Data Compilation, Selection, and Derivation of PNEC Values for the Freshwater Compartment

The Existing Substances Risk Assessment of Nickel was completed in 2008. The straightforward explanation of the goal of this exercise was to determine if the ongoing production and use of nickel in the European Union (EU) causes risks to humans or the environment. The European Union launched the Existing Substances regulation in 2001 to comply with Council Regulation (EEC) 793/93. "Existing" substances were defined as chemical substances in use within the European Community before September 1981 and listed in the European Inventory of Existing Commercial Chemical Substances. Council Regulation (EEC) 793/931 provides a systematic framework for the evaluation of the risks of existing substances to human health and the environment.

The conceptual approach to conducting the environment section of the EU risk assessment of nickel included the following steps (Figure 1):

Fish are one of the ten taxonomic groups represented in the nickel freshwater database.

- Emissions of nickel and nickel compounds to the environment were quantified for the whole life cycle, *i.e.*, from production, use, and disposal;
- Concentrations of nickel resulting from these emissions were determined in relevant environmental media (water, sediment, soil, tissue) at local and regional scales (PECs);
- Critical effects concentrations (PNECs) were determined for each of the relevant environmental media;
- Exposure concentrations were compared to critical effects concentrations for each of the relevant environmental media (risk characterization); and
- Appropriate corrective actions (also described as risk management) were identified for situations where exposure concentrations were greater than critical effects concentrations. Where exposure concentrations were below critical effects concentrations, there was no need for concern or action.

The EU Risk Assessments for Nickel and Nickel Compounds were developed over the period from 2002 to 2008. The Danish Environmental Protection Agency (DEPA) acted as the Rapporteur in this process, in close collaboration with the international nickel industry. EU Risk Assessment Reports (RARs) for the environment for nickel substances (metallic nickel, nickel carbonate, nickel chloride, nickel nitrate, and nickel sulfate) were submitted in the spring of 2008 after thorough review by the Technical Committee on New and Existing Substances (TCNES), which was comprised of technical representatives from the EU Member States. A final peer review was provided by the Scientific Committee on Health and Environmental Risks (SCHER) (see Section 5). The European Commission's Institute for Health and Consumer Protection published the final Risk Assessment Reports for nickel and nickel compounds in November 2009.

After the EU RARs received approval within Europe, the data sets were discussed at the international level within the Organization of Economic Cooperation and Development (OECD). The nickel ecotoxicity data sets used in the EU RARs were accepted at the OECD's SIDS (Screening Level Information Data Set) Initial Assessment Meeting (SIAM 28, October 2008), as was the use of nickel bioavailability models to normalize the nickel ecotoxicity data.

1 INTRODUCTION

Environmental risks are typically characterized in the risk assessment framework by considering the ratio between exposure concentrations and critical effect concentrations. In OECD countries, critical effect concentrations are based on Predicted No-Effects Concentrations (PNECs), which are typically derived from long-term laboratory-based ecotoxicity tests using well-defined protocols on a limited number of species. Such information is usually retrieved from relevant literature and/or internationally recognized databases. Because the quality of the extracted data may vary considerably among individual source documents, it is important to evaluate all ecotoxicity data with regard to their adequacy for PNEC derivation and risk assessment. This fact sheet provides clear guidance on how to perform such evaluation for the freshwater aquatic compartment, including criteria for acceptance (or rejection) of a study in accordance with the purpose of the assessment and examples how these data were applied in the European Union Environmental Risk Assessment for Nickel and Nickel Compounds (EU RA).

In the EU RA, a stepwise approach is used for the derivation of the freshwater PNEC value. Figure 2 provides an overview of the steps that need to be accomplished in order to derive the critical effect concentrations (PNEC) for nickel for the freshwater compartment.

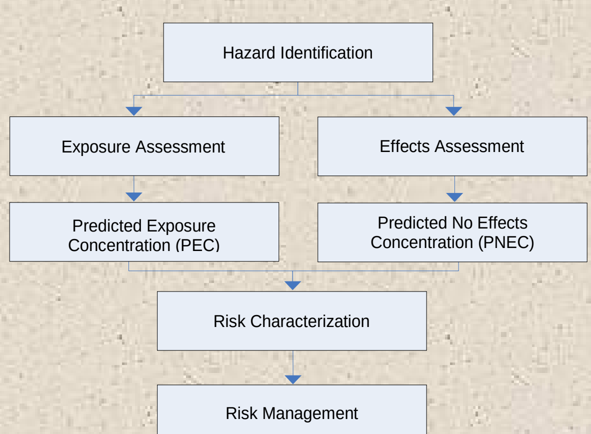

Figure 1: Schematic overview of the steps in the EU Environmental Risk Assessment

2 GUIDANCE

2.1 DATA COMPILATION

The data on the toxicity of nickel to freshwater organisms were compiled from three main sources: open literature, internationally recognized databases (*e.g.*, Science Direct, Web of Science), and industry-sponsored research programs. A large dataset on the chronic ecotoxicity of nickel to freshwater organisms was compiled. All gathered data were further screened using the criteria as outlined in Section 2.2.

2.2 DATA QUALITY SCREENING

Each individual ecotoxicity data point was screened for quality before incorporation in the nickel ecotoxicity database based on the following criteria[i]:

- data were retained for the following groups of organisms: algae, higher plants, invertebrates, amphibians, and fish;
- data covered the following relevant endpoints: survival, growth, and/or reproduction;
- Ni-only exposure data were considered relevant (studies were rejected if indications of impurities or other substances might have an effect on the toxic properties of nickel);
- the results reported measured pH, hardness (Ca and Mg concentration), and dissolved organic carbon (DOC);
- the range of the physico-chemistry of the test media (pH, hardness, DOC) were within the range of the developed/validated bioavailability models (BLMs), (Fact Sheet 4);
- the data were from studies conducted according to approved international standard test guidelines (however, data from non-standardized tests were also assessed);
- only long-term or chronic toxicity data, involving endpoints that are realized over periods of several days to years depending on the organism, were used;
- the tests were performed according to standard operational procedures, with a detailed description of the methods employed during toxicity testing;
- preference was clearly given on the use of measured nickel concentrations in the test concentrations;
- a clear concentration-response was observed;
- toxicity threshold values calculated as $L(E)C_{10}$ (the concentration that causes 10% effect during a specified time interval) values were preferred; however, NOEC values (No Observed Effect Concentration) were seen as equivalent;
- the toxicity tests were performed with soluble nickel salts (*e.g.*, $NiCl_2$ and $NiSO_4$);
- the toxicity test results reflected dissolved nickel concentrations and were expressed as µg Ni/L; and
- ecotoxicity threshold values were derived using the proper statistical methods.

Only identified ecotoxicity data fulfilling the above mentioned criteria were used for the freshwater PNEC derivation.

2.3 DATABASE DEVELOPMENT

Applying the above mentioned quality screening criteria to the identified ecotoxicity data resulted in the selection of an extensive high quality database on the ecotoxicity of nickel to freshwater organisms. Indeed, the database comprised 31 different "species means" for 19 different families from 214 individual high quality $L(E)C_{10}$/NOEC values [58 individual $L(E)C_{10}$/NOEC values for algae, 6 for higher plants; 113 for invertebrates; 37 for fish/amphibians]. An overview of accepted individual high quality chronic ecotoxicity data is presented in the Environmental Risk Assessment of Nickel and Nickel Compounds (Section 5).

2.4 INCORPORATION OF BIOAVAILABILITY (DATA NORMALIZATION)

There is extensive evidence demonstrating the importance of bioavailability and water quality conditions on the toxicity of nickel to aquatic organisms. Indeed, site-specific geochemical conditions (*e.g.*, pH, hardness, DOC) influence the degree to which organisms take up nickel and exhibit adverse effects. From a risk assessment perspective, it is critical to consider bioavailability, as geographically distinct eco-regions, watersheds, and sites will often show distinctive geochemical characteristics leading to different critical effects concentrations (PNECs). For further guidance, see Fact Sheet 4 entitled *Bioavailability Models for the Freshwater Compartment.*

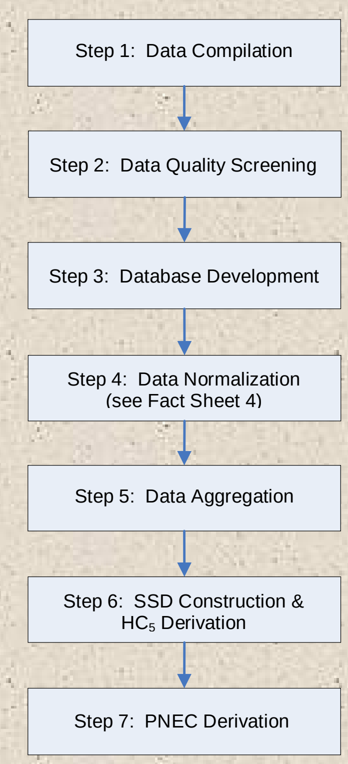

Figure 2: Stepwise approach used for the derivation of the freshwater PNEC value

2.5 DATA AGGREGATION

Normalized high quality ecotoxicity data are grouped/aggregated in order to avoid over representation of ecotoxicological data from one particular species. The following major rules were used to aggregate data:

- If several chronic NOEC/L(E)C_{10} values based on the same toxicological endpoint were available for a given species, the values were averaged by calculating the geometric mean, resulting in the "species mean" NOEC/L(E)C_{10}.
- If several (geometric mean) chronic NOEC/L(E)C_{10} values based on different toxicological endpoints were available for a given species, the lowest (geometric value) value was selected.

After the data aggregation step, only one ecotoxicity value (*i.e.*, the geometric mean for the most sensitive endpoint) was assigned to a particular species.

2.6 CALCULATION OF PNEC USING STATISTICAL EXTRAPOLATION METHODS

Estimation of the HC_5 from the species sensitivity distribution

When a large data set for different taxonomic groups is available, the PNEC can be calculated using a statistical extrapolation method. In this approach, the ecotoxicity data are ranked from low (most sensitive species) to high (least sensitive species). A species sensitivity distribution (SSD) was then constructed by applying an appropriate curve fitting distribution (usually a log-normal distribution) to the normalized high quality aggregated chronic toxicity data (Aldenberg & Jaworska, 2000). From the SSD, a 5^{th} percentile value (at the median confidence interval) is calculated (*i.e.*, median HC_5) using the software program ETx, as described by Van Vlaardingen *et al.* (2004).

Selection of appropriate assessment factor and derivation of the PNEC

To account for uncertainty, an assessment factor (AF) may be applied to the median HC_5. In general, such AFs vary between 1 and 5 and are determined on a case-by-case basis. The freshwater PNEC would therefore be calculated as follows:

$$\text{freshwater PNEC} = \text{median } HC_5/AF$$

Based on the available chronic NOEC/L(E)C_{10} data, the following points were considered when determining the AF:

- The overall quality of the database and the endpoints covered (*e.g.*, are all the compiled data representative of "true" chronic exposure?)
- The diversity of the taxonomic groups (Table 1) covered by the database (*e.g.*, do the databases contain, at a minimum, organisms belonging to the eight taxonomic groups as defined by the 2001 London workshop?)
- The number of species (*e.g.*, does the SSD cover at least 10 different L(E)C_{10}/NOECs and preferably more than 15?)
- Use of bioavailability models and approach for bioavailability correction [*e.g.*, do the bioavailability models (see Fact Sheet 4) allow the toxicity data for all species to be normalized?]
- Statistical extrapolation (*e.g.*, how well does the SSD fit the toxicity data?)
- Comparisons between field and mesocosm studies and the PNEC (*e.g.*, is the PNEC value protective for the effects observed in mesocosm/field studies?)

In the Nickel EU RA, no mesocosm/field data were available that allowed the determination of threshold concentrations of nickel in freshwaters under field conditions. All other identified criteria were fulfilled. Therefore, based on the weight of evidence, the Danish Rapporteur proposed to use an *AF of 2*.

Taxonomic Groups	
1.	Fish (usually tested species like salmons, bluegill, channel catfish, etc.)
2.	A second family in the phylum Chordata (fish, amphibian, etc.)
3.	A crustacean (*e.g.*, cladoceran, copepod, ostracod, isopod, amphipod, crayfish, etc.)
4.	An insect (*e.g.*, mayfly, dragonfly, damselfly, stonefly, caddisfly, mosquito, midge, etc.)
5.	A family in a phylum other than Arthropoda or Chordata (*e.g.*, Rotifera, Annelida, Mollusca, etc.)
6.	A family in any order of insect or any phylum not already represented
7.	Algae
8.	Higher plants

Table 1: Taxonomic group requirements according to the criteria developed at the London workshop (2001)

3 EXAMPLE

3.1 DATA COMPILATION

See Section 2.1

3.2 DATA QUALITY SCREENING

The quality screening criteria as defined in Section 2.2 were applied to select the high quality chronic ecotoxicity data of nickel to freshwater organisms.

3.3 DATABASE DEVELOPMENT

An overview of all accepted individual high quality chronic ecotoxicity data is presented in the Environmental Risk Assessment of Nickel and Nickel Compounds (see Section 5).

3.4 DATA NORMALIZATION

In this example, the data were normalized to the physico-chemical conditions prevailing in the river Rhine using the bioavailability models as explained in the Fact Sheet 4. The river Rhine is characterized by a pH of 7.8, a hardness of 217 mg/L $CaCO_3$, and a DOC of 2.8 mg/L.

3.5 DATA AGGREGATION

The selected normalized individual high quality chronic ecotoxicity data of nickel to freshwater organisms are aggregated according to the criteria mentioned in Section 2.5. An overview of the normalized species mean NOEC/L(E)C_{10} value for the most sensitive endpoint is provided in Table 2.

3.6 SSD CONSTRUCTION AND MEDIAN HC_5 DERIVATION

The normalized species mean NOEC/L(E)C_{10} values in Table 2 were further ranked from low to high. Subsequently, a log-normal distribution was fitted through the ranked species mean toxicity data. From this SSD the median HC_5 was calculated using the ETx model. The SSD and the median HC_5 value for the normalized ecotoxicity data to the physico-chemical conditions prevailing in the river Rhine for nickel are presented in Figure 3.

3.7 PNEC DERIVATION

An AF of 2 is applied to the median HC_5 value calculated for the river Rhine results in a freshwater PNEC = median HC_5 / 2 = 10.8 µg/L / 2 = 5.4 µg/L.

The example of the SSD construction and PNEC derivation for nickel as shown here above only applies for the water chemistry prevailing in the river Rhine. However, other water chemistries are encountered in EU surface waters (freshwater rivers and lakes) resulting therefore in the setting of different PNEC values for Ni. These different eco-regions, as shown in Table 3, have been selected in the EU risk assessment to provide *examples* of typical conditions covering a wide range of physico-chemical conditions (pH between 6.67 and 8.2; hardness between 27.8 and 260 mg/L $CaCO_3$, DOC between 2.5 and 27.5 mg/L) occurring in EU surface waters. Therefore, PNEC values for typical eco-regions in EU surface waters vary, depending on the water chemistry, between 3.6 and 21.8 µg Ni/L. The water chemistry and median HC_5/PNEC values calculated for the different selected eco-regions in EU surface waters are summarized in Table 3.

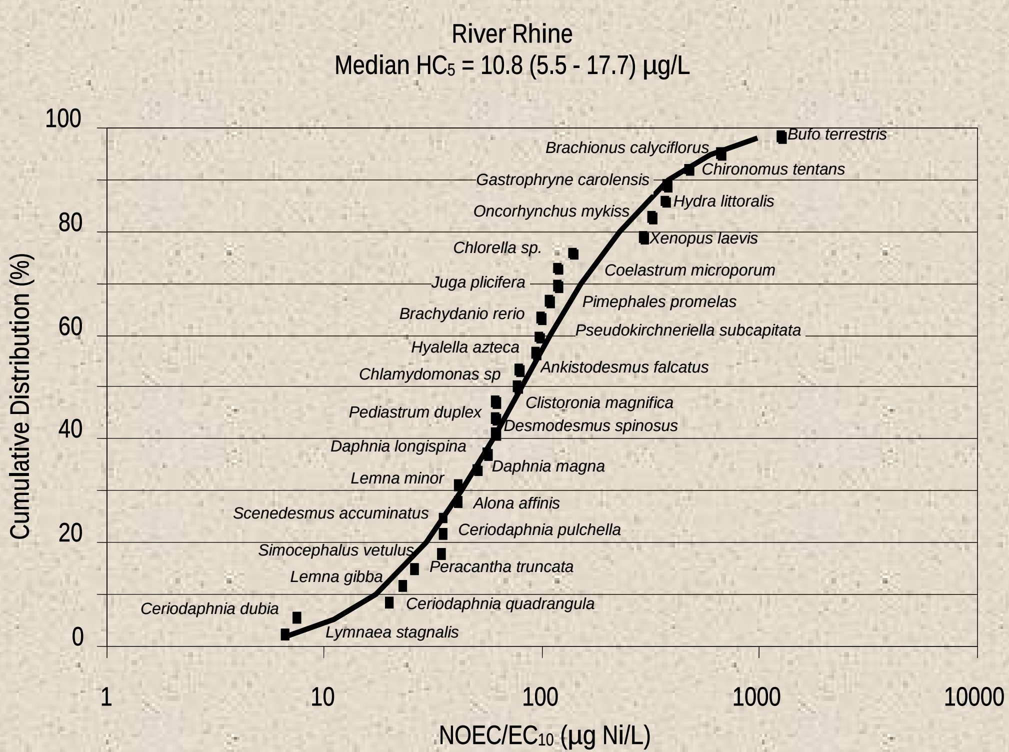

Figure 3: SSD and median HC_5 derivation for nickel using normalized ecotoxicity data for the river Rhine

Taxonomic Group	*Species*	*Most Sensitive Endpoint*	*Species Mean NOEC/L(E)C_{10} Value (µg/L)*
Algae	*Scenedesmus accuminatus*	Growth rate	35.9
	Desmodesmus spinosus	Growth rate	61.8
	Pediastrum duplex	Growth rate	62.0
	Chlamydomonas sp	Growth rate	77.3
	Ankistodesmus falcatus	Growth rate	78.8
	Chlorella sp	Growth rate	115.3
	Coelastrum microporum	Growth rate	114.1
	Pseudokirchneriella subcapitata	Growth rate	98.5
Higher plants	*Lemna minor*	Growth	41.7
	Lemna gibba	Growth rate	23.3
Rotifer	*Brachionus calyciflorus*	Intrinsic rate of growth	670.6
Molluscs	*Lymnaea stagnalis*	Growth	6.7
	Juga plicifera	Mortality	109.7
Cladocerans	*Ceriodaphnia dubia*	Reproduction	7.5
	Ceriodaphnia quadragula	Mortality	20.4
	Peracantha truncata	Reproduction	26.1
	Simocephalus vetulus	Reproduction & mortality	35.9
	Ceriodaphnia pulchella	Reproduction & mortality	35.8
	Alona affinis	Mortality	41.5
	Daphnia longispina	Mortality	56.6
	Daphnia magna	Reproduction	50.7
Insects	*Clistoronia magnifica*	Mortality	62.2
	Chironomus tentans	Biomass	481.7
Hydrozoans	*Hydra littoralis*	Growth	369.0
Amphipods	*Hyalella azteca*	Mortality	94.3
Fish	*Brachydanio rerio*	Hatchability	99.2
	Pimephales promelas	Growth	108.7
	Oncorhynchus mykiss	Growth	324.5
Amphibians	*Xenopus laevis*	Malformation	293.3
	Gastrophryne carolensis	Mortality	384.3
	Bufo terrestris	Growth	1265.9

