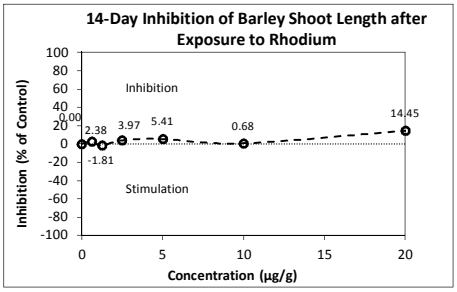
RESULTS (cont.)

EMERGENCE

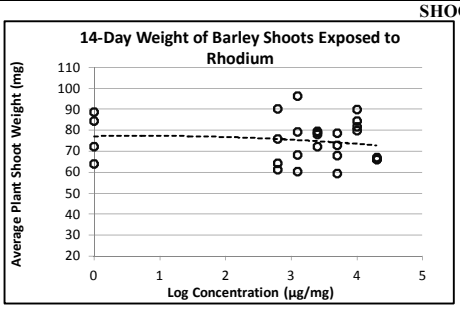


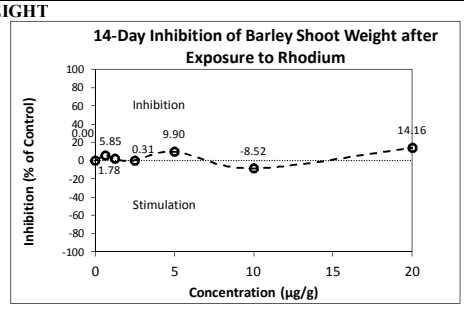
SHOOT LENGTH



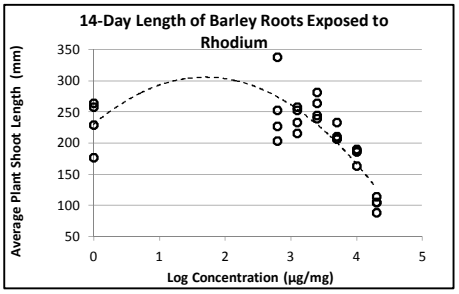


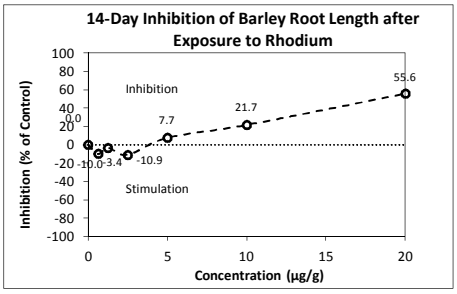
SHOOT WEIGHT



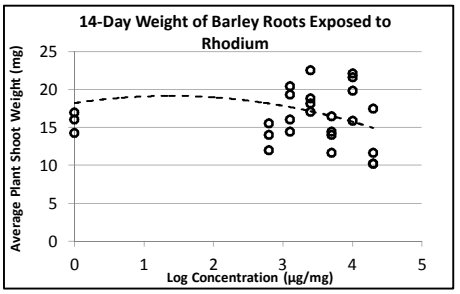


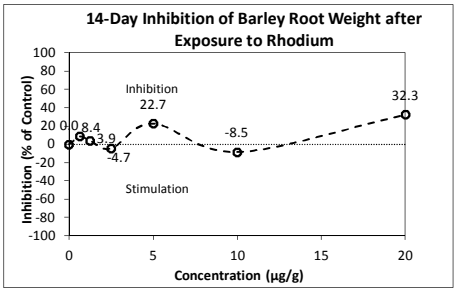
ROOT LENGTH





ROOT WEIGHT





•A negative value for inhibition (%) indicates stimulation compared to the control.

Work Order : 234748
Sample Number : 52859

PREPARATION OF TEST MEDIUM

Artificial Soil was formulated in the laboratory following procedures described in AquaTox SOP #364 (AquaTox, 2015c). The ingredients of Artificial Soil included 70% silica sand, 20% kaolinite clay, 10% Sphagnum spp. fine grind peat, and calcium carbonate ($CaCO_3$). The Artificial Soil was allowed to stabilize for a minimum of three days prior to test initiation.

Testing followed the general conditions of the cited test method. Solutions used for soil spiking were prepared without the use of any solubilizing agent. A 991 µg/L (nominal, w/v) stock solution was prepared by thoroughly mixing the test item with distilled water. Appropriate volumes of the stock solution were added to individual portions of Artificial Soil to achieve each desired nominal test concentration. The stock solution was added by pouring the solution over the soil surface. Each soil was mixed using a hand-held mechanical mixer for 10 minutes to ensure homogeneity. Additional distilled water was added to the each soil in order to achieve the required moisture content. The soil was then mixed with the hand-held mechanical mixer for 5 minutes. Once homogenized, the spiked soils were dispensed into the appropriate test vessels. Contrc treatments were prepared in the same manner, but without the addition of stock solution.

The lowest, middle and highest exposure concentrations were confirmed analytically, although test endpoints were generated using nominal test concentrations. The total Rh concentrations were measured at test start, day 7 and at test end (day 14). These results were provided separately to NWMO.

SOIL CHARACTERISTICS

Concentration (µg/g)	Initial pH[1]	Final pH[1]	Initial Conductivity[1] (µS/cm)	Final Conductivity[1] (µS/cm)	Initial Soil Moisture (% WHC)	Final Soil Moisture (% WHC)
0.00	7.59	6.88	139	247	80	91
0.625	7.41	6.97	185	219	76	73
1.25	7.30	6.78	211	244	77	82
2.50	7.07	6.59	293	304	79	78
5.00	6.73	6.50	449	426	80	83
10.0	6.08	6.05	768	668	80	85
20.0	5.26	5.44	1364	1350	87	91

[1] pH and conductivity were measured using a 2:1 water:soil slurry

ARTIFICIAL SOIL COMPOSITION [2]

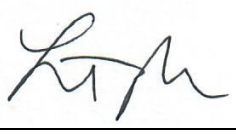
Sand (%)	Silt (%)	Clay (%)	Organic Matter (mg/kg)	Organic Carbon (mg/kg)	Nitrogen (%)	Plant Available Phosphoru (µg/g dry)
76	3.8	21	27000	16000	0.080	150

[2] Analysis conducted by Maxxam Analytics, 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700

COMMENTS

Noted Deviation(s) : •A reference toxicant test was not conducted in conjunction with this test, as required by the test method. The client has declined the option to include a positive control as part of the terrestrial testing.

Date : 2019-03-08 *yyyy-mm-dd*

Approved By :  *Project Manager*

Work Order : 234748
Sample Number : 52859

EMERGENCE DATA - DAY 7

Concentration (µg/g)	Replicate	Emergence	Emergence (%)	Treatment Average (%)	Standard Deviation	Notes	Analyst(s)
Control	1	5	100	95.00	10.00	Healthy	EJS
	2	4	80			Healthy	EJS
	3	5	100			Healthy	EJS
	4	5	100			Healthy	EJS
0.625	1	5	100	95.00	10.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	5	100			Healthy	EJS
	4	4	80			3 plants healthy, 1 plant bent over, slightly chlorotic.	EJS
1.25	1	5	100	95.00	10.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	4	80			Healthy	EJS
	4	5	100			Healthy	EJS
2.50	1	5	100	95.00	10.00	Healthy	EJS
	2	5	100			Healthy, 1 short plant	EJS
	3	5	100			Healthy	EJS
	4	4	80			Healthy	EJS
5.00	1	5	100	100.00	0.00	Healthy, 1 short plant	EJS
	2	5	100			4 healthy, 1 short (10mm) and chlorotic.	EJS
	3	5	100			Healthy, 1 short plant	EJS
	4	5	100			Healthy	EJS
10.0	1	5	100	95.00	10.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	5	100			Healthy, 1 short plant	EJS
	4	4	80			Healthy	EJS
20.0	1	5	100	95.00	10.00	Healthy	EJS
	2	4	80			Healthy	EJS
	3	5	100			Healthy	EJS
	4	5	100			3 plants healthy, 2 plants short, 1 of the 2 short plants has a torn stem with some chlorosis.	EJS

EMERGENCE DATA - DAY 14

Concentration	Replicate	Emergence	Emergence	Treatment	SD	Notes	Analyst(s)
Control	1	5	100	95.00	10.00	Healthy	EJS
	2	4	80			Healthy	EJS
	3	5	100			Healthy	EJS
	4	5	100			Healthy	EJS
0.625	1	5	100	95.00	10.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	5	100			Healthy	EJS
	4	4	80			Healthy	EJS
1.25	1	5	100	95.00	10.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	4	80			Healthy	EJS
	4	5	100			Healthy	EJS
2.50	1	5	100	100.00	0.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	5	100			Healthy	EJS
	4	5	100			1 plant bent over, very short, the rest are healthy	EJS
5.00	1	5	100	100.00	0.00	Healthy	EJS
	2	5	100			Healthy, 1 short plant	EJS
	3	5	100			Healthy	EJS
	4	5	100			Healthy	EJS
10.0	1	5	100	95.00	10.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	5	100			Healthy	EJS
	4	4	80			Healthy	EJS
20.0	1	5	100	100.00	0.00	Healthy	EJS
	2	5	100			Healthy	EJS
	3	5	100			Healthy	EJS
	4	5	100			Healthy	EJS

•No outlying data points were detected according to Grubbs Test (CETIS®).

Test Data Reviewed By : JL
Date : 2019-03-07

Work Order : 234748
Sample Number : 52859

SHOOT AND ROOT LENGTH DATA - DAY 14

Concentration (µg/g)	Replicate	Average Shoot Length per Plant (mm)	Treatment Average Shoot Length (mm)	Standard Deviation	Average Root Length (mm)	Treatment Average Root Length (mm)	Standard Deviation	Notes	Analyst(s)
Control	1	322.00	335.88	10.88	264.40	232.10	39.78	–	CZN
	2	336.50			177.00[3]			–	CZN
	3	348.60			229.20			–	CZN
	4	336.40			257.80			–	CZN
0.625	1	338.80	327.88	15.65	202.80	255.25	58.98	–	CZN
	2	319.00			338.20[3]			–	CZN
	3	343.20			253.00			–	CZN
	4	310.50			227.00			–	CZN
1.250	1	332.60	341.95	9.79	257.80	239.89	19.35	–	CN
	2	354.80			253.00			–	CN
	3	344.00			215.75			Healthy	EJS/CG
	4	336.40			233.00			Healthy	CG
2.50	1	344.60	322.55	30.29	244.40	257.45	19.30	–	CZN
	2	311.80			239.60			–	CZN
	3	349.20			281.60			–	CN
	4	284.60			264.20			Plant #5 shoot is chlorotic and wilting.	CZN
5.00	1	313.80	317.70	23.89	207.00	214.30	12.71	Healthy	CG
	2	288.20			206.60			Plant #4 appears limp and wilted.	EJS
	3	322.80			210.40			Healthy	CG
	4	346.00			233.20			Healthy	EJS
10.0	1	341.40	333.59	9.34	186.20	181.68	12.41	Healthy	CG
	2	320.40			163.20			Plant #1 is healthy, but 1 leaf has necrotic tip	EJS
	3	333.80			189.80			Healthy	CG
	4	338.75			187.50			Healthy	EJS
20.0	1	291.60	287.35	5.52	113.60	103.10	10.46	–	CZN
	2	283.20			105.00			Plant #5 has partial necrosis of shoot (~50%)	CG
	3	292.60			105.20			Healthy	EJS
	4	282.00			88.60			Healthy	EJS

[3]Outlier according to Grubbs Test (CETIS)[a]. Outlying data points were not excluded from statistical analysis, since they could not be attributed to error.

Test Data Reviewed By : JL
Date : 2019-03-07

Work Order : 234748
Sample Number : 52859

SHOOT WEIGHT DATA - DAY 14

Concentration (µg/g)	Replicate	Weigh Boat (g)	Weigh Boat + Dry (g)	Dry Weight (mg)	Number of Plants	Dry Weight/Individual Plant (mg)	Treatment Average Weight (mg)	Standard Deviation
Control	1	0.9558	1.2758	319.98	5	63.9960	77.39	11.34
	2	0.9410	1.2790	337.97	4	84.4925		
	3	0.9430	1.3868	443.87	5	88.7740		
	4	0.9205	1.2819	361.43	5	72.2860		
0.625	1	0.9608	1.4120	451.22	5	90.2440	72.86	13.22
	2	0.9265	1.2320	305.53	5	61.1060		
	3	0.9509	1.2720	321.11	5	64.2220		
	4	0.9114	1.2148	303.42	4	75.8550		
1.250	1	0.9206	1.2623	341.74	5	68.3480	76.01	15.51
	2	0.9589	1.3543	395.43	5	79.0860		
	3	0.9306	1.3155	384.95	4	96.2375		
	4	0.9590	1.2609	301.83	5	60.3660		
2.50	1	0.9310	1.3204	389.33	5	77.8660	77.15	3.37
	2	0.9568	1.3540	397.23	5	79.4460		
	3	0.9229	1.3182	395.36	5	79.0720		
	4	0.9566	1.3176	360.99	5	72.1980		
5.00	1	0.9386	1.3031	364.54	5	72.9080	69.72	8.09
	2	0.9753	1.3155	340.17	5	68.0340		
	3	0.9348	1.2320	297.11	5	59.4220		
	4	0.9634	1.3560	392.62	5	78.5240		
10.0	1	0.9662	1.3751	408.86	5	81.7720	83.98	4.43
	2	0.9250	1.3752	450.14	5	90.0280		
	3	0.9582	1.3573	399.06	5	79.8120		
	4	0.9239	1.2612	337.29	4	84.3225		
20.0	1	0.9157	1.2466	330.96	5	66.1920	66.43	0.47
	2	0.9535	1.2849	331.44	5	66.2880		
	3	0.9224	1.2580	335.65	5	67.1300		
	4	0.9550	1.2856	330.57	5	66.1140		

