LEACHING BEHAVIOUR AND POTENTIAL FOR GEOCHEMICAL AND TRANSPORT MODELLING OF CONTAMINANTS IN SOIL AND SEDIMENTS IN RELATION TO ENVIRONMENTAL IMPACT ASSESSMENT

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ECN – Environmental Risk Assessment

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MAIN CONCERNS IN RELATION TO LEACHING TEST USE AND DEVELOPMENT

- Too many leaching/extraction tests addressing the same question
- Too many ways of data representation
- Too limited relation of test conditions with the actual problem
- Too limited use and relevance of the vast amount of leaching test data generated annually in the industry and research (missing parameters!)
- Key information relevant to the outcome and possible interpretation of a leaching test often not reported (pH, EC, Eh, DOC)

STRONG NEED FOR HARMONISATION OF LEACHING TEST METHODS AND DATA EVALUATION!

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TYPICAL QUESTIONS FOR SEDIMENTS

Release from contaminated sediment under water

Release from contaminated sediment brought on land

Release from contaminated sediment used as fertilizer

Release of treated contaminated sediment by

- cement stabilisation
- bitumen encapsulkation
- sintering
- vitrification
- co-firing in cement kiln

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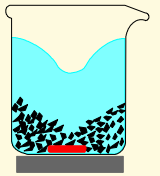
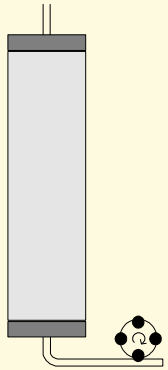
RELEVANT TYPES OF LEACHING TESTS

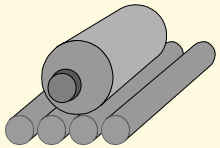
BATCH LEACHING TEST (GRANULAR)

EN12457 (1-4)

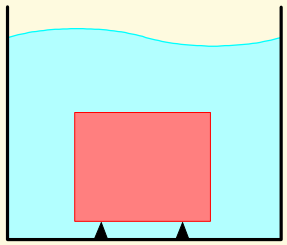




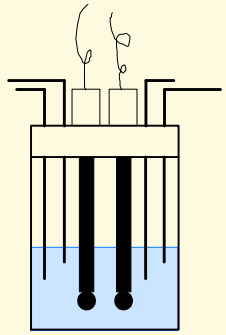
PERCOLATION LEACHING TEST (GRANULAR PrEN 14405)



TANK LEACH TEST (MONOLITH) en CGLT. NEN 7345
EN in development



pH STAT TEST



pH DEPENDENCE TEST:
BATCH MODE ANC and COMPUTER CONTROLLED
prEn 14429 **PrEn xxxx (in enquiry)**

Limited number of tests will cover 80- 90% of the questions for a wide range of materials

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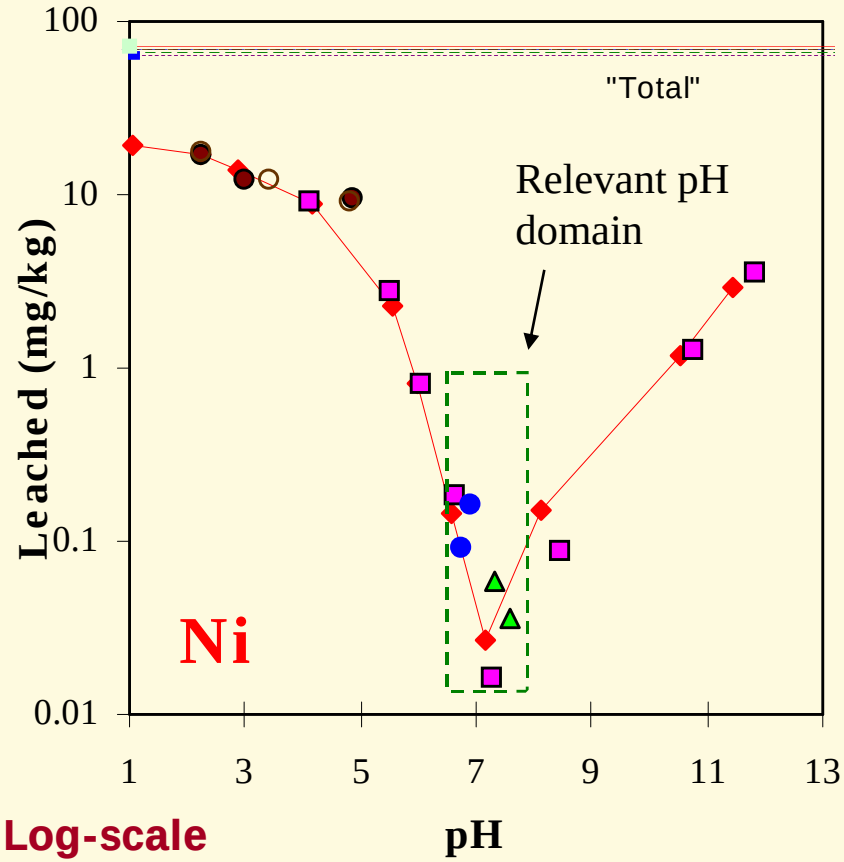
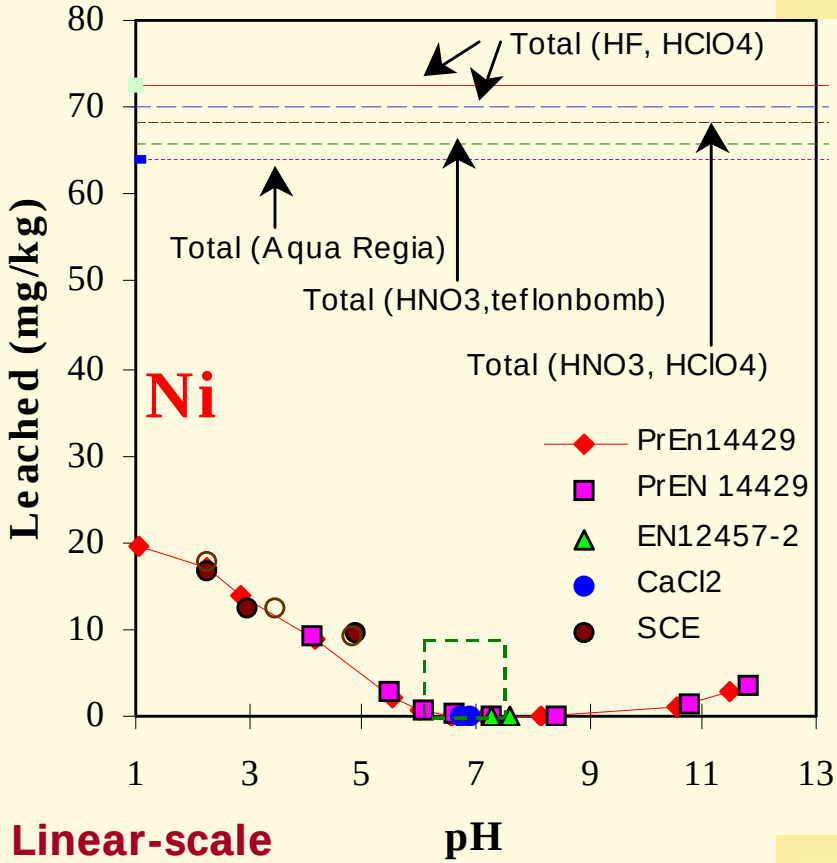
JUDGEMENT OF ENVIRONMENTAL IMPACT ON TOTAL COMPOSITION OR ON LEACHING?



Log-scale



Linear-scale

Contaminated harbour sediment (Rhine)

Relevance of different methods for total composition for environmental judgement questionable. Leaching by far more relevant for environmental impact assessment

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pH DEPENDENCE TEST TO ASSESS SENSITIVITY TO CHANGES IN pH

pH stat and “ANC” mode

TEST CONDITIONS **ANC MODE**:

BATCH TEST

8 FINAL pH VALUES (pH 4-12)

LEACHANT: PREDETERMINED AMOUNTS OF ACID OR BASE

LIQUID TO SOLID RATIO (L/S) = 10

RESULTS IN mg/l (GEOCHEMICAL MODELLING) OR mg/kg (RELEASE EVALUATION)

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pH DEPENDENCE TEST TO ASSESS SENSITIVITY TO CHANGES IN pH, E_H AND TEMPERATURE

CEN/TC 292 - ENV 12920

Scenario Description

Material characterization

Controlling factors

Modelling leaching

Validation verification

Evaluation

Conclusions

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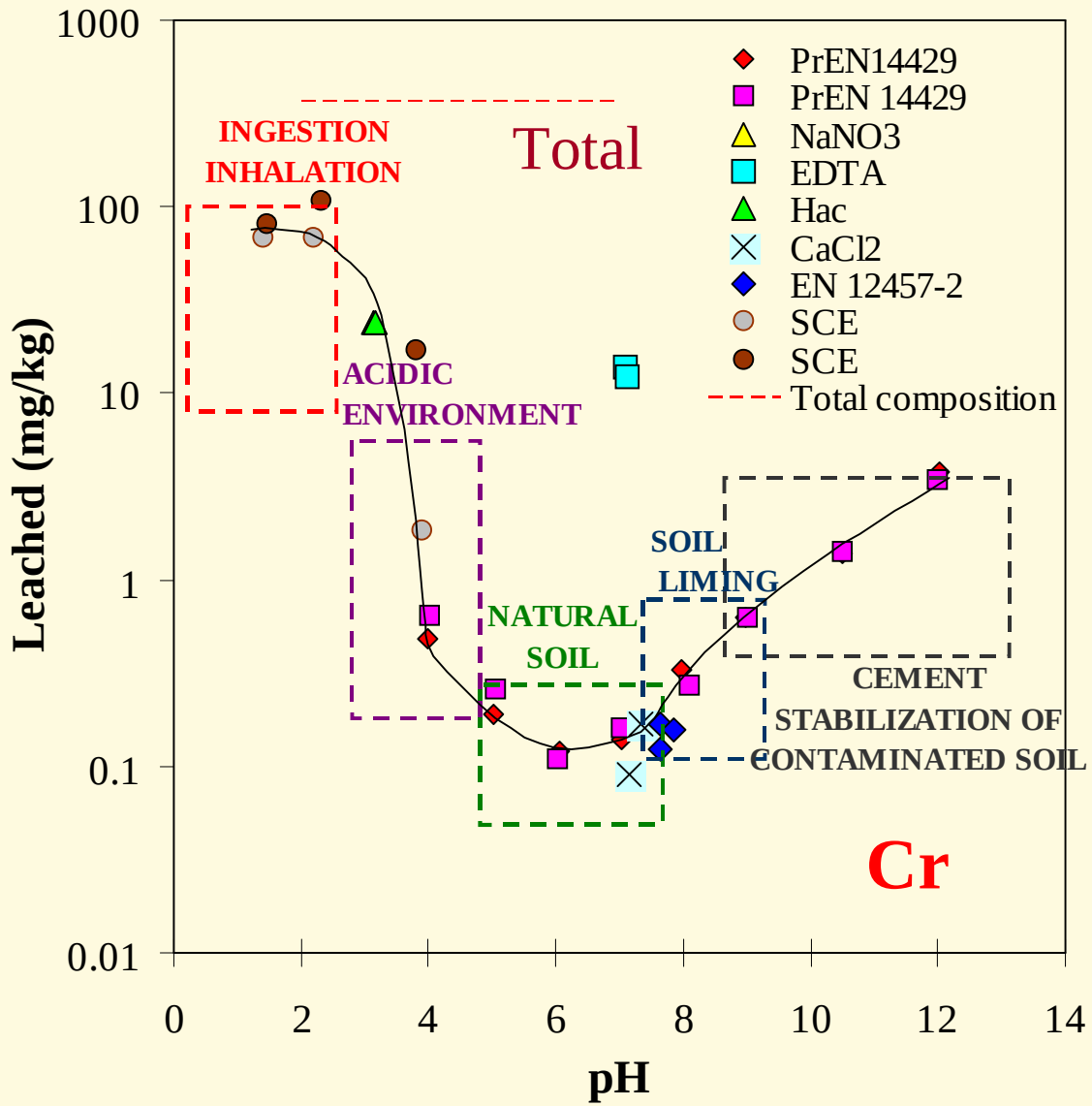
TEST CONDITIONS RELATED TO DIFFERENT EXPOSURE CONDITIONS

Relevant pH domains for assessing different questions in relation to different types of impact

Contaminated river sediment



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ADVANTAGES OF pH DEPENDENCE TEST

- Identification of sensitivity of leaching to small pH changes
- Provides information on pH conditions imposed by external influences
- Basis for comparison of international leaching tests
- Basis for geochemical speciation modelling
- Provides acid neutralization capacity information
- Mutual comparison of widely different materials to assess similarities in leaching behaviour
- Recognition of factors controlling release
- For non-interacting species possible to assess sub-sampling error

Applicable to almost any material

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PERCOLATION TEST TO ASSESS LONG TERM RELEASE FOR GRANULAR MATERIALS

Liquid to solid ratio (L/S) related to a time scale by infiltration rate, density and height of application.

TEST CONDITIONS:

Pre-equilibration after saturation for more than 48 hrs

Up-flow

L/S range 0.1 - 10 (100 - 1000 yrs)

Test data in mg/l or mg/kg cumulative

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ADVANTAGES OF PERCOLATION TEST

- Identification of solubility control versus wash out
- Indication of pore water concentrations relevant to field leachate from low L/S data
- Local equilibrium established quite rapidly
- Basis for geochemical speciation modelling
- Allows comparison with lysimeter and field data provided L/S value can be obtained from such measurements
- Projection towards long term behaviour possible

  Solubility controlled release

  Wash-out of non-interacting species

Applicable to many materials. Limited or not applicable to clayey soils and sediments (low permeability).

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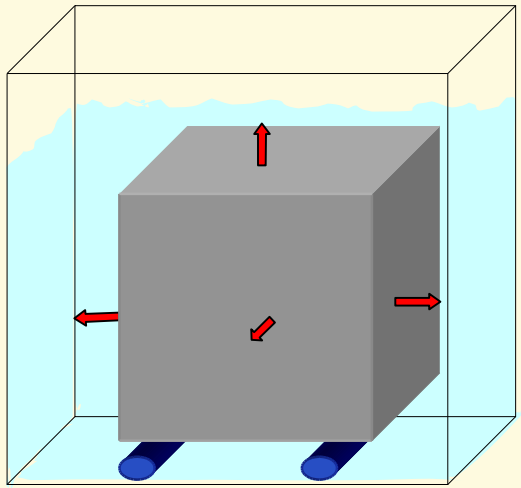
TANK LEACH TEST OR COMPACTED GRANULAR LEACH TEST (CGLT) FOR MONOLITHIC MATERIALS (modified)



TEST CONDITIONS:

First step: pre-equilibration

for 48 hrs at liquid to

volume ratio: 5

Second step: leaching

at low L/V ratio (1) for 24 hrs

Then contact times: 2, 4, 8,16, 32 and 64 days

Leachant: demineralised water (own pH)

Expression of results in mg/m^2 (cumulative) against time

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EXPERIMENTAL SET-UP

CGLT = Compacted Granular Leach Test

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ADVANTAGES OF TANK LEACHING TEST OR COMPACTED GRANULAR LEACH TEST

- Relevant for materials with monolithic character (durable materials) or materials behaving as monolith (low permeability soil and sediments)
- Identification of solubility control versus dynamic leaching possible
- Isolation of surface wash-off effects
- Quantification of intrinsic release parameters
- Basis for reactive/transport modelling
- Projection towards long term behaviour possible

Applicable to sediments, clayey soils, stabilised materials and construction materials produced

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DEVELOPMENT OF STANDARDS

European:

Granular waste compliance leaching test – EN 12457 1- 4 validated CEN TC 292 WG2

Monolith compliance leaching test – Tank leach test 3 days (in enquiry) CEN TC 292 WG2

pH dependence leaching test – 2004 for formal vote - PrEN 14429 CEN TC 292 WG6

Percolation test – 2003 formal vote - PrEN 14405 CEN TC 292 WG6

NWIP Dynamic leach test (similar to NEN 7345; in preparation) CEN TC 292 WG6

International:

Batch tests and percolation test for soil materials (based on CEN TC 292 procedures; 2004 F-DIS) ISO TC 190 SC7 WG6

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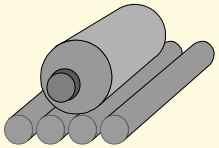
BASIC CHARACTERISATION TESTS

GRANULAR MATERIALS



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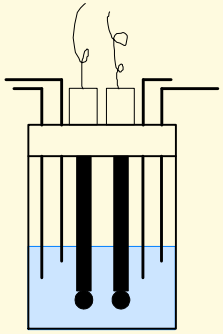
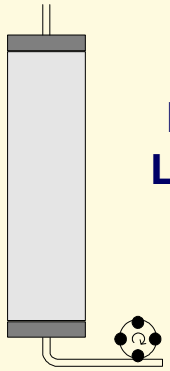
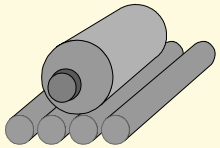


pH DEPENDENCE TEST : BATCH MODE ANC prEn 14429 or COMPUTER CONTROLLED



PERCOLATION LEACHING TEST (PrEN 14405)

MONOLITHIC MATERIALS



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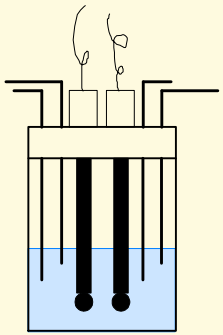
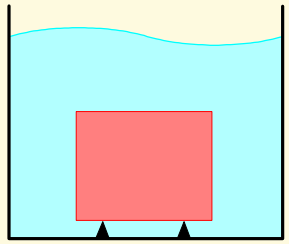


pH DEPENDENCE TEST : BATCH MODE ANC prEn 14429 or COMPUTER CONTROLLED



TANK LEACH TEST (MONOLITH) and COMPACTED GRANULAR LEACH TEST.

Chemical speciation aspects

Time dependent aspects of release

CEN/TC 292
ENV 12920

- Scenario Description
- Material characterization
- Controlling factors
- Modelling leaching
- Validation verification
- Evaluation
- Conclusions

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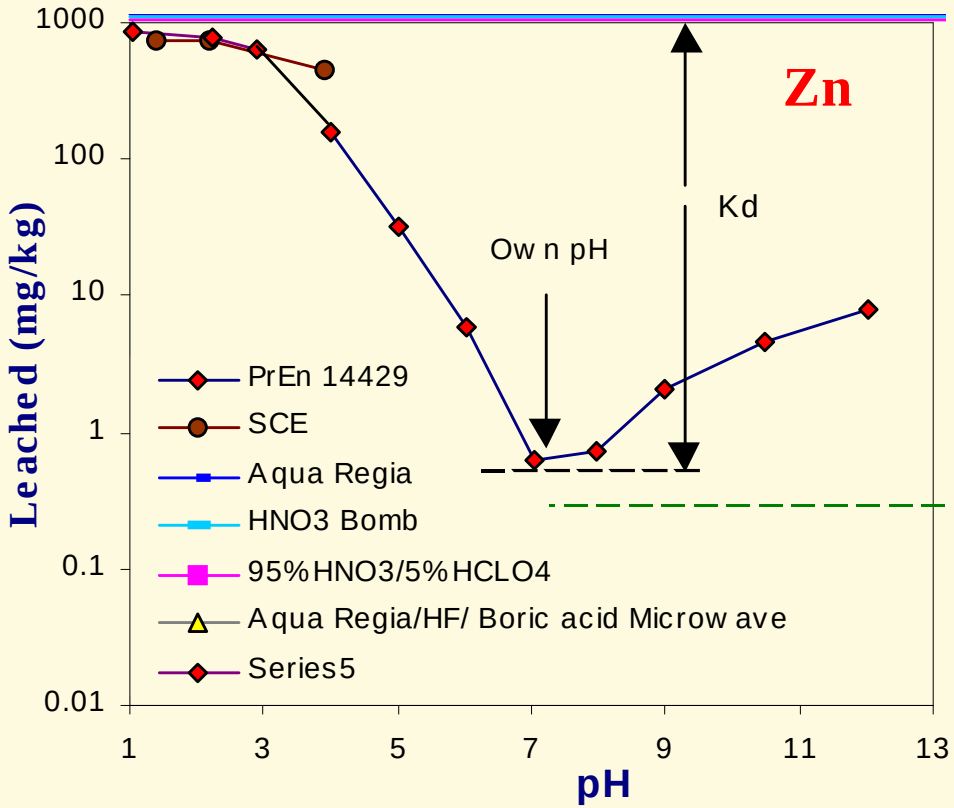
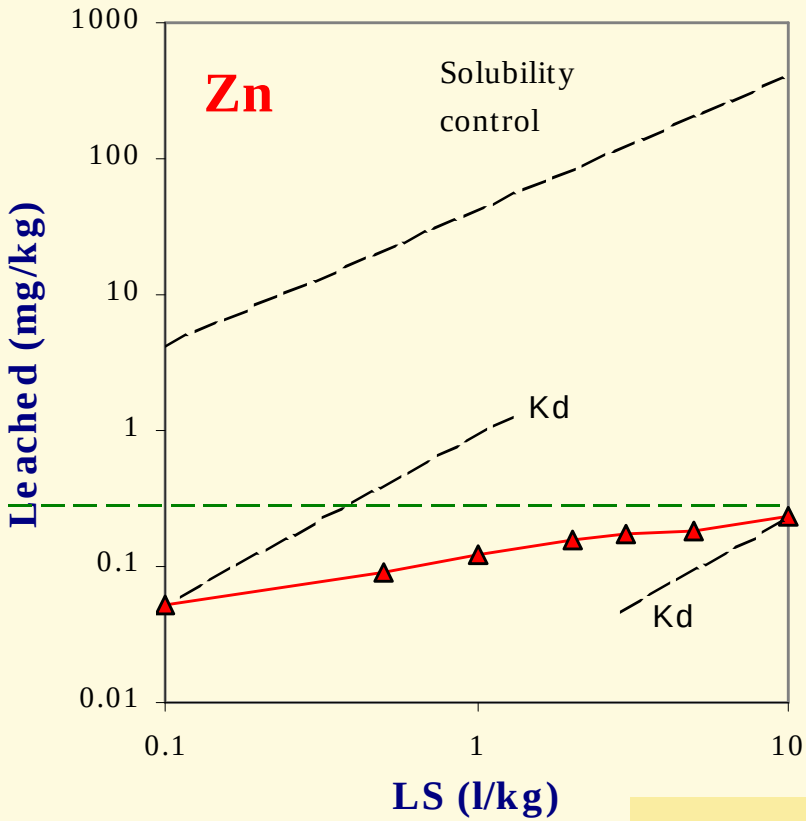
RELATIONSHIPS BETWEEN CHARACTERISATION TEST RESULTS, POTENTIALLY LEACHABLE AND TOTAL COMPOSITION FOR GRANULAR MATERIALS





Internal consistency and coherence of test data crucial

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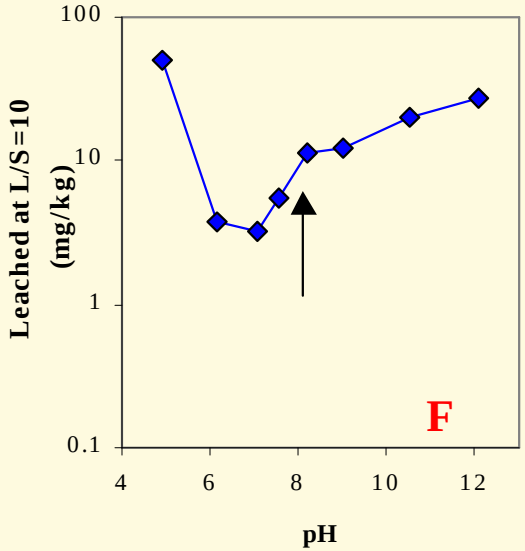
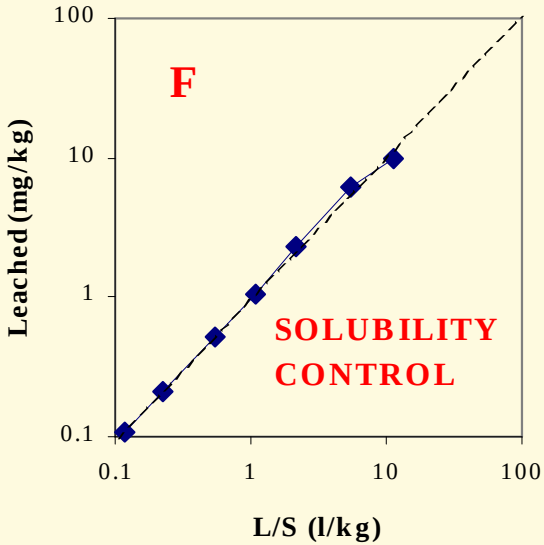
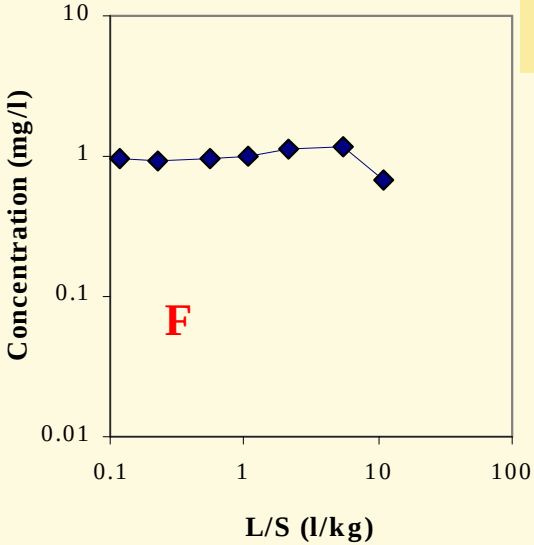
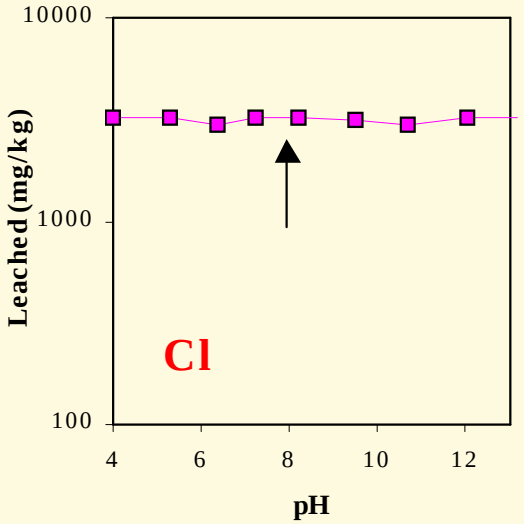
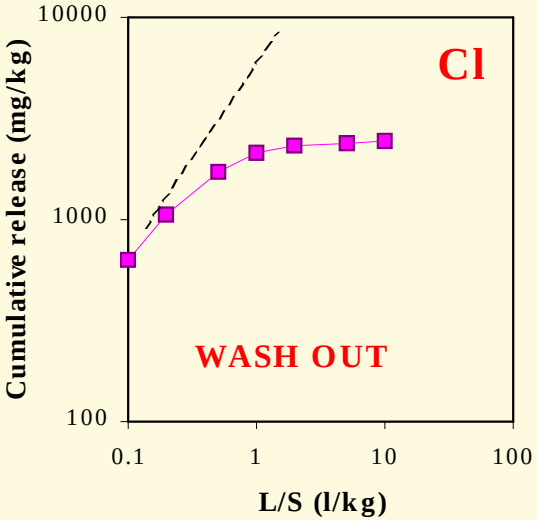
RELEASE PROCESSES FROM MATERIALS

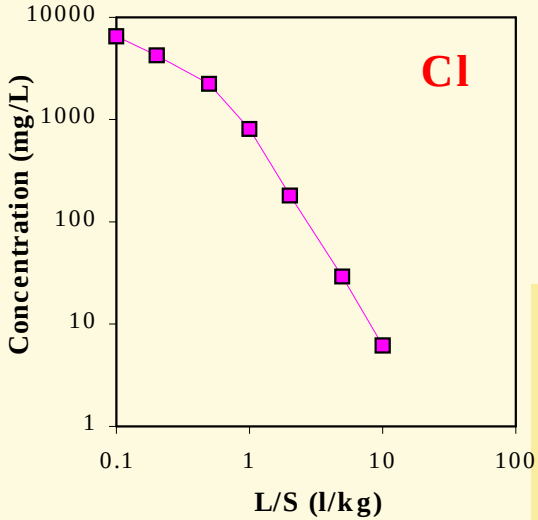












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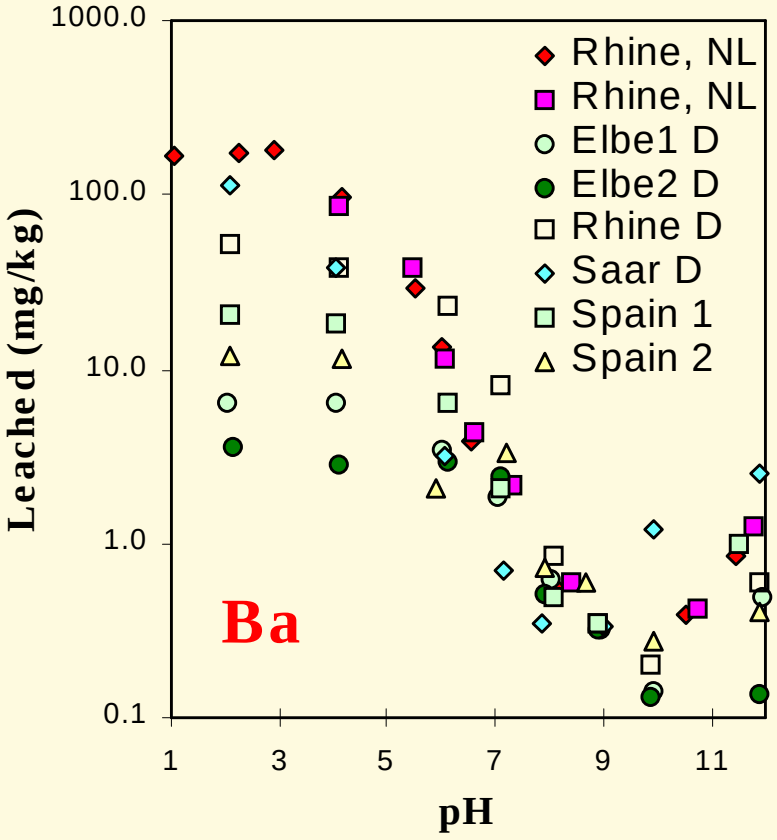
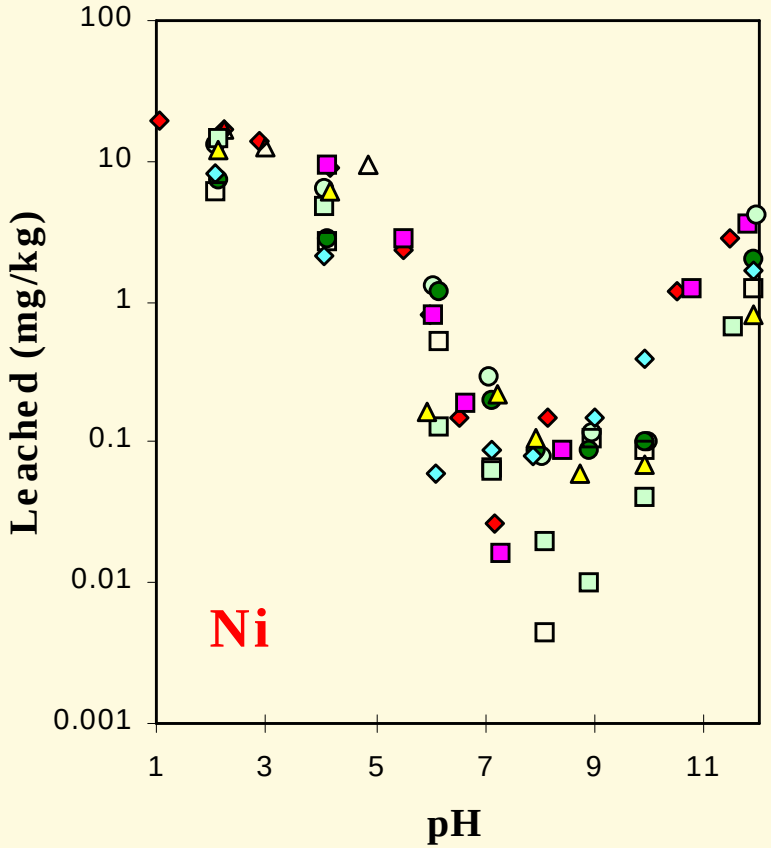
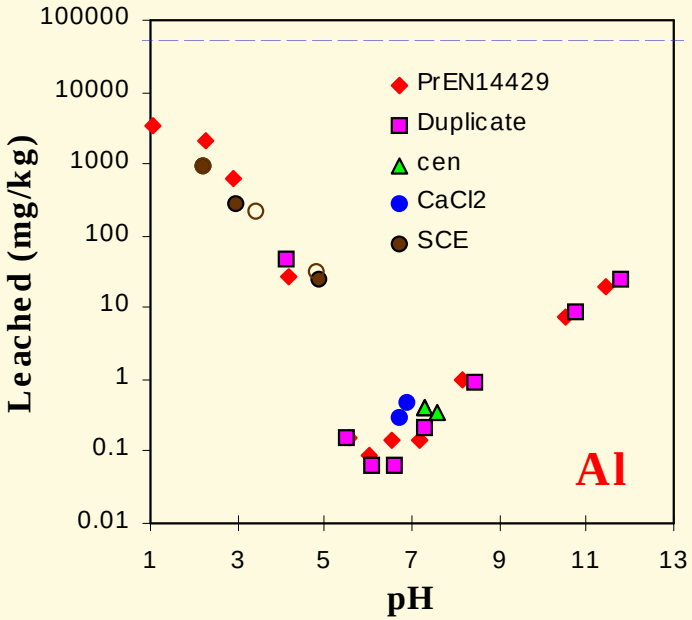
COMPARISON OF SEDIMENT LEACHING CHARACTERISTICS

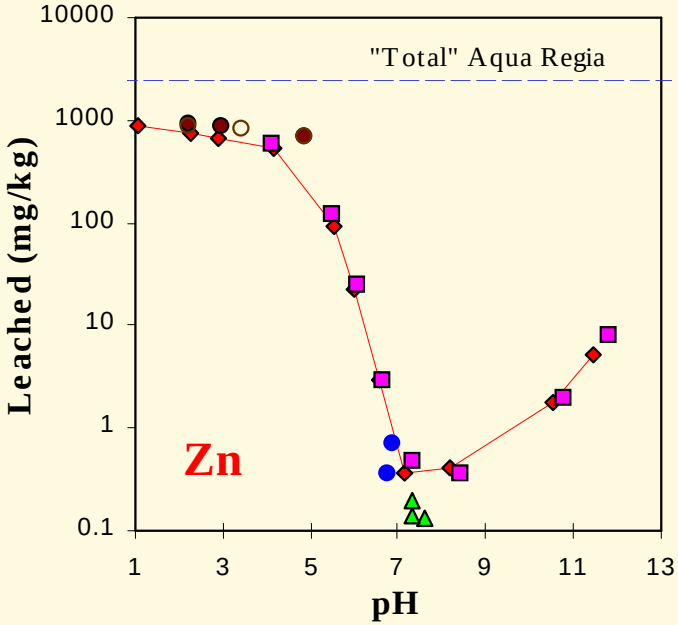
Marine and fresh water systems

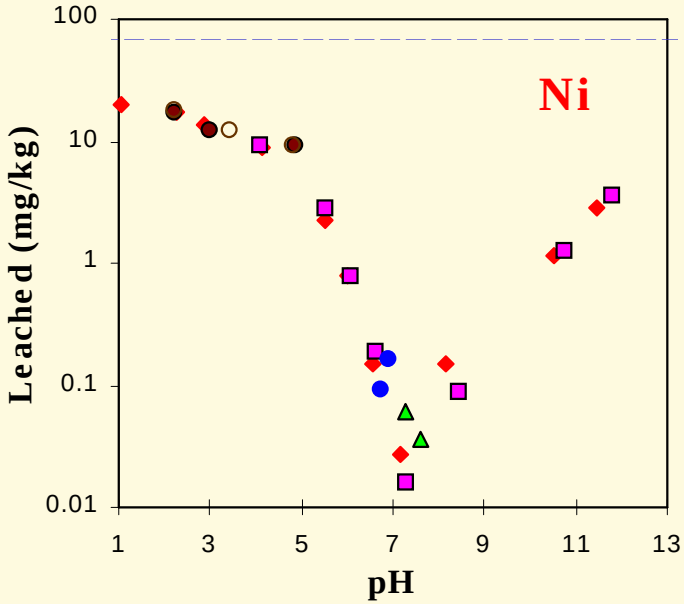


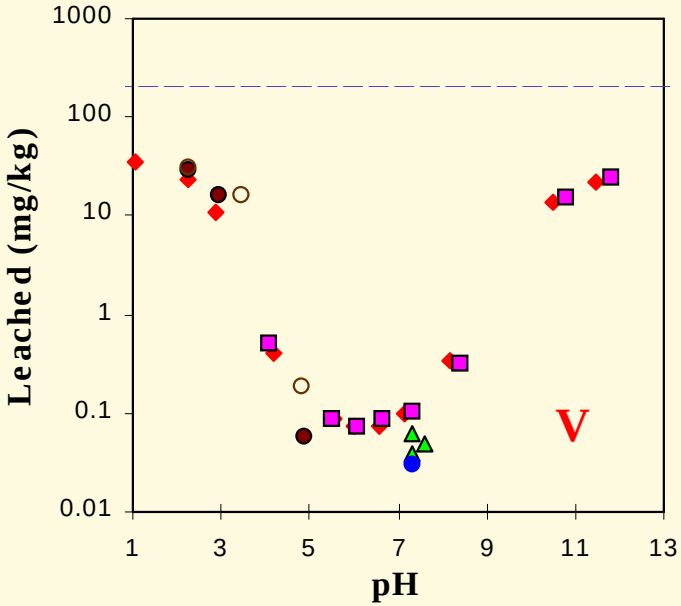


COMPARISON OF DIFFERENT LEACHING TESTS WITH pH DEPENDENCE LEACHING TEST FOR A CONTAMINATED RIVER SEDIMENT









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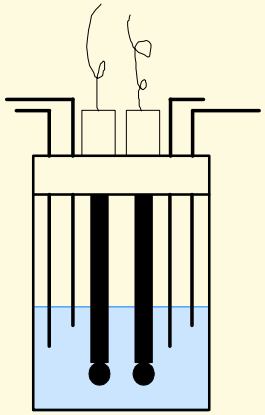
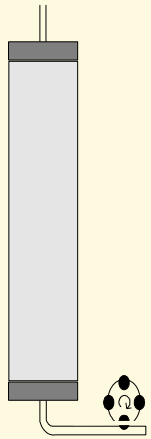
GEOCHEMICAL MODELLING





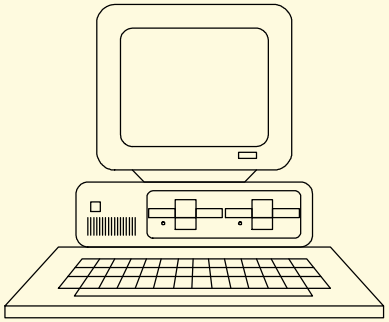
pH stat test and

L/S = 10; t = 48 hr

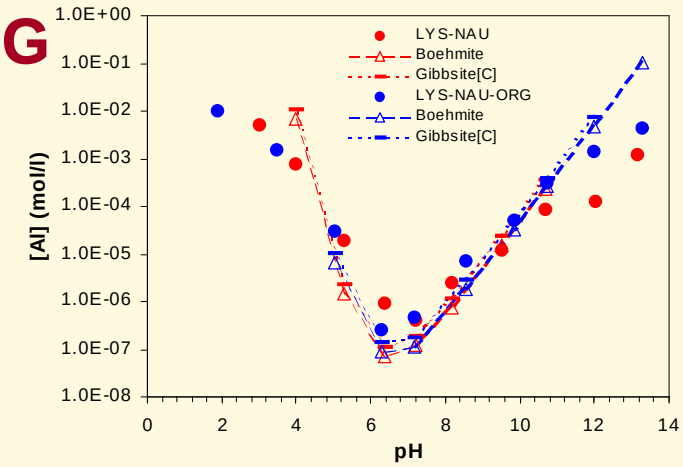
percolation test

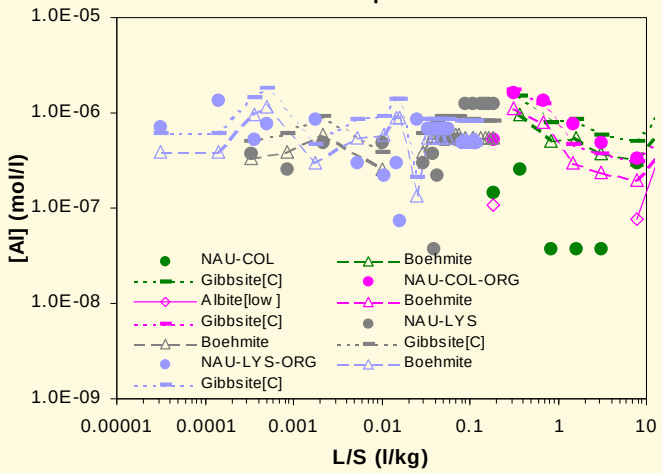
L/S=0.1-10

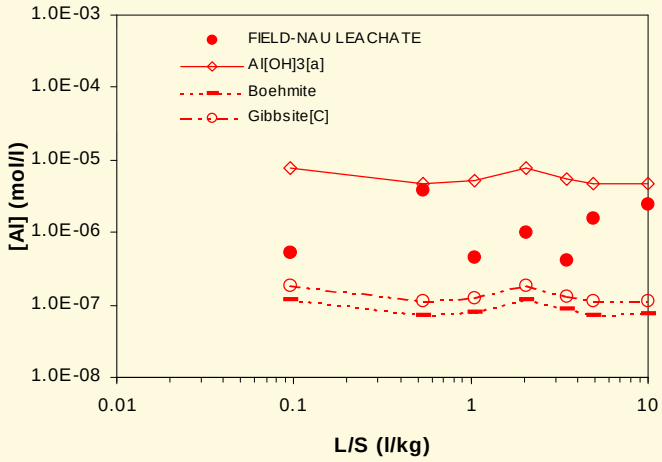
Field leachate



Geochemical modelling







ORCHESTRA with extended MINTEQ database + Nicca Donnan

- Scenario Description
- Material characterization
- Controlling factors
- Modelling leaching
- Validation verification
- Evaluation
- Conclusions

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GEOCHEMICAL MODELLING USING ORCHESTRA

- JAVA based object oriented modelling environment (Meeussen)
- Extended MINTEQA2 thermodynamic mineral database
- Fe oxide sorption module (Dzomback)
- Clay surface sorption module
- NICCA DONNAN based POM and DOC association of metals

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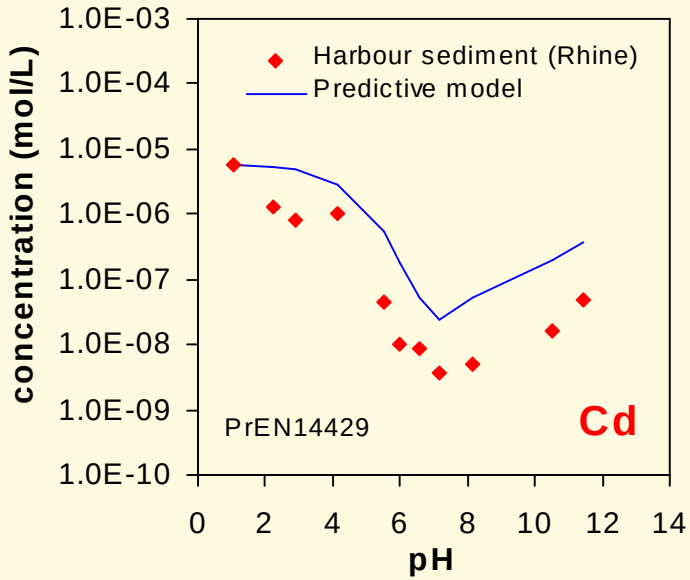
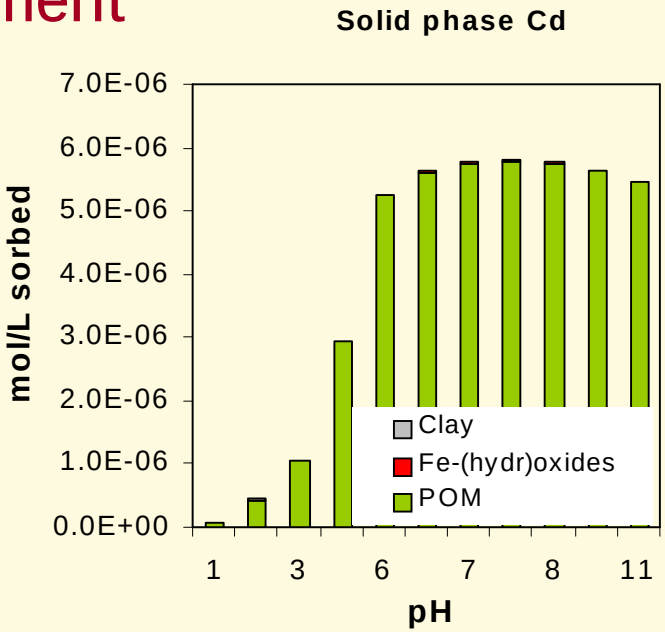
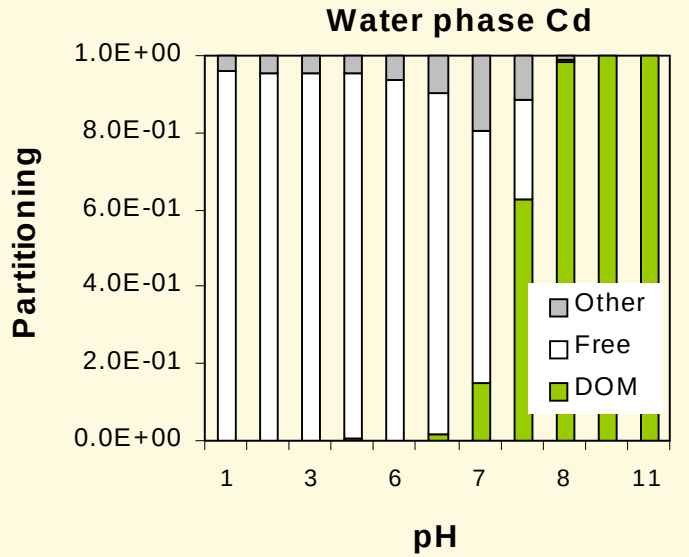
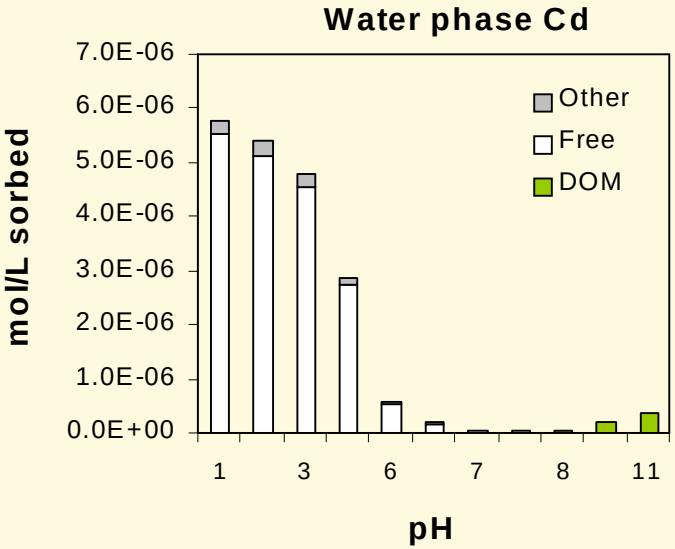
ORCHESTRA modelled solid phase and liquid phase speciation of Cd in a contaminated river sediment









