The use of a Geographic Information System (GIS) with integrated human health risk assessment capabilities to optimize the remediation strategy for a sensitive brownfield redevelopment.

V Seminário Internacional sobre Remediação e Revitalização de Áreas Contaminadas - Sao Paolo, 6 November 2007

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Foreword

As the project and land sale discussions are still on-going, the presentation will focus on the technical approach and associated tools illustrated with a hypothetical case.

Key parameters are taken from the real case, but all figures, site layout and associated data have been made up.
Context and objectives

- **Key project parameters**
  - 11 ha industrial site in urban area: chemical development
  - Sensitive use redevelopment: school, nursery, residential areas, hospital, etc…
  - Short deadlines: final site closure by the end of 2006 / future construction works should begin by the end of 2008

- **In the French regulatory context, the remediation project is validated by the administration if residual risk assessment shows that residual concentrations are compatible with detailed future site use**

- **Need to develop a sophisticated tool in order to**
  - Manage and archive large number of data
  - Run risk assessment simulations quickly in order to anticipate the influence of architectural changes in the project
  - Meet deadlines and optimize the project costs
Site closure and remediation process

Key Steps

OWNER

1 – Site closure

2 – Site investigations

3 – Characterization of future site use

Upload of data in GIS and risk-based assessment to optimize works and future use projects

4 – Remediation works

5 – Deed restrictions

BUYER/REDEVELOPER

6 – Redevelopment

Use of GIS & Database

Field observations
## Remediation of industrial site for a sensitive Brownfield redevelopment

<table>
<thead>
<tr>
<th>Description</th>
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<tr>
<td><strong>2006 : Site closure</strong></td>
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### Sensitive Future Use
- School, residential housing, hospital, nursery...

### Activity
- 1912 – 1937: metals pre-treatment
- 1938 – 2007: chemical development

### Resources
- Max: 475 employees
- Min: 142 (2006) employees

### Hydrogeology
- Alluviums
- Groundwater at 15m depth

### Other stakeholders
- Global redevelopment plan defined with all stakeholders such as town hall, regulatory authorities, redeveloper
Remediation of industrial site for a sensitive Brownfield redevelopment

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Field observations

BUYER/REDEVELOPER

6 – Redevelopment
Site characterization plan elaborated in cooperation with authorities and third party expert:

- soil borings and monitoring wells based on a 15 m x 15 m x 1m grid
- up to 7 or 15 m depth – for 45 substances
2 – Site investigations

Soil Log

Automated importation of data

Lab certificates

Samples
2 – Site Investigations

Groundwater

Log

Lab certificates

PCE plume

VOCs concentrations in Pz1 (µg/l)

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Average value
2 – Site investigations

Summary

Over 200,000 data were generated by site investigations of 11ha site

Sampling
• Soil
• Groundwater
• Demolition material
Automated grid of the site (15 m x 15 m x 1 m h)
## Site investigations

### Organization in GIS

- **Identification (reference name/id)**
- **Localisation (x, y, z, l, h, p, z top, z bottom)**
- **History**
  - Past use (basement, backfill, …)
- **Future Use**
- **Areas (grids) requiring excavation**
- **Analysis**
- **Geology**

### Table

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**sanofi aventis**

L'essentiel c'est le savoir.

**EN Viron**
2 - Site investigations

Organization in GIS

Layer 4: Soil borings
Layer 3: APCs
Layer 2: Piezometers
Layer 1: Current and future buildings

Storage of data by grid and by layer
Remediation of industrial site for a sensitive Brownfield redevelopment

Key Steps

OWNER

1 – Site closure
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3 – Characterization of future site use
4 – Remediation works
5 – Deed restrictions

Use of GIS & Database

BUYER/REDEVELOPER

6 – Redevelopment

Upload of data in GIS and risk-based assessment to optimize works and future use projects

Field observations
3 – Characterization of future site use
Redevelopment project

All data associated with redevelopment project is uploaded in GIS

- Depth of excavation
- Building activities
- Ventilation rates
- Construction specifications
- ....
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Use of GIS & Database

Field observations
Risk Module
Conceptual Site Model

Exposition 7 h/j aux concentrations maximales calculées au dessus du vide sanitaire ou des locaux techniques

3,5
Locaux "technique" au bâtiment énergies
4
Locaux "technique" sur la partie sud du bâtiment

3
Locaux "technique"

2,8

0,9

VS

Ft3

Sous sol

Ft1

Vie sanitaire

Exposition 1 h/j aux concentrations maximales calculées à l'extérieur ou dans le parking

Extérieur/Parking enterré - 1 h/j
- **Fate & Transport equations**
  - from international literature: J&E, VOLASOIL, CSOIL,…
  - for all types of media: soil & gw vapors, plant uptake, …

- **Exposure equations**
  - for all types of pathways: vapor inhalation, soil & plant uptake, dermal contact…
Risk Module
Database Structure

- Physchem & tox data
  - Henry’s law
  - Koc
  - Inhalation slope factor
  - Oral tolerable daily intake
  - ...

- Building properties
  - Building ventilation rate
  - Building perimeter
  - Room height
  - Crawl space
  - Dust emission
  - Vapor migration
  - Soil characteristics
  - Porosity
  - ...

- Transfer pathways
  - Lifetime duration
  - Exposure duration
  - Exposure frequency
  - Soil, water ingestion rate
  - Skin surface
  - ...

- Human exposure parameters
### Scenario

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<td>Enfant / Prise du corps (kg)</td>
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<td>Lenf</td>
<td>Enfant / Durée d'une vie (jours)</td>
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<td>TouEnf</td>
<td>Enfant / Temps passé sur le site à l'extérieur (h/jour)</td>
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<td>Var</td>
<td>Vitesse du vent (m/sec)</td>
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<td>W</td>
<td>Ligne de la zone source parallèle à la direction du vent (cm)</td>
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<tr>
<td>Pe</td>
<td>Taux d'émission des particules à partir du sol (g/cm²/sec)</td>
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<td>Pourcentage de poussière à l'intérieur issues de l'extérieur</td>
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<tr>
<td>ER</td>
<td>Taux de renouvellement de l'air (sec⁻¹)</td>
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</table>

**Notes:**
- **Lb:** Hauteur du plafond du bâtiment (cm) 280
- **Forad:** Fraction de fissures dans les fondations 0.001
- **Qaard:** Fraction d'air contenu dans les fissures des fondations 0.06
- **Qwad:** Fraction d'eau contenu dans les fissures des fondations 0.12
- **Jb:** Surface du bâtiment (cm²) 120000
- **deltaP:** Différentiel de pression (g/cm²-s) 30
- **Kv:** Permeabilité des sols (vapeur) (cm²) 0.00000001
- **Xm:** Profondeur du bâtiment (cm) 1406
- **Uair:** Viscosité de l'air (g/cm²-s) 0.000175
- **Lraad:** Profondeur de la fissure (cm) 25
- **Lw:** Profondeur de la nappe (cm) 1406
- **h:** Coefficient de la frange capillaire (cm) 5
- **Vsi:** Fraction volumique de sols 0.59
- **QT:** Porosité totale 0.41
- **Qas:** Fraction d'air contenu dans la zone vadose 0.33
- **Qve:** Fraction d'eau contenu dans la zone vadose 0.06
- **Qcap:** Fraction d'air contenu dans la frange capillaire 0.1841
- **Qv:** Fraction d'eau contenu dans la frange capillaire 0.305
- **s:** Densité 1.7
- **Fco:** Fraction de carbone organique 0.012
- **Vdis:** Valeur sanitaire (1 : sans valeur sanitaire, 10 : avec valeur sanitaire) 1
GIS & Risk module
Interpretation of data

Site database
- Geology,
- Depth,
- Concentrations,
- ....

Risk database
- Scenario,
- Transport equations,
- Ventilation rates,
- ....

Visual risk characterization

Estimation of volume of excavation / backfill
Estimation of remediation costs
GIS & Risk module
Optimization of remediation works
Initial redevelopment project
Assessment of 2 scenarios

Outdoor areas
Assessment of worst case exposure scenario (adult, 8 h/day, direct exposure to soils)

Future constructed area
Assessment of worst case exposure scenario (child, 24h/24h, no basement, no underground structures)
Initial redevelopment project
Assessment of 2 scenarios

Risk interpretation

Outdoor areas
Assessment of worst case exposure scenario (adult, 8 h/day, direct exposure to soils)

Future constructed area
Assessment of worst case exposure scenario (child, 24 h/24 h, no basement, no underground structures)
GIS & Risk module
Optimization of remediation works

- Identification of grids/areas generating unacceptable risk
- Simulation of remediation works
  - Building concrete volume
  - Backfill/earth volume
  - Cost estimate

Risk interpretation
Joint optimization of detailed future use project and remