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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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

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:
    o Expert judgment
    o Deterministic interpolations
    o Geostatistical methods
  – Conditions of estimation during remediation
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
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
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

<table>
<thead>
<tr>
<th>Investigation conditions</th>
<th>Average</th>
<th>High</th>
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</thead>
<tbody>
<tr>
<td>Empirical</td>
<td>Empirical</td>
<td>Situation to be absolutely avoided</td>
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<tr>
<td>+Deterministic</td>
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<td>Important risk of really significant discrepancy between characterization and remediation results, whatever the estimation method.</td>
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<td>+Geostatistics</td>
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**Note:**
- Average: Investigation conditions are considered as typical.
- High: Investigation conditions are considered as extreme.
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?

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<tr>
<th>CHARACTERISTICS SUCCESS FACTORS</th>
<th>DECISIVE FACTORS</th>
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<tbody>
<tr>
<td>• Former Heating plant</td>
<td>• Not very complex situation</td>
</tr>
<tr>
<td>• Petroleum hydrocarbons</td>
<td>• Investigation quality criteria:</td>
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<tr>
<td>• Heterogeneous backfill</td>
<td>o Homogeneous protocol</td>
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<tr>
<td>• In situ treatment + excavation</td>
<td>o 1 borehole / 24 m²</td>
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<tr>
<td></td>
<td>• Geostatistical estimation</td>
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<table>
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<tr>
<th>CHARACTERISTICS FAILURE FACTORS</th>
<th>DECISIVE FACTORS</th>
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<tr>
<td>• Former oil depot + bitumen plant</td>
<td>• Investigation quality criteria not fulfilled:</td>
</tr>
<tr>
<td>• Backfill, lime, sand and marl</td>
<td>• Over and under-sampled areas</td>
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<tr>
<td>• Heavy hydrocarbons, PAH</td>
<td>• Oriented vertical sampling</td>
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<td>• On site treatment with biopile</td>
<td>• Weak density of 1 sample / 1.40 m</td>
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<td>• Errors when applying geostatistics</td>
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LESS CONTRASTED SITUATION: OVER-ESTIMATION OF 76%
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