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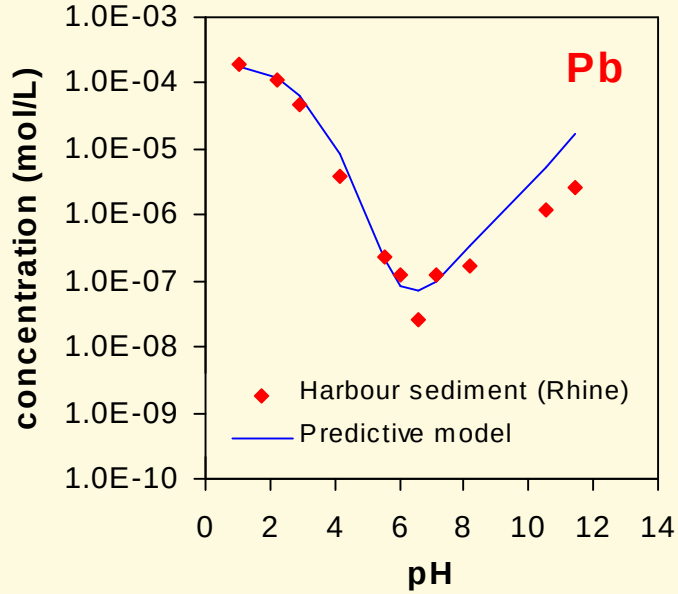
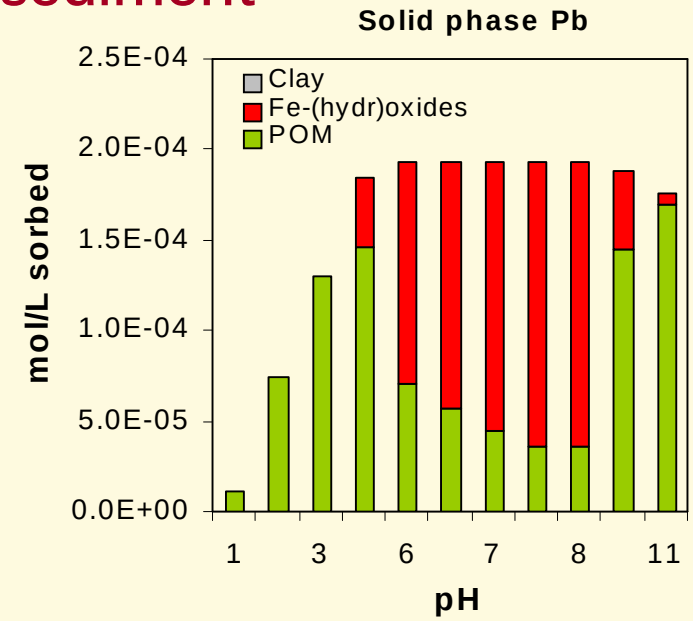
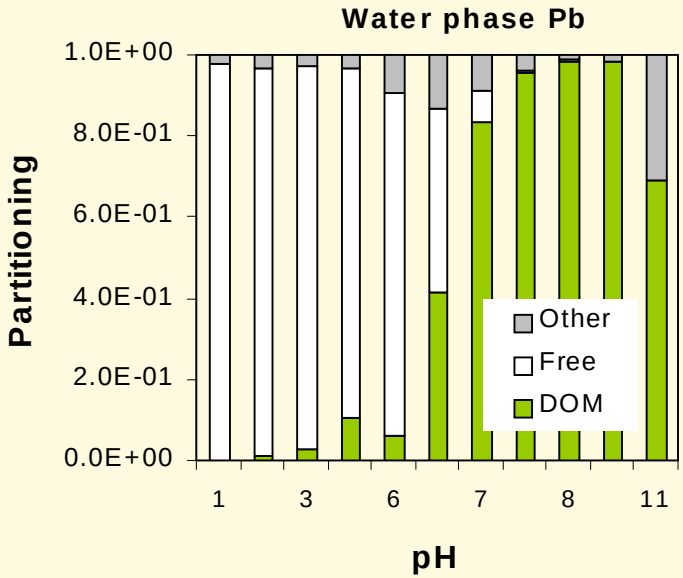
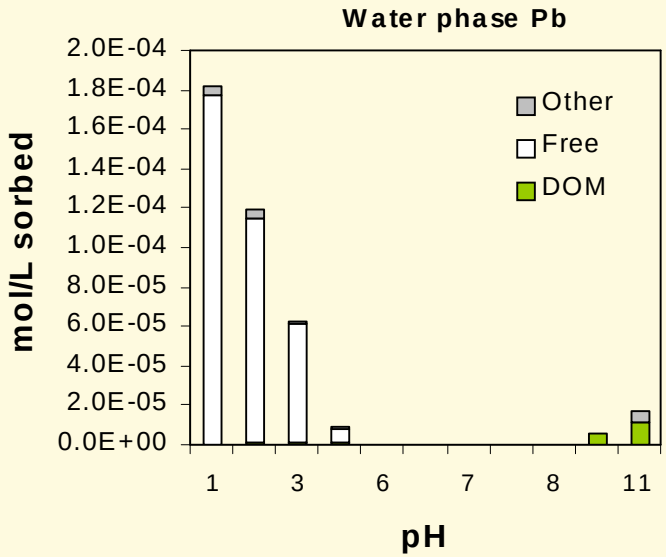
ORCHESTRA modelled solid phase and liquid phase speciation of Pb in a contaminated river sediment

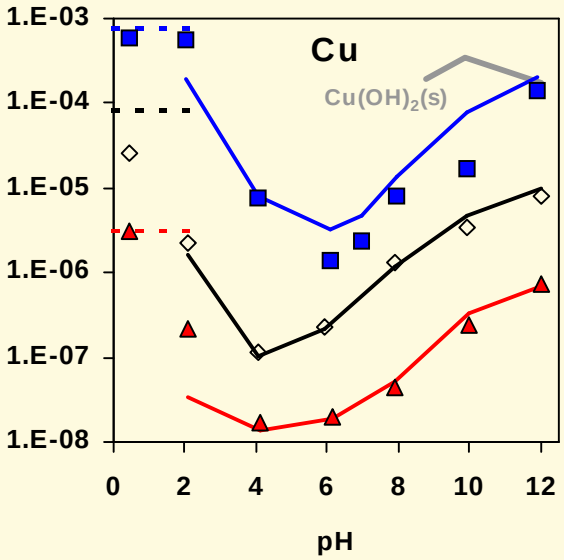


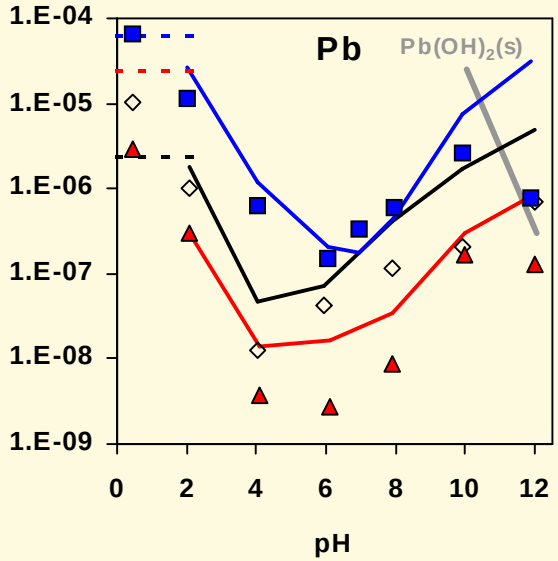


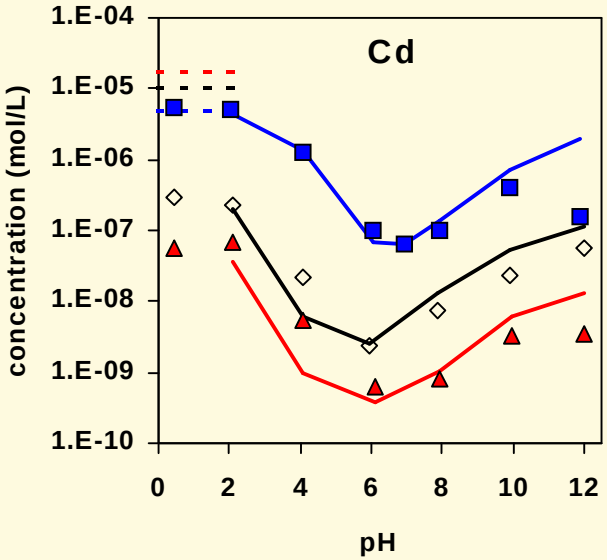


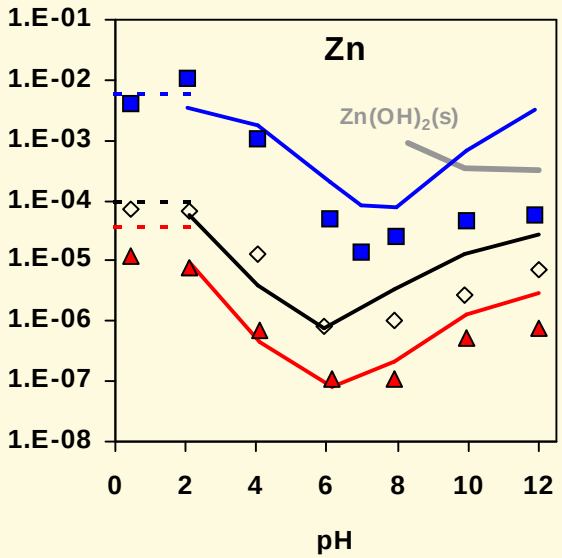


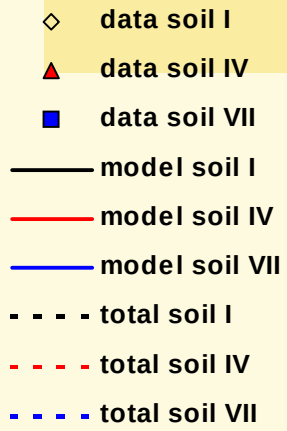
PREDICTION OF LEACHING TEST DATA FOR (CONTAMINATED) SOIL BY GEOCHEMICAL SPECIATION









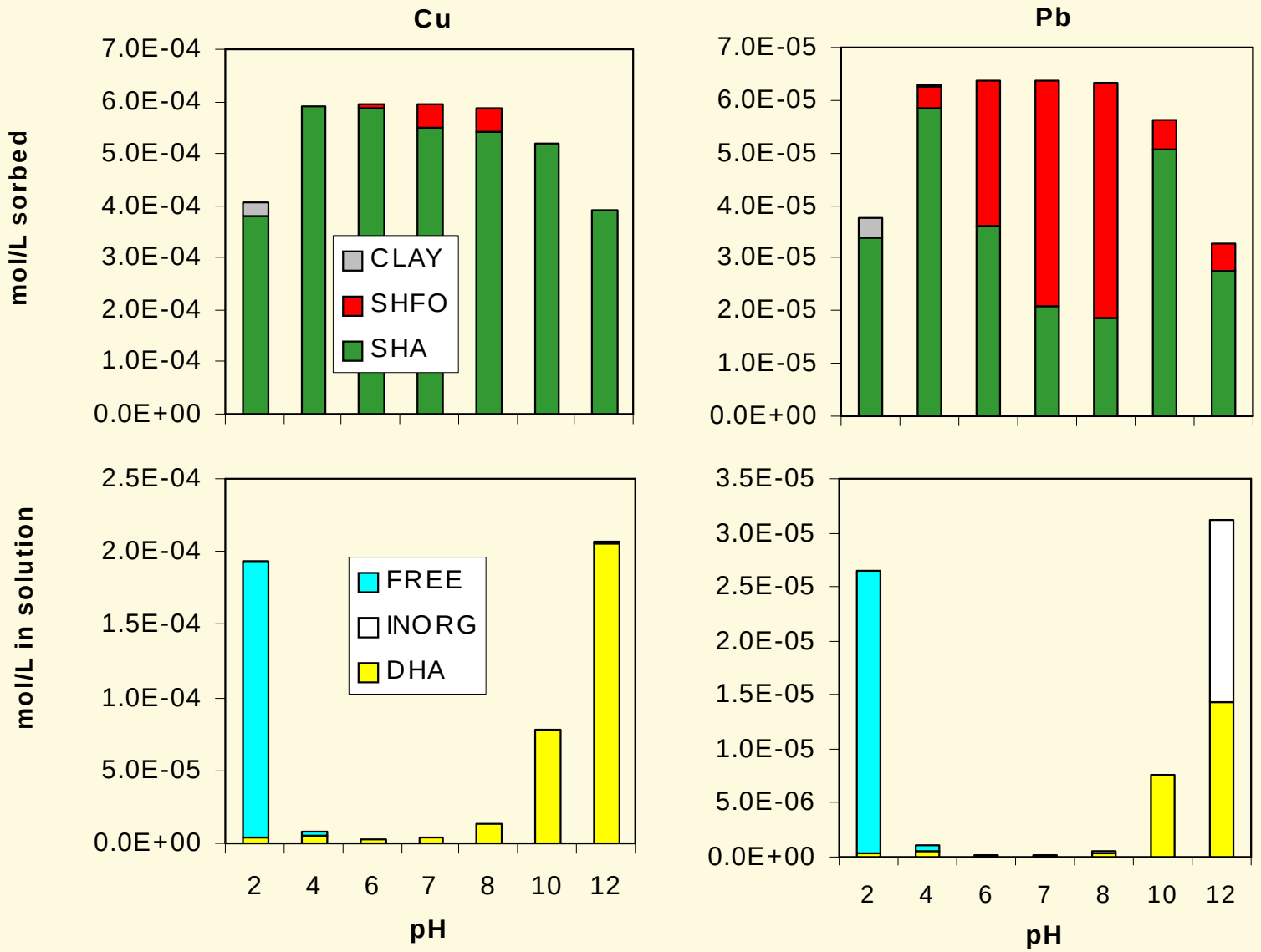


Dijkstra, J.J., Meeussen, J.C.L. and Comans, R.N.J. Leaching of heavy metals from contaminated soils: an experimental and modeling study. (*Accepted.*)

