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)

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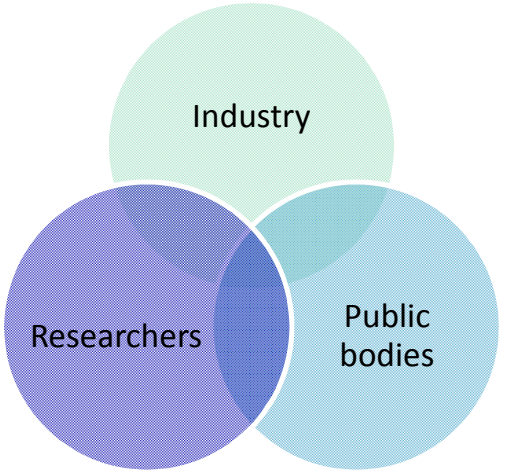
eOde

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:

Geovariances, EDF, ENGIE, Renault, Solvay, Total, SNCF, Trédi, Sarpi Veolia, Ministère de l'Écologie, du Développement durable et de l'Énergie, ADEME, tiru Groupe EDF, Socotec, Suez, SCORE LCA, eOde

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

Blockages identification

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

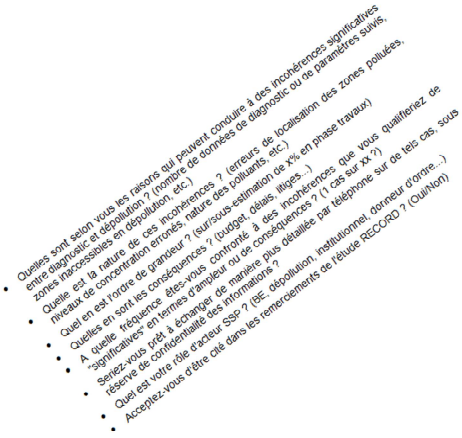
Keys to success

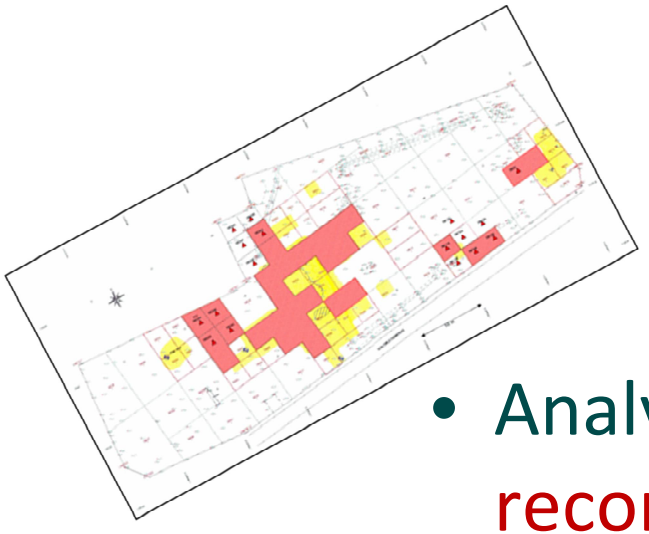
- Recommendations
  - Characterization conditions
  - Estimation methods at the characterization stage
  - Indirect information
  - Remediation controls

  → Validation on the industrial case studies

Methodology

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

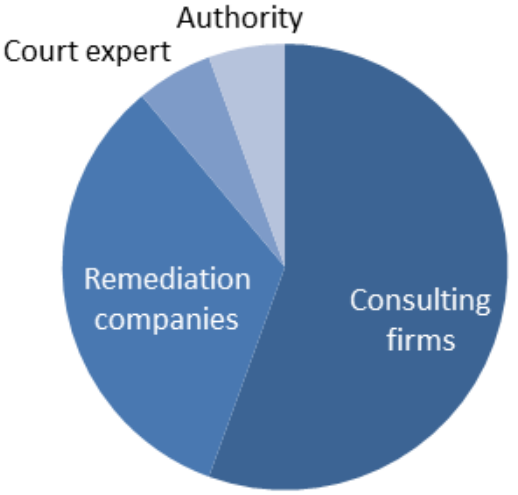




- Collection of industrial datasets:
  - From characterized and remediated sites

- Analysis leading to operational recommendations
- Valorization including a seminar

Qualitative survey



- Sent to 80 contacts
- 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?

