Assessing the consistency of estimated contaminated soil volumes / pollutant masses between characterization and remediation stages: Feedback from real cases and key success criteria (RECORD project)

NICOLE Workshop , Vienna, 15-17 June 2016

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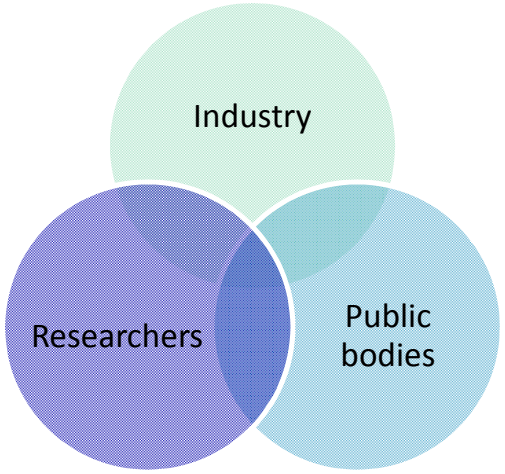
eOde

Geovariances
Where no one has gone before

RECORD: Cooperative research network on waste and the environment

→ Increase the applied knowledge and experience sharing around the end-of-life products, waste, contaminated soils and resources efficiency in the outlook of circular economy

- French network open to all public or privately owned organizations.
- Unique, threefold framework in which **industry, public bodies and researchers** can engage in collaborative research projects.



- 4 major lines of research:
  - Evaluation and characterization of waste and pollutions
  - Management and treatment of waste and contaminated sites
  - Evaluation of the impacts on health and on the natural environment
  - Evaluation of social and economic dimensions

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Record Members:

Context and objective

- Amount of soil to be excavated, treated and valorized/eliminated
  → Impact on the global economy of the remediation project
- Objective:
  - Consistency of estimated contaminated soil volumes / pollutant masses between characterization and remediation stages?
- Inconsistencies have important implications:
  - Financial terms,
  - Scheduling,
  - Health and environmental aspects.
- Many factors:
  - Complexity of pollution,
  - Inadequate characterization methodology,
  - Improper approach for estimating contaminated quantities.

Outline

FAILURES

What kind?
Reasons for?

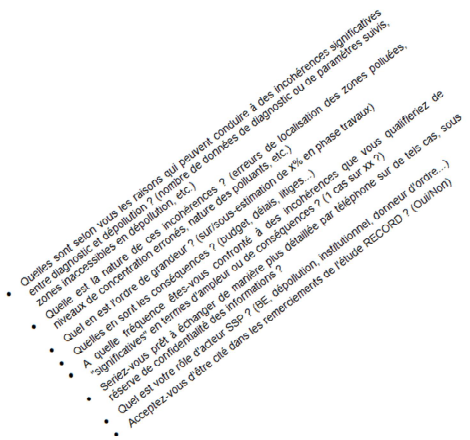
- Methodology
- Results
  - Qualitative survey
  - Analysis of industrial case studies
  - Summary of results

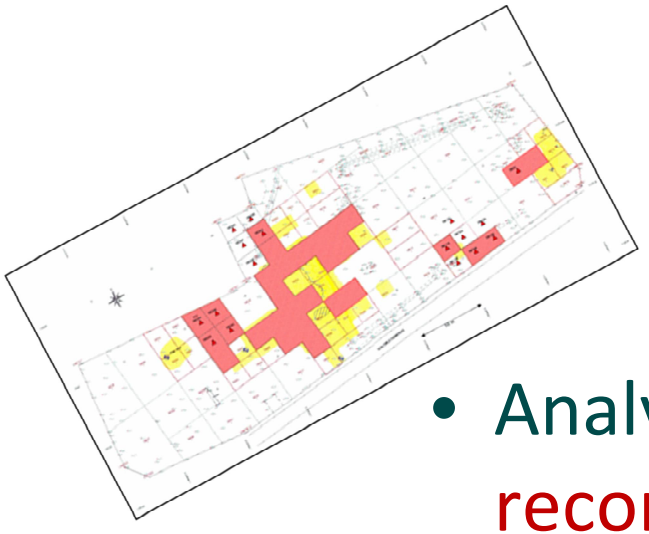
How to solve?
Lessons learned?

- Recommendations
  - Characterization conditions
  - Estimation methods at the characterization stage
  - Indirect information
  - Remediation controls
    → Validation on the industrial case studies

Methodology

- Qualitative survey:
  - Amongst professionals from contaminated land management
  - → To collect their impression about factors explaining the discrepancies

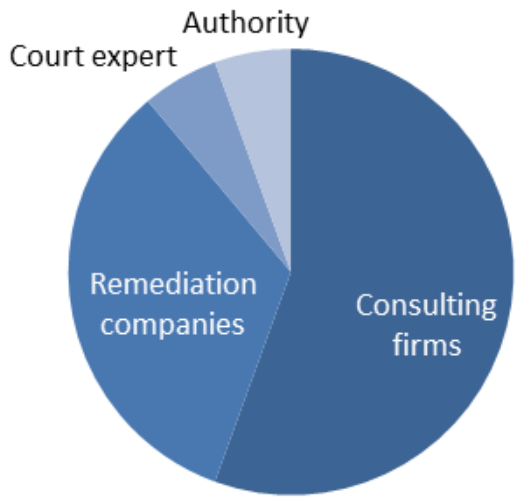




- Collection of industrial datasets:
  - From characterized and remediated sites

- Analysis leading to operational recommendations
- Valorization including a seminar

Qualitative survey



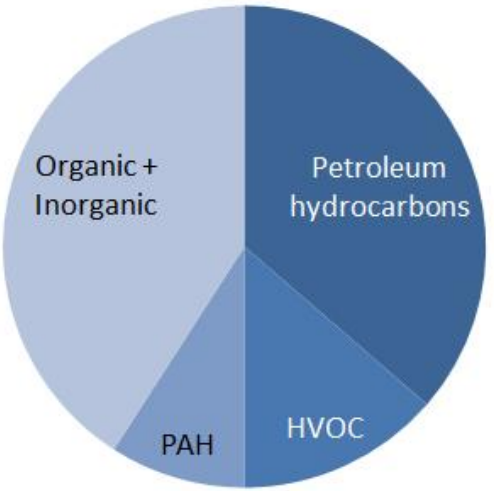
- Sent to 80 contacts / 17 answers
- Reasons leading to inconsistencies?
  - → Data quantity and quality
  - → Issues linked to sampling
  - → Elements insufficiently appreciated during characterization for dimensioning remediation works
  - → Heterogeneity (pollution/geology)
- Nature of the inconsistencies?
  - Wrong delineation is the main source
  - Estimating pollutant masses requires a good assessment of concentrations levels + inappropriate controls during remediation?

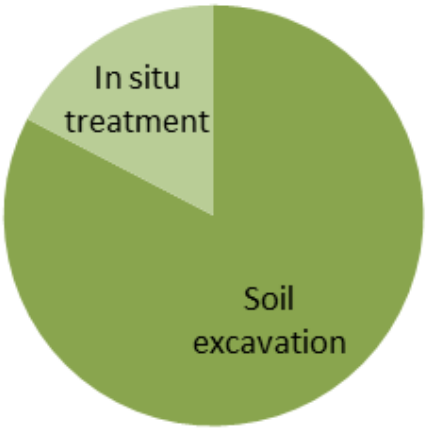
Qualitative survey

- Order of magnitude of the differences?
  - 10-30%: usual and "acceptable". *"One should systematically inform the client that an estimation with an error lower than 10% is pure luck"*
  - 50-100% sometimes: significant errors
  - Up to 1000% happens: unacceptable situations!
- Frequency of the differences?
  - Between 1 in 2 and 1 in 10 cases
  - Significant differences (≥25%) in 25% of cases
- Consequences?
  - Financial issues
  - Times delays
  - Litigation (not always a legal action)
  - Problems between the final client and the soil remediation company (consultancy usually not involved anymore)