•No outlying data points were detected according to Grubbs Test (CETIS®).

Test Data Reviewed By : JL
Date : 2019-03-07

Work Order : 234748
Sample Number : 52859

ROOT WEIGHT DATA - DAY 14

Concentration (µg/g)	Replicate	Weigh Boat (g)	Weigh Boat + Dry (g)	Dry Weight (mg)	Number of Plants	Dry Weight/Individual Plant (mg)	Treatment Average Weight (mg)	Standard Deviation
Control	1	1.2672	1.3387	71.49	5	14.2980	18.3236	5.2099
	2	1.2756	1.3436	67.93	4	16.9825		
	3	1.2763	1.4061	129.79	5	25.9580		
	4	1.2823	1.3625	80.28	5	16.0560		
0.625	1	1.2755	1.4034	127.95	5	25.5900	16.7789	6.0483
	2	1.2729	1.3505	77.62	5	15.5240		
	3	1.2680	1.3280	60.02	5	12.0040		
	4	1.3096	1.3655	55.99	4	13.9975		
1.25	1	1.2824	1.3627	80.26	5	16.0520	17.6050	2.8041
	2	1.2690	1.3715	102.43	5	20.4860		
	3	1.2864	1.3640	77.56	4	19.3900		
	4	1.2973	1.3698	72.46	5	14.4920		
2.50	1	1.2816	1.3671	85.58	5	17.1160	19.1910	2.3686
	2	1.2682	1.3592	91.01	5	18.2020		
	3	1.2803	1.3932	112.87	5	22.5740		
	4	1.2777	1.3720	94.36	5	18.8720		
5.00	1	1.2789	1.3510	72.09	5	14.4180	14.1725	1.9917
	2	1.2781	1.3364	58.33	5	11.6660		
	3	1.2711	1.3415	70.39	5	14.0780		
	4	1.2907	1.3734	82.64	5	16.5280		
10.0	1	1.3218	1.4300	108.18	5	21.6360	19.8874	2.8456
	2	1.2799	1.3907	110.79	5	22.1580		
	3	1.2780	1.3774	99.39	5	19.8780		
	4	1.2941	1.3576	63.51	4	15.8775		
20.0	1	1.2813	1.3689	87.58	5	17.5160	12.4055	3.4730
	2	1.2804	1.3386	58.27	5	11.6540		
	3	1.2713	1.3226	51.30	5	10.2600		
	4	1.2805	1.3315	50.96	5	10.1920		

•No outlying data points were detected according to Grubbs Test (CETIS)[a].

DEFINITIONS

IC*x* : The concentration of test item estimated to cause x% inhibition compared to the Control.
EC50 : The concentration of test item estimated to show an effect in 50% of the test organisms.
WHC : Water-holding capacity of the soil.

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Test Data Reviewed By : JL
Date : 2019-03-07

AquaTox Testing & Consulting Inc.
B-11 Nicholas Beaver Road
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Tel. (519) 763-4412
Fax. (519) 763-4419

TOXICITY TEST REPORT

Eisenia andrei
EPS 1/RM/43

Work Order : 234748
Sample Number : 52859

SAMPLE IDENTIFICATION

Company :	NWMO - Nuclear Waste Management Organization	Supplier :	Sigma-Aldrich®
Location :	Toronto ON	Chemical Batch :	MKBW7418V
Test Item :	Rhodium (1000 µg/mL Rh in 5% HCl)	Date Received :	2017-11-03
Test Item Type :	Chemical	Time Received :	Not recorded
Storage Temperature :	Ambient room temp.	Date Initiated :	2018-01-19
Test Item Description :	Dark pink liquid	Date Completed :	2018-03-16

Test Method : Tests for Toxicity of Contaminated Soil to Earthworms (*Eisenia andrei* , *Eisenia fetida* , or *Lumbricus terrestris*). Report EPS 1/RM/43, June 2004 with June 2007 amendments, with deviation(s) as noted.