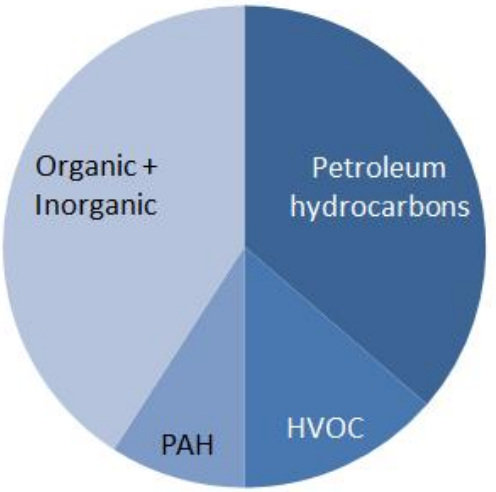
Qualitative survey

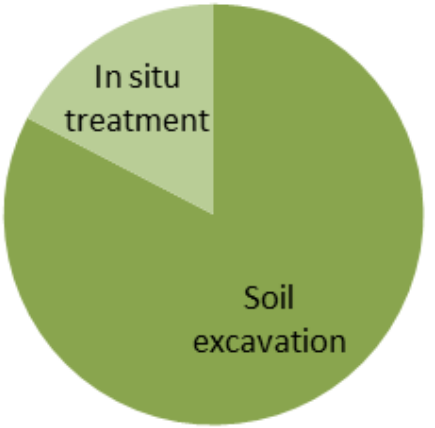
"A lot of decontamination projects is going well, with costs and time controls!"

- 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, some extreme cases: +100%
- Frequency of the differences?
  - Significant differences (≥25%) in 25% of cases
  - Between 1 in 2 and 1 in 10 cases
- Consequences?
  - Financial issues (> 50% of answers)
  - Times delays (~50%)
  - Litigation (not always a legal action)
  - Depending on the global amount of contaminated volume (25% of difference does not have the same impact when decontamination costs 100 k€ or 4 M€!)

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

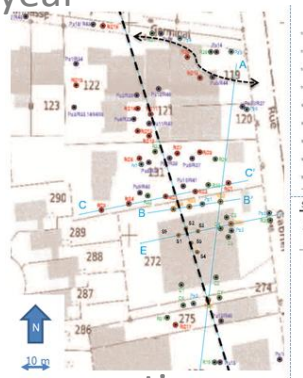




Industrial case studies

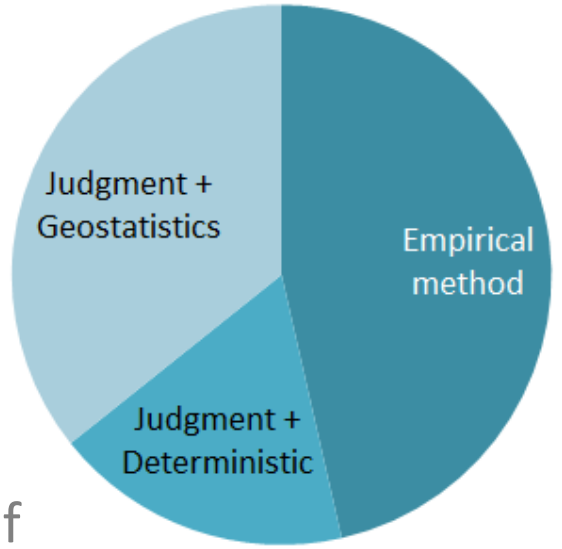
- Developing comparison criteria

o Complexity	Type of pollutants, size of the area… Number of activities, of groups of chemical compounds, of geological layers…
o Characterization conditions	Density of boreholes, spatial coverage of data (horizontal/vertical), homogeneity of sampling protocol…
o Seniority of the characterization	Number of phases, total duration, ending year
o Methodology to assess contaminated quantities	Expert judgment Deterministic interpolations Geostatistical methods
o Conditions of estimation during remediation	Controls on the borders and bottom of the excavation, Controls of the quality of the evacuated soils, Controls nearby the treatment area, ….



