Development and application of predictive bioavailability models to assess chronic toxicity of nickel in freshwater sediments

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Nickel sediment Effects database

A high quality data set on the chronic toxicity of nickel to freshwater invertebrates have been generated (Besser et al, 2011)*. Besides fulfilling the requirements imposed by REACH (derivation PNEC) the data set has been successfully used to identify relationships between important sediment parameters and the toxicity of nickel to sediment-dwelling organisms. These observation have led to the development of bioavailability models for specific key species: *hyalella*, *gammarus* and *hexagenia.*

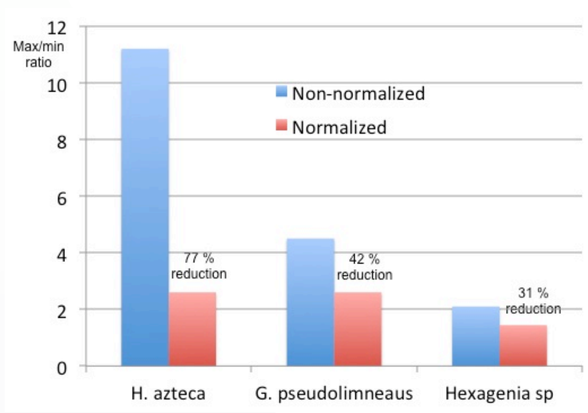
Organism	Most sensitive endpoint	Species EC_{10} (mg total Ni/kg dry wt.)	Life strategy
Hyalella azteca (amphipod)	Biomass	149 (geomean SR and Dow sediment)	Swimmers, sprawlers: surface deposit feeders
Gammarus pseudolimnaeus (amphipod)	Biomass	228 (Dow sediment)	Swimmers, sprawlers: surface deposit feeders
*Hexagenia species (*mayfly)	Biomass	237	Burrowers: surface & subsurface feeding
Lumbriculus variegatus (oligochaete)	Abundance	554	Burrowers: subsurface feeding
Chironomus dilutus/ Chironomus riparius (insects*), Lampsilis siliquoidea* (fat mucket*)* and *Tubifex tubifex (*oligochaete)		> 762	Burrowers: surface & subsurface feeding

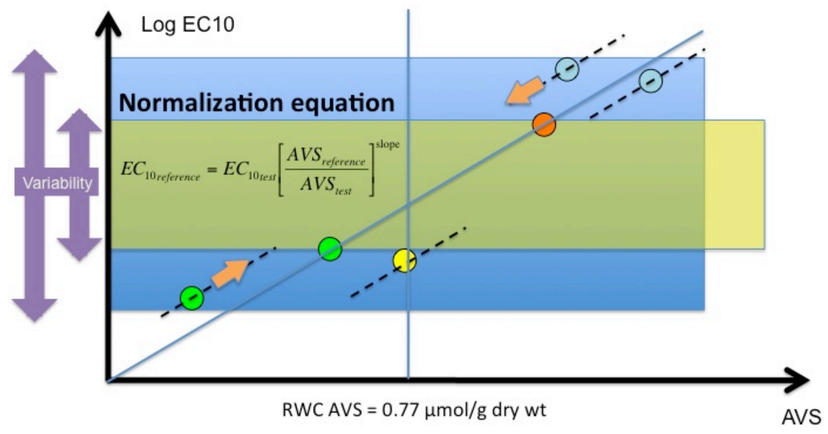
For the development of a baseline realistic worst case nickel sediment effects hazardous concentration ($HC_{5\text{-}50}$), sediment toxicity test results were successfully conducted with 7 species on Spring River (SR) sediment and 1 with Dow river sediment, both spiked with nickel and representing a sediments with a low nickel binding capacity (≈ 10th percentile EU sediments). The Acid Volatile Sulfide (AVS) concentration was < 1 µmol/g dry wt. The organic carbon (OC) content was 0.4 %.The final sediments effect data set (8 species) is representative of different exposure pathways and a variety of feeding strategies and taxonomic groups. A Species Sensitivity Distribution (SSD) as a lognormal function was fitted to the data an yielded an $HC_{5\text{-}50}$ of 94 mg/kg dry wt.

* Besser, JM, Brumbaugh WG, Kemble NE, Ivey CD, Kunz JL, Ingersoll CG, Rudel D, 2011. Toxicity of nickel spiked freshwater sediments to benthic invertebrates: spiking methodoloy, species sensitivity and nickel bioavailability. USGS Open-file Report Series

Development bioavailability models

Bioavailability models were developed for the three most sensitive organisms. A set of ecotoxicity tests was conducted in six sediments representing a range of sediment parameters typically found in the EU (10thP-90thP). Correlations, single and multiple regressions between toxicity thresholds (EC_{20} values) and sediment properties measured revealed a significant ($p < 0.05$) co-variation. A a result the the regression outcomes contains only one variable.