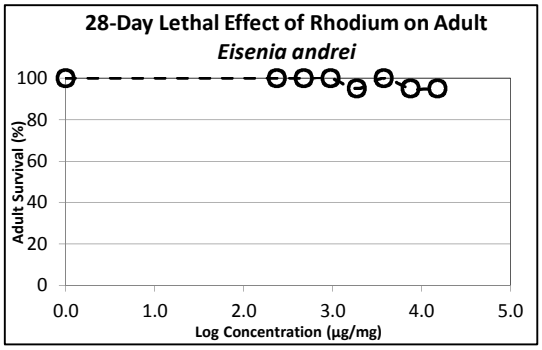
TEST RESULTS

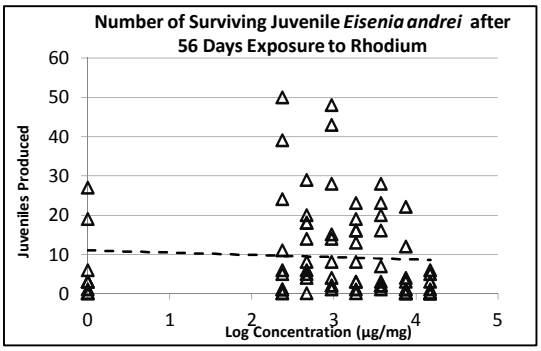
Effect	Endpoint	Value	95% Confidence Limits	Calculation Method
Survival	28-day LC50	>15.0 µg/g	–	–
Reproductive Success	56-day IC25	6.64 µg/g	0.124* - 9.66 µg/g	Linear Interpolation (CETIS)[a]
Growth	56-day IC25	<0.234 µg/g	–	Linear Interpolation (CETIS)[a]

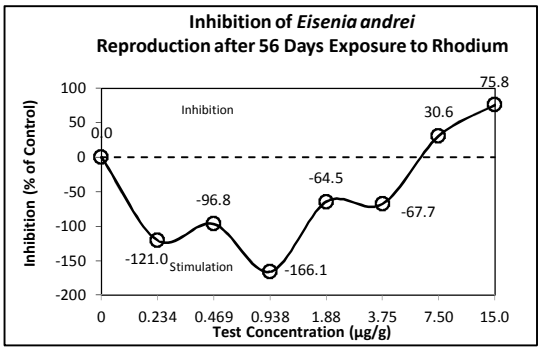
*The lower 95% confidence limit is less than the lowest concentration tested.

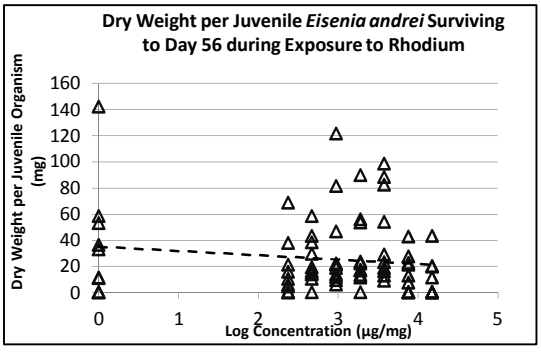
Results are based on nominal concentrations of the test item (µg/g).

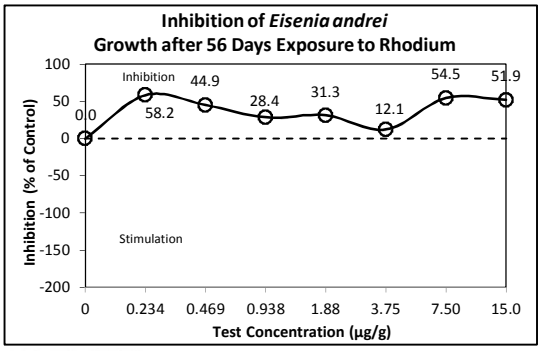
The results reported relate only to the item tested and as received.