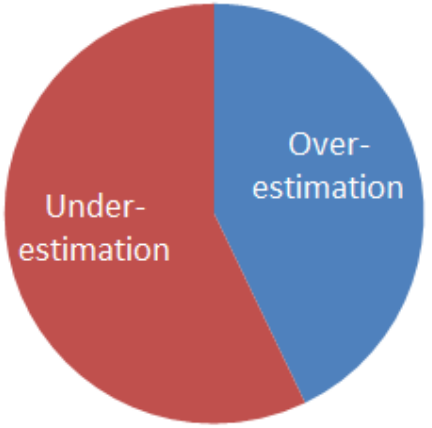
Summary of results

- 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 (23 case studies)
  - Main criterion
  - Errors of 26% in average, ranging from 1% to 84%
  - Differences larger than 30% in approximately 30% of cases
    → Errors are acceptable in 70% of cases
  - More under-estimations than over-estimations



- Remarks:
  - 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

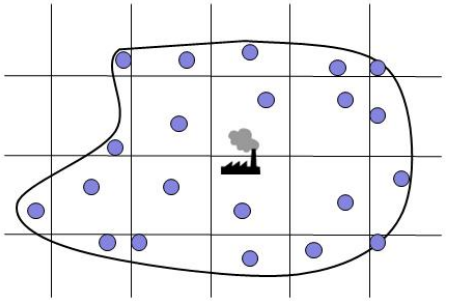
- Complexity:
  - risk of significant differences is higher in complex pollution contexts
  - … but can be compensated with relevant investigation conditions

  → Adequate characterization effort + Increased controls during remediation

Recommendations: Characterization conditions

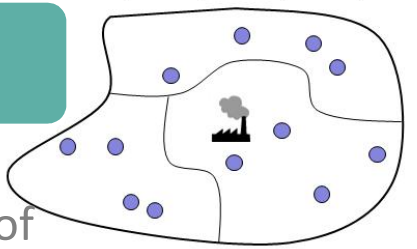
Characterization conditions

- 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

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

MODEL CASE : UNDER-ESTIMATION OF 2%	
CARACTERISTICS	SUCCESS FACTORS
• Former laundry • Marly-limestone • Perchloroethylene • In situ treatment (venting) combined with excavation	• Mid-complex situation • High technical level • 4/5 criteria of investigation quality: o Homogeneous Protocol o 1 borehole every 40 m^2 o Regular sampling + Vertical o > 1 sample / m • Geostatistics in the state of art

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?

COUNTEREXAMPLE : OVER-ESTIMATION OF 72%	
CARACTERISTICS	FAILURE FACTORS
• Former oil depot + bitumen plant • Backfill, lime, sand and marl • Heavy hydrocarbons, PAH • On site treatment with biopile	• Very complex situation • Investigation quality criteria not fulfilled : o Heterogeneous protocol o 1 borehole / 286 m^2 o Over and under-sampled areas o Vertical sampling • Empirical estimation

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:

- Record
- Reading committee: R. Bayard, Ph. Botella, J.-P. Cazalets, J.-M. Cormier, L. Cimolino, B. Couffignal, F. Decung, D. François, L. Geneau, P. Jolly, G. Lanfrey, C. Ollivier-Delahaye, V. Restoin, H. Romano, H. Roussel, E. Serre
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- Case studies providers