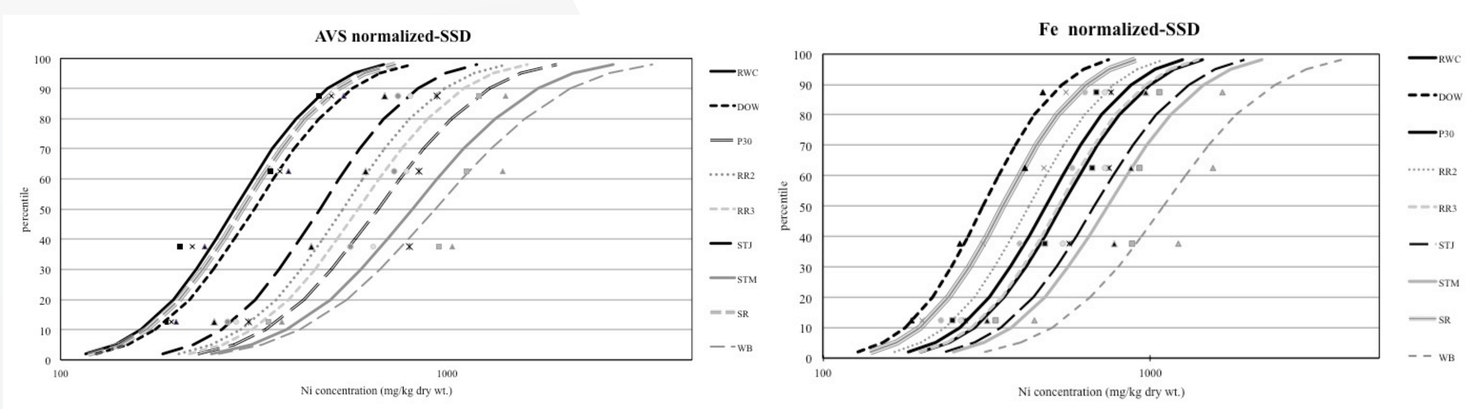




Organism	Model TR Ni (mg/kg dry wt.) * Not significant (P>0.05)	R^2	Slope
	AVS (µmol/g dry wt.) based		
Hyalella	Log EC_{20} TR Ni = 2.65 + 0.492log AVS	0.74	0.492
Gammarus	Log EC_{20} TR Ni = 2.8 + 0.358log AVS	0.62	0.358
Hexagenia.	Log EC_{20} TR Ni = 2.35 + 0.175log AVS	0.59*	0.175
	Fe (mg/kg dry wt.) based		
Hyalella	Log EC_{20} TR Ni = - 0.54 + 0.854log Fe	0.62	0.854
Gammarus	Log EC_{20} TR Ni = 0.31 + 0.666log Fe	0.68	0.666
Hexagenia	Log EC_{20} TR Ni 0.75+ 0.418log Fe	0.79	0.418

Normalizations towards AVS reduced the inter sediment variability in a significant way (31 to 78 %) reduction) as shown by the max/min ratios above. Similar reduction in variability was observed for the other parameter Fe: 38-65 %. Bioavailability relationships and reduction in variability were more pronounced for the amphipods and less outspoken for the mayfly *Hexagenia.*

The different bioavailability models have been subsequently used to normalize the EC_{10} values of the SR/DOW dataset towards the test conditions prevailing in a suit of different bioavailability scenarios (8 sediments). Data were normalized using a species-specific developed bioavailability model when available. Data for *Lumbriculus* were normalized using the *Hexagenia* model which best resembles the lifestyle of *Lumbriculus* and resulting also in the most conservative outcome.



Conclusions

Meaningful bioavailability relationships were obtained between the different sediments organisms, in spiked nickel chronic laboratory sediment toxicity tests and the sediment parameters AVS and Fe. However, due to the co-variance none of the sediment parameters could be singled out as the **predominant parameter.** Application of the chronic univariate regressions reduced a large component of uncertainty within the effects assessment and could be applied for setting an ecologically relevant $HC_{5\text{-}50}$. Ranges of $HC_{5\text{-}50}$ values obtained for the significant different bioavailability scenarios were: **AVS model: 126-281 mg/kg dry wt; Fe model: 143-265 mg/kg dry wt.** The **initial $HC_{5\text{-}50}$** directly obtained from the toxicity experiments performed on sediments low in AVS was **94 mg/kg dry wt**.