Date : 2019-03-08
yyyy-mm-dd

Approved By : _____
Project Manager

Work Order : 234748
Sample Number : 52859

TEST ORGANISM

Test Organism :	*Eisenia andrei*
Culture Origin :	Environment Canada (Ottawa, ON)
Test Organism Source :	In-house culture
Average Wet Weight (±SD) :	440.2 mg (± 62.9) at start of test

•No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

TEST CONDITIONS

Test Type :	Prolonged exposure (static)	Soil Type :	Artificial Soil
Test Duration :	56 days	Test Chamber :	500 mL glass jar
Number of Treatments :	7 + 1 Control	Test Chamber Covering :	Perforated cover
Discrete Samples per Treatment :	1	Soil per Replicate :	270 g wet weight
Replicates per Treatment :	10	Test Temperature :	20 ± 2 °C
Test Organisms per Replicate :	2	Test Photoperiod :	16 h light : 8 h dark
Test Organisms per Treatment :	20	Light Quality :	Cool white fluorescent
Test/Dilution/Misting Water :	Autoclaved dilution water	Test Method Deviation(s) :	Yes (see 'Comments')

FOOD PREPARATION AND FEEDING

Date	Test Day	Food Type	Ration (per Replicate)
2018-01-19	0	Un-cooked oatmeal + Magic® Worm Food	~4 mL
2018-02-02	14	Un-cooked oatmeal + Magic® Worm Food	~4 mL
2018-02-16	28	Un-cooked oatmeal + Magic® Worm Food	~4 mL
2018-03-02	42	Un-cooked oatmeal + Magic® Worm Food	~4 mL

For each feeding event, a fresh batch of food was prepared. Dry un-cooked oatmeal (250 mL) was mixed thoroughly with 75 mL of Magic® Worm Food. The food mixture was added to each test replicate, and hydrated by spraying 10 times with distilled water.

PREPARATION OF TEST MEDIUM

Artificial Soil was formulated in the laboratory following procedures described in AquaTox SOP #364 (AquaTox, 2015c). The ingredients of Artificial Soil included 70% silica sand, 20% kaolinite clay, 10% Sphagnum spp. fine grind peat, and calcium carbonate ($CaCO_3$). The Artificial Soil was allowed to stabilize for a minimum of three days prior to test initiation.

Testing followed the general conditions of the cited test method. Solutions used for soil spiking were prepared without the use of any solubilizing agent. A 991 µg/L (nominal, w/v) stock solution was prepared by thoroughly mixing the test item with distilled water. Appropriate volumes of the stock solution were added to individual portions of Artificial Soil to achieve each desired nominal test concentration. The stock solution was added by pouring the solution over the soil surface. Each soil was mixed using a hand-held mechanical mixer for 10 minutes to ensure homogeneity. Additional distilled water was added to the each soil in order to achieve the required moisture content. The soil was then mixed with the hand-held mechanical mixer for 5 minutes. Once homogenized, the spiked soils were dispensed into the appropriate test vessels. Control treatments were prepared in the same manner, but without the addition of stock solution.

The lowest, middle and highest exposure concentrations were confirmed analytically, although test endpoints were generated using nominal test concentrations. The total Rh concentrations were measured at test start, day 14, 28, 42 and at test end (day 56). These results were provided separately to NWMO.

Work Order : 234748
Sample Number : 52859

ADULT SURVIVAL (DAY 28)

Date : 2018-02-16
Analyst(s) : EJS, RD, AS

Concentration (µg/g)	Replicate	Number of Live Adults	Number of Healthy Adults	Comments	Adult Survival (%)	Average Survival (%)	Standard Deviation
Control	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	One test organism only slightly clitellatec	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
0.234	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
0.469	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
0.938	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
1.88	1	1	1	–	50	95	15.81
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
3.75	1	2	2	–	100	100	0.00
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	Test organisms mating	100		
	6	2	2	–	100		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
7.50	1	2	2	–	100	95	15.81
	2	2	2	–	100		
	3	2	2	–	100		
	4	2	2	–	100		
	5	2	2	–	100		
	6	1	1	–	50		
	7	2	2	–	100		
	8	2	2	–	100		
	9	2	2	–	100		
	10	2	2	–	100		
15.0	1	2	2	One test organism partially discoloured	100	95	15.81
	2	2	2	–	100		
	3	2	2	One test organism discoloured	100		
	4	1	1	–	50		
	5	2	0	Test organisms lethargic	100		
	6	2	0	Test organisms pale and lethargic	100		
	7	2	2	–	100		
	8	2	0	Test organisms lethargic	100		
	9	2	0	Test organisms lethargic	100		
	10	2	0	Test organisms lethargic	100		

Test Data Reviewed By : JL
Date : 2018-06-27

Work Order : 234748
Sample Number : 52859

SURVIVING JUVENILES (DAY 56)