Test: PrEN 14429

ECN

GEOCHEMICAL SPECIATION OF LEACHING TEST DATA FOR (CONTAMINATED) SOIL

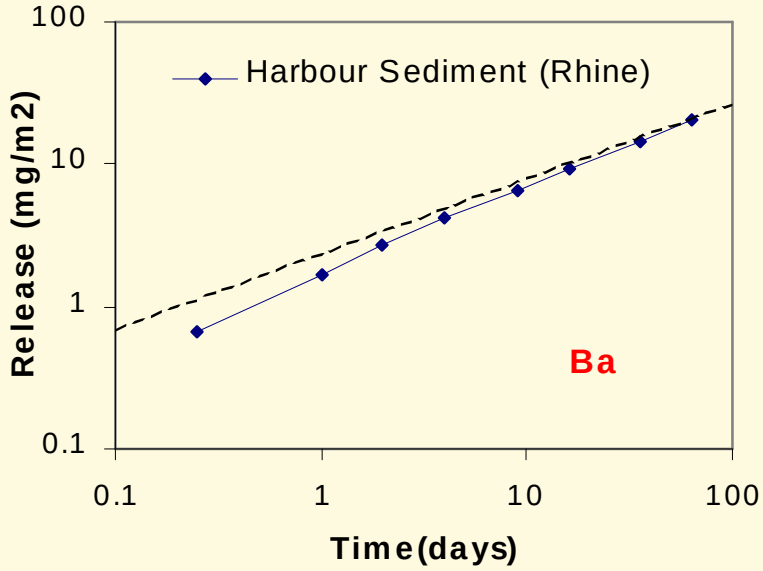


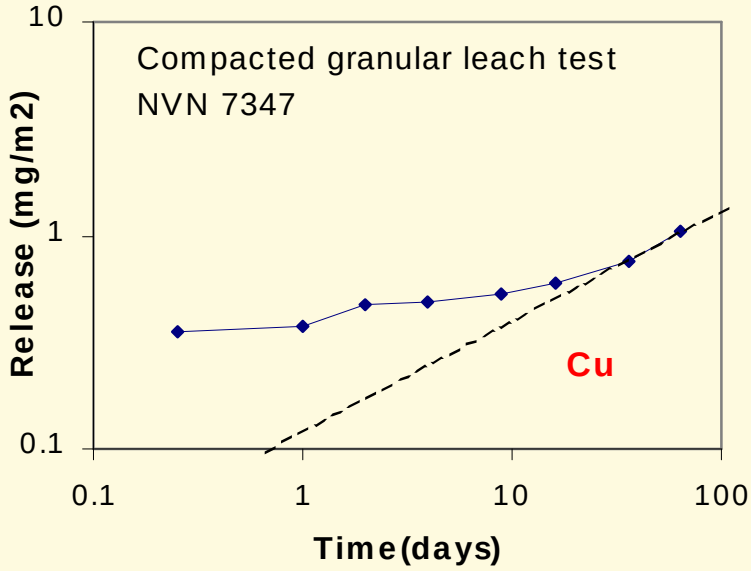
ORCHESTRA with extended MINTEQ database + Nicca Donnan +HFO

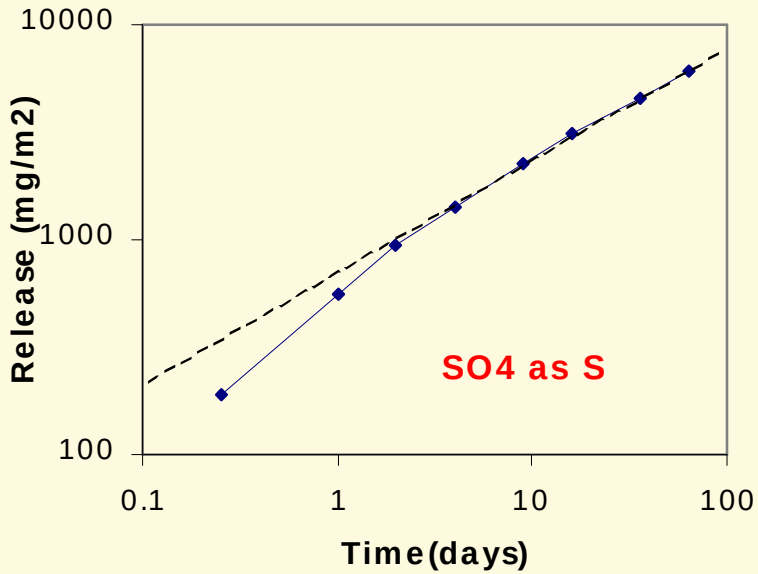
Dijkstra, J.J., Meeussen, J.C.L. and Comans, R.N.J. Leaching of heavy metals from contaminated soils: an experimental and modeling study. (*Accepted)*

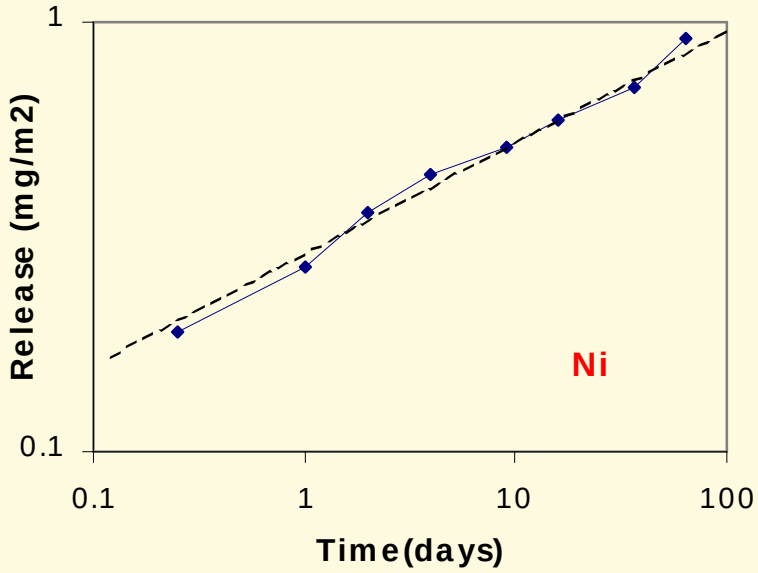
ECN

COMPACTED GRANULAR LEACH TEST RESULTS FOR CONTAMINATED HARBOUR SEDIMENT (SEDIMENT UNDER WATER)





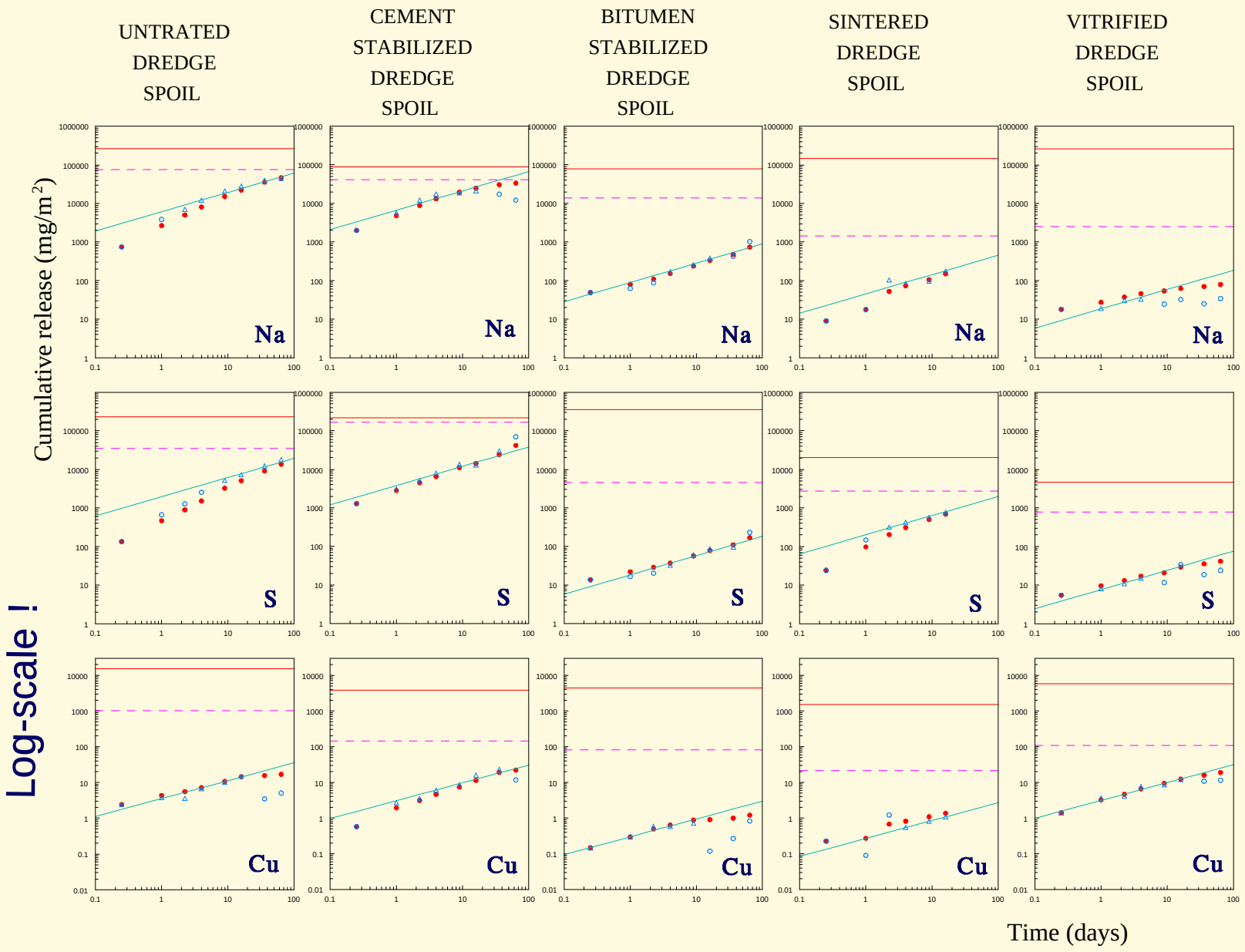




Potential for prediction of long term release

ECN

COMPARISON OF LEACHING BEHAVIOUR OF SEDIMENT (CGLT) AND TREATED SEDIMENT ACCORDING TO DIFFERENT TECHNIQUES WITH TANK TEST



TOTAL

POTENTIALLY LEACHABLE

RELEASE FROM MONOLITH

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FRAMEWORK

A robust and scientifically sound, while practical, **framework for characterisation of environmental behaviour** of soils, sludges, sediments, wastes and constructions materials in a range of applications and exposure scenarios is in development in EU and US

The framework is a **tiered approach**, allowing the user to select the level of testing and evaluation required based on the degree of conservatism needed, prior information available, and balancing costs of testing against benefits from more detailed information

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SCENARIO APPROACH IN JUDGING IMPACT

Expert system /database

Data integration between fields and tests, modeling and verification against field data

Problem definition and test selection

↓

Lab, lysimeter, field data collection, data management, data formatting, storage and retrieval

↓

Management Scenario Description – configuration, design specifications, infiltration, climate

↓

Physical , chemical, biological properties

↓

pH, L/S & time dependence - redox, DOC, EC, ANC

↓

Release with time

Granular — Percolation related

Monolithic — Surface area

↓

Source term description

↓

Impact evaluation subsoil and groundwater

↓

Judgement and decision making
QC; Regulatory aspects
Treatment, Disposal, Utilization, Remediation end-points, long-term stewardship requirements

APPLICABLE TO:

SOIL,

SLUDGE,

SEDIMENT,

WASTE,

LANDFILL,

CONSTRUCT.

MATERIALS,

etc

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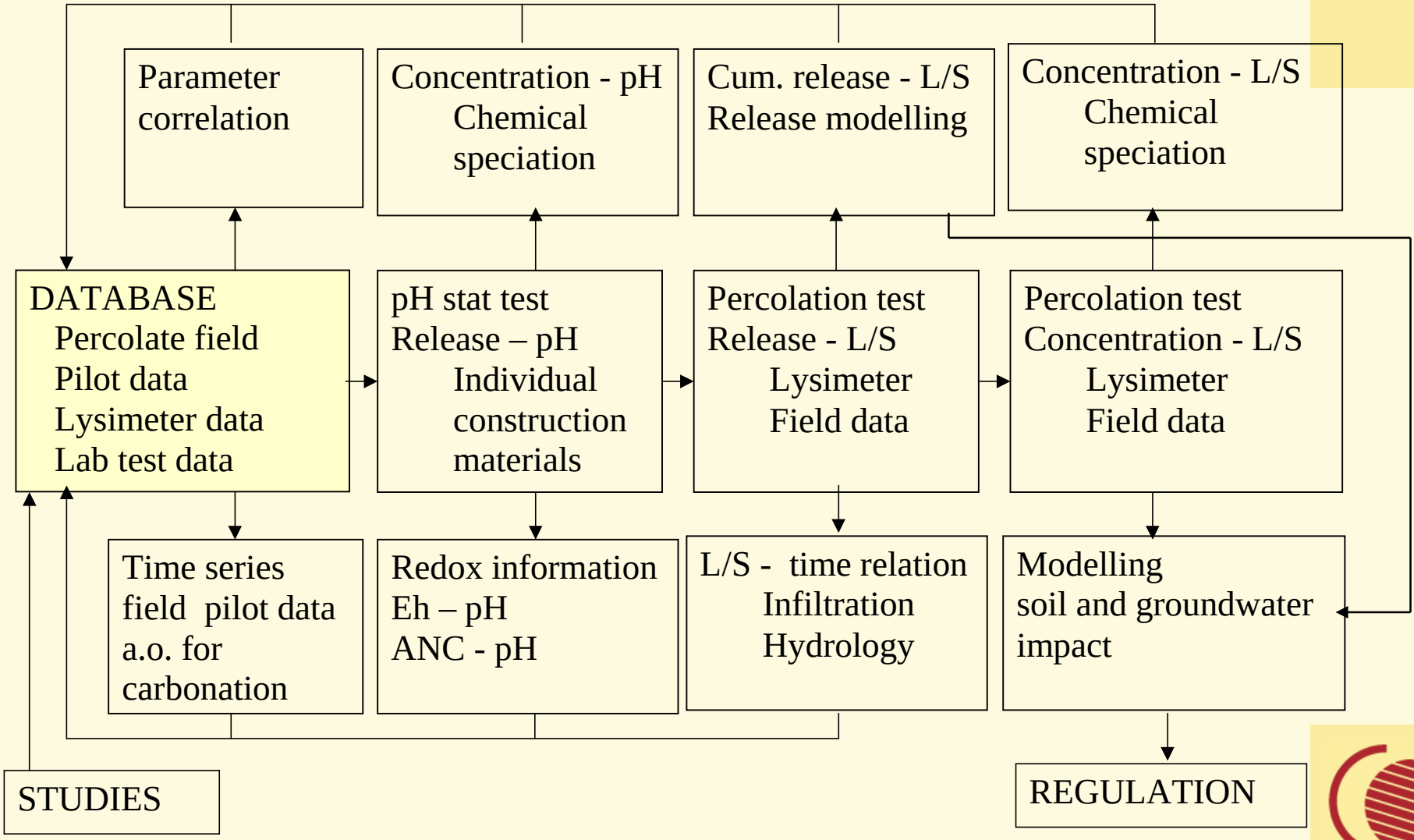
ENV 12920

DATABASE/EXPERT SYSTEM - SEDIMENTS AND SOILS



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HIERARCHICAL APPROACH IN TESTING

- Conservative Estimates (over-estimation of release)
  - Total > Potential > Equilibrium ≥ Mass Transfer limited
- Characterization Testing
  - Detailed baseline evaluation of leaching behaviour for a class of materials (data to be made available in expert system/database)
- Compliance Testing
  - Is the material tested the same as previously characterized class of materials? (Always characterisation data as background)
  - Prior characterization data available from similar material
- Quality Control Testing
  - Is the material changing over time or from batch to batch?
  - Prior characterization data available, history with compliance testing (frequency of testing based on critical nature in view of regulation)

CEN/TC 292 - ENV 12920

Scenario Description

Material characterization

Controlling factors

Modelling leaching

Validation verification

Evaluation

Conclusions

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CRUCIAL VERIFICATION OF LABORATORY DATA WITH FIELD OBSERVATIONS

THE ULTIMATE MODEL VALIDATION IS A VERIFICATION IN THE FIELD AT AN ACTUAL FULL SCALE DEMONSTRATION

IN SOME CASES, MEASUREMENTS ON LONG TERM FIELD EXPOSED MATERIALS PROVIDES RELEVANT INFORMATION

IN MANY CASES, CONSISTENCY BETWEEN DATA FROM DIFFERENT TYPE OF TESTS AND BETWEEN DIFFERENT SOURCES WILL SUFFICE AS FIELD STUDIES WILL NOT BE POSSIBLE IN ALL CASES.

IN SOME CASES, COMPARISON WITH NATURAL ANALOGUES OR HISTORICAL INFORMATION IS POSSIBLE.

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CONCLUSIONS

- In any leaching extraction test on soil or sediments as a minimum pH, EC, redox and DOC should be measured.

- Existing leaching/extraction tests, when placed in perspective to pH dependence leaching test, prove that they are largely governed by pH.

- The pH dependence leaching test has been shown to be a very powerful tool to assess a variety of properties relevant to judgement of environmental behaviour of soil and sediments in a range of utilisation and disposal scenarios.

ECN

CONCLUSIONS

- The SCE when presented as a cumulative leached amount as function of pH matches generally well with the pH dependence test.

- The present geochemical speciation modelling now possible with ORCHESTRA goes well beyond the results and interpretation of SCE as more quantitative and justifiable partitioning can be obtained.

- The pH dependence test in combination with the speciation capabilities will provide new opportunities for bioavailability assessment as free and complexed metals can be quantified.

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CONCLUSION

- Harmonisation of leaching tests across the different fields (soil, waste, sludge, construction materials, etc) strongly needed.
- Leaching proves to be a more relevant property for environmental impact evaluation than composition and it is less sensitive to sampling errors due to solubility control.
- Hierarchy in testing needed in all fields to ensure fundamental knowledge when needed and simple approaches where possible.
- Although not discussed now many of the aspects mentioned are as relevant for organic contaminants as for inorganics. The key issue is avoiding loss of analyte by the equipment.

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CONCLUSION

- The methods of analysis of inorganic and organic contaminants being developed in project HORIZONTAL can be very valuable in combination with the standardised leaching tests discussed here.
- Validation studies of characterisation test methods (not limited to soil and sediments) now available as European standards is needed to be able to quantify test performance.
- Sampling uncertainties sometimes over-stressed, as situations where solubility control is ruling can provide very consistent results from seemingly heterogeneous materials.

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INFORMATION ON LEACHING AVAILABLE AT:

LEACHING BACKGROUND

www.leaching.net (Wascon 2003 workshop)

GRACOS

www.uni-tuebingen.de/gracos

LEACHING IN PROJECT HORIZONTAL

www.ecn.nl/library/horizontal

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