Table 2: Selected freshwater normalized species mean ecotoxicity data to nickel for the most sensitive endpoint

Eco-Region	*Water Chemistry*	*Median HC_5 (µg/L)*	*PNEC (µg/L)[ii]*
Ditch in The Netherlands	pH 6.9, H 260 mg/L, DOC 12.0 mg/L	43.6	21.8
River Otter in the United Kingdom	pH 8.1, H 165 mg/L, DOC 3.2 mg/L	8.1	4.1
River Teme in the United Kingdom	pH 7.6, H 159 mg/L, DOC 8.0 mg/L	19.0	9.5
River Rhine in The Netherlands	pH 7.8, H 217 mg/L, DOC 2.8 mg/L	10.8	5.4
River Ebro in Spain	pH 8.2, H 273 mg/L, DOC 3.7 mg/L	8.7	4.4
Lake Monate in Italy	pH 7.7, H 48.3 mg/L, DOC 2.5 mg/L	7.1	3.6
Neutral-acidic lake in Sweden	pH 6.7, H 27.8 mg/L, DOC 3.8 mg/L	12.1	6.1

Table 3: Overview of the water chemistry and median HC_5/PNEC values for the different selected EU eco-regions

4 CONCLUSIONS AND NEXT STEPS

This fact sheet presents the approach for data gathering, data selection, and data aggregation to be used for the derivation of the PNEC value for the freshwater compartment based on the statistical extrapolation method using the SSD approach. Because the ecotoxicity of nickel is mitigated by the physico-chemistry of the freshwaters (pH, hardness, DOC) it is highly recommended to normalize the ecotoxicity data for PNEC derivation using the available bioavailability models as described in the Fact Sheet 4.

5 LINK TO EU RISK ASSESSMENT DOCUMENTS

The final report on the Environmental Risk Assessment of Nickel and Nickel Compounds can be retrieved from the following website:
http://echa.europa.eu/documents/10162/cefda8bc-2952-4c11-885f-342aacf769b3
(last accessed July 2015)

The opinion of the SCHER can be found at the following address:
http://ec.europa.eu/health/ph_risk/committees/04_scher/docs/scher_o_112.pdf
(last accessed July 2015)

6 REFERENCES

Aldenberg, T. and Jaworska, J. S. 2000. Estimation of the hazardous concentration and fraction affected for normally distributed species sensitivity distributions. Ecotoxicology and Environmental Safety, 46, 1-18.

London, workshop, 2001. Report of the expert consultation workshop on statistical extrapolation techniques for environmental effects assessments. London, VK, European Chemicals Bureau, 17-18 January 2001.

SIDS (Screening Level Information Data Set) Initial Assessment Meeting (SIAM) 28. Ottawa, Ontario, Canada. October, 2008.

Van Vlaardingen, P. L.; T. P. Traas; A. M. Wintersen; and T. Aldenberg. 2004. ETX 2.0. A program to calculate risk limits and fraction affected, based on normal species sensitivity distributions. Report no. 601501028/2004, National Institute for Public Health and the Environment (RIVM), Bilthoven, The Netherlands.

i The application of the quality screening criteria would also apply in case additional or new ecotoxicity data would be considered.

ii PNEC is calculated using an assessment factor of 2.

Fact Sheets on the European Union Environmental Risk Assessment of Nickel

This is the first in a series of fact sheets addressing issues specific to the environment section of the European Union's Existing Substances Risk Assessment of Nickel (EU RA). The fact sheets are intended to assist the reader in understanding the complex environmental issues and concepts presented in the EU RA by summarizing key technical information and providing guidance for implementation.

NiPERA welcomes questions about the concepts and approaches implemented in the EU RA. For inquiries, please contact:

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