Date : 2018-03-16
Analyst(s) : EJS, MR, RD, AS, CG, CZN

Concentration (µg/g)	Replicate	Comments	Surviving Juveniles	Average Surviving Juveniles	Standard Deviation
Control	1	–	3	6.2	9.25
	2	–	3		
	3	–	0		
	4	–	27		
	5	–	0		
	6	–	0		
	7	–	19		
	8	–	3		
	9	–	6		
	10	–	1		
0.234	1	–	11	13.7	17.96
	2	–	0		
	3	Large amount of uneaten food	1		
	4	–	0		
	5	–	50[1]		
	6	Many very small juvenile:	39		
	7	Large amount of uneaten food	5		
	8	–	24		
	9	–	1		
	10	–	6		
0.469	1	–	6	12.2	9.05
	2	–	29		
	3	–	0		
	4	–	18		
	5	–	5		
	6	–	20		
	7	–	8		
	8	–	4		
	9	–	14		
	10	–	18		
0.938	1	Large amount of uneaten food	4	16.5	17.40
	2	–	2		
	3	–	48		
	4	Large amount of uneaten food	1		
	5	–	43		
	6	–	14		
	7	–	2		
	8	–	28		
	9	–	15		
	10	–	8		
1.88	1	Large amount of uneaten food	3	10.2	8.26
	2	–	16		
	3	–	19		
	4	–	3		
	5	–	23		
	6	–	8		
	7	–	13		
	8	–	16		
	9	–	0		
	10	–	1		
3.75	1	–	16	10.4	10.32
	2	–	2		
	3	–	3		
	4	–	1		
	5	–	2		
	6	–	23		
	7	–	7		
	8	–	28		
	9	–	20		
	10	–	2		
7.50	1	–	22	4.3	7.23
	2	–	0		
	3	–	4		
	4	–	0		
	5	–	0		
	6	Large amount of uneaten food	0		
	7	–	1		
	8	–	3		
	9	–	1		
	10	–	12		
15.0	1	–	0	1.5	2.32
	2	–	1		
	3	–	0		
	4	–	0		
	5	–	3		
	6	–	6		
	7	–	5		
	8	–	0		
	9	–	0		
	10	–	0		

•[1] Outlier according to Grubbs Test (CETIS)[a]. Outlying data points were not excluded from statistical analysis, since they could not be attributed to error.

Test Data Reviewed By : JL
Date : 2018-06-27

Work Order : 234748
Sample Number : 52859

SURVIVING JUVENILE WEIGHT DATA (DAY 56)