Industrial case studies

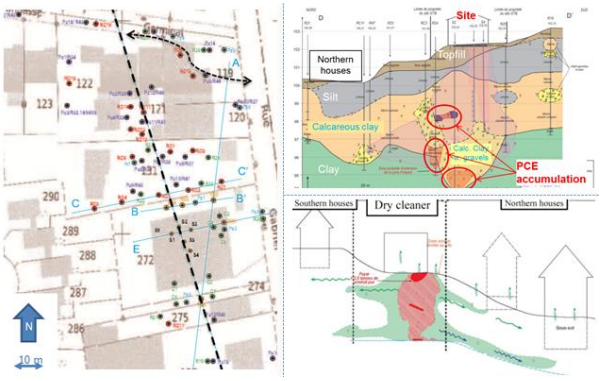
- 23 industrial datasets, with information regarding:
  - Soil volumes/Pollutant masses estimated at characterization stage
  - Soil volumes/Pollutant masses actually remediated
  - Known estimation conditions
- Provided by site owners / consultancies, remediation companies
- Great diversity of situations:
  - Size
  - Activity type
  - Pollution nature





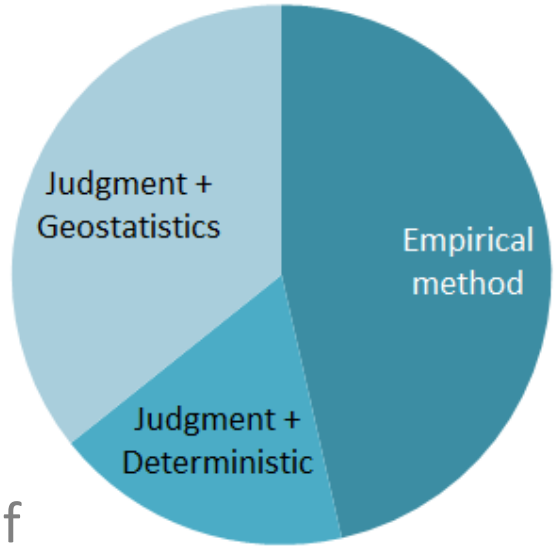
Industrial case studies

- Developing comparison criteria
  - Pollution situation: type of pollutants, size of the area…
  - Complexity: number of activities, of groups of chemical compounds, of geological layers…
  - Seniority of the characterization: number of phases, total duration, ending year
  - Characterization conditions: density of boreholes, spatial coverage of data, homogeneity of sampling protocol…
  - Methodology to assess contaminated quantities:
    - Expert judgment
    - Deterministic interpolations
    - Geostatistical methods
  - Conditions of estimation during remediation

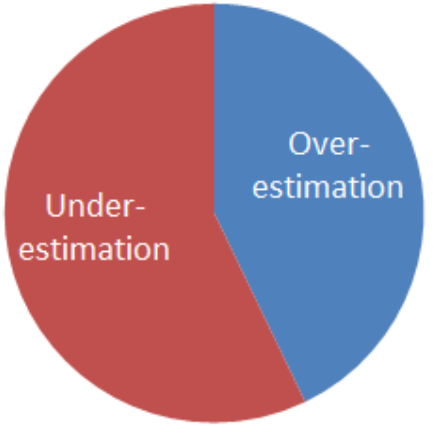


Summary of results

- Some limitations:
  - Not enough case studies to allow assessing in an accurate and conclusive way the impact of the numerous criteria
  - Proportion of sites with geostatistics greater than in reality
  - All collected cases are rather complex (with pathological cases excluded) → findings and recommendations valid for sites with a certain level of complexity



Summary of results



- Relative estimation errors
  - Main criterion
  - Errors of 26% in average, ranging from 1% to 84%
  - Differences larger than 25% in approximately 25% of cases
- Every estimate is affected by uncertainties and errors…even during remediation!
- Numerous factors complicate the comparison: changes of objectives, new pollutants,…more difficult with in situ treatment

→ Definition of a reliability criterion of the estimated contaminated quantities during remediation

Summary of results

- Factors influencing the quality of the prediction:

Favorable factors

- Characterization conditions: estimation error of 18% in average in favorable conditions, 32% if not
- Smallest and less dispersed errors when applying geostatistical methods in the rules of art

Unfavorable factors

- Complexity due to the diversity of contamination and lithology (number and heterogeneity of soils)
- More significant differences with heavy hydrocarbons and PAHs in the form of bitumen
- Uncertainty in the remediation results

Recommendations

→Clear operational recommendations

- To be kept in mind:
  - It is possible to be really lucky!
  - The risk of making a « radical error » can never be fully excluded

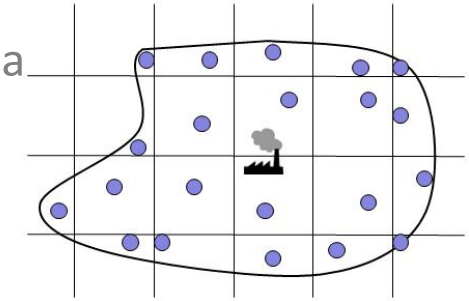
- Complexity:
  - risk of significant differences is higher in complex pollution contexts
  - … but can be compensated with relevant investigation conditions

  → Adequate characterization effort + Increased controls during remediation

Recommendations: Characterization conditions

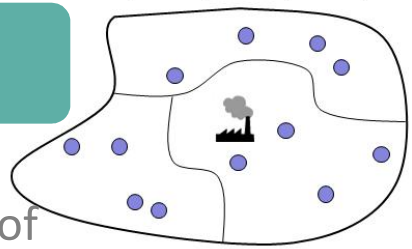
Characterization conditions

- Homogeneity of the sampling procedures
- Homogeneous spatial distribution of the boreholes in the investigation area
- At least one borehole per 100m²
- Systematic sampling along the borehole
- At least one sample per meter in each borehole



Indirect information

- Study the correlation between pollutant and indirect information
- Integrate the indirect data in estimation of contaminated quantities in case of a « good » correlation



Remediation controls

- Sampling and analysis on the border and at the bottom of the excavation area
- Sampling and analysis of the excavated material
- Sampling and analysis nearby the area addressed by the remediation
- Assessment of potential residual pollution

Recommendations: Estimation method at the characterization step

- Empirical approaches:
  - Provide very good results in some cases / Strong dispersion
  - Success factors: tricky to identify
- Geostatistical approaches (+ expert judgment):
  - Improves the consistency
  - Choice of the suited approach is important (conditional simulations / support)
- Deterministic method:
  - poorer than expert judgment or geostatistics
  - …but too few cases

		Complexity of the pollution situation	
		Average	**High**
Investigation conditions	**Favorable**	Empirical	Empirical
		+Deterministic	+Deterministic
		+Geostatistics	**+ Geostatistics**
	Unfavorable	Empirical	**Situation to be absolutely avoided** Important risk of really significant discrepancy between characterization and remediation results, whatever the estimation method.
		+Deterministic	
		+Geostatistics	

Validation on the industrial case studies

- Posterior analysis:
  - Validating the relevance of the success factors
  - What should have been done to improve the prediction quality?

LESS CONTRASTED SITUATION: OVER-ESTIMATION OF 76%		
CARACTERISTICS		DECISIVE FACTORS
• Former Heating plant • Petroleum hydrocarbons • Heterogeneous backfill • In situ treatment + excavation	SUCCESS FACTORS	• Not very complex situation • Investigation quality criteria: o Homogeneous protocole o 1 borehole / 24 m^2 • Geostatistical estimation
	FAILURE FACTORS	• Investigation quality criteria not fulfilled: • Over and under-sampled areas • Oriented vertical sampling • Weak density of 1 sample / 1.40 m • Errors when applying geostatistics

Conclusion

- Original approach combining a survey and 23 case studies
- A lot of operational recommendations:
  - Even if the number of answers/cases is not large
  - Similar conclusions from different information
- Positive evolution of practice / Discrepancies are acceptable in 75% of cases
- The project could be enriched by other case studies in the future to establish a precious database on the evolution of characterization and decontamination practices

THANK YOU

… for your attention

… to all participants: survey answers, case studies providers and reading committee

… to NICOLE network for their numerous contributions to RECORD projects