Analyst(s) : EJS, MR, RD, AS, CZN, CG

Concentration (µg/g)	Replicate	Number of Surviving Juveniles	Total Wet Weight of Juveniles (mg)	Total Dry Weight of Juveniles (mg)	Dry Weight per Juvenile (mg)	Average Dry Weight per Juvenile (mg)	Standard Deviation
Control	1	3	753.45	158.85	52.95	49.28	44.71
	2	3	535.61	109.17	36.39		
	3	0	–	–	–		
	4	27	1558.33	310.77	11.51		
	5	0	–	–	–		
	6	0	–	–	–		
	7	19	1052.35	209.41	11.02		
	8	3	813.68	175.60	58.53		
	9	6	1113.88	196.50	32.75		
	10	1	702.78	141.82	141.82[1]		
0.234	1	11	814.16	171.96	15.63	20.61	22.66
	2	0	–	–	–		
	3	1	2.07	0.42	0.42		
	4	0	–	–	–		
	5	50	1164.83	241.79	4.84		
	6	39	1287.21	245.49	6.29		
	7	5	529.65	105.69	21.14		
	8	24	1163.48	246.13	10.26		
	9	1	368.49	68.67	68.67		
	10	6	1046.45	225.93	37.66		
0.469	1	6	1033.96	230.34	38.39	27.15	16.38
	2	29	1549.20	305.47	10.53		
	3	0	–	–	–		
	4	18	1467.19	267.24	14.85		
	5	5	828.35	215.11	43.02		
	6	20	1569.48	328.90	16.45		
	7	8	1171.86	235.87	29.48		
	8	4	1258.45	233.88	58.47		
	9	14	1421.39	269.46	19.25		
	10	18	1241.72	249.82	13.88		
0.938	1	4	454.24	84.86	21.22	35.31	37.77
	2	2	513.16	93.30	46.65		
	3	48	1434.94	293.04	6.11		
	4	1	612.75	121.40	121.4[1]		
	5	43	2014.42	419.01	9.74		
	6	14	1226.28	260.28	18.59		
	7	2	819.00	162.92	81.46		
	8	28	1556.28	331.48	11.84		
	9	15	1495.97	335.24	22.35		
	10	8	838.38	109.90	13.74		
1.88	1	3	792.70	168.01	56.00	33.85	26.60
	2	16	1343.10	266.83	16.68		
	3	19	1231.30	259.04	13.63		
	4	3	903.98	160.45	53.48		
	5	23	1484.65	269.29	11.71		
	6	8	1004.72	191.42	23.93		
	7	13	1009.96	228.27	17.56		
	8	16	1811.02	355.81	22.24		
	9	0	–	–	–		
	10	1	429.23	89.45	89.45		
3.75	1	16	1892.43	299.26	18.70	43.31	34.54
	2	2	322.02	58.30	29.15		
	3	3	880.75	161.98	53.99		
	4	1	486.45	82.58	82.58		
	5	2	123.22	176.49	88.25		
	6	23	1628.51	301.56	13.11		
	7	7	740.40	164.02	23.43		
	8	28	1249.57	250.96	8.96		
	9	20	1629.46	328.21	16.41		
	10	2	1021.09	196.96	98.48		
7.50	1	22	1433.68	281.31	12.79	22.43	12.25
	2	0	–	–	–		
	3	4	834.66	170.93	42.73		
	4	0	–	–	–		
	5	0	–	–	–		
	6	0	–	–	–		
	7	1	105.50	21.08	21.08		
	8	3	459.83	82.96	27.65		
	9	1	63.46	7.72	7.72		
	10	12	1337.02	271.12	22.59		
15.0	1	0	–	–	–	23.69	13.73
	2	1	273.46	43.44	43.44		
	3	0	–	–	–		
	4	0	–	–	–		
	5	3	295.98	60.51	20.17		
	6	6	344.60	69.60	11.60		
	7	5	564.03	97.79	19.56		
	8	0	–	–	–		
	9	0	–	–	–		
	10	0	–	–	–		

• [1] Outlier according to Grubbs Test (CETIS)[a]. Outlying data points were not excluded from statistical analysis, since they could not be attributed to error.

Test Data Reviewed By : JL
Date : 2018-06-27

SOIL CHARACTERISTICS

Concentration (µg/g)	Initial pH[2]	Final pH[2]	Initial Conductivity[2] (µS/cm)	Final Conductivity[2] (µS/cm)	Initial Soil Moisture (% WHC)	Final Soil Moisture (% WHC)
Control	7.62	7.19	237	454	76	90
0.234	7.58	7.09	203	512	77	90
0.469	7.55	7.11	216	471	76	93
0.938	7.52	7.08	244	536	78	85
1.88	7.48	7.27	306	604	75	87
3.75	7.32	7.13	427	721	77	83
7.50	7.14	6.84	672	940	78	76
15.0	6.84	6.48	1116	1535	81	82

[2] pH and conductivity were measured using a 2:1 water:soil slurry

ARTIFICIAL SOIL COMPOSITION[3]

Sand (%)	Silt (%)	Clay (%)	Organic Matter (mg/kg)	Organic Carbon (mg/kg)	Nitrogen (%)	Plant Available Phosphorus (µg/g dry)
76	3.8	21	27000	16000	0.080	150

[3] Analysis conducted by Maxxam Analytics, 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700

COMMENTS

Noted Deviation(s) : A reference toxicant test was not conducted in conjunction with this test, as required by the test method. The client has declined the option to include a positive control as part of the terrestrial testing.

•Statistical analyses for IC25 endpoints could not be conducted using Non-Linear Regression, since none of the available models were able to successfully describe the concentration - response relationships. Therefore, test results were calculated using Linear Interpolation (CETIS)[a]. Data for test concentrations where reproduction/growth was stimulated (greater than the control), data were replaced with the control values for the purposes of statistical analysis, as recommended by Environment Canada (2005).

•All test validity criteria as specified in the test method were satisfied.

DEFINITIONS

IC*x* : The concentration of test item estimated to cause x% inhibition compared to the Control.

LC50 : The concentration of test item estimated to cause mortality in 50% of the test organisms.

WHC : water-holding capacity of the soil

REFERENCES

[a] CETIS™, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Softwa LLC, McKinleyville, CA 95519 [Program on disk and printed User's Guide].

Environment Canada, 2005. Guidance Document on Statistical Methods for Environmental Toxicity Tests. Environmental Protection Series, Ottawa, Ont., Rept. EPS 1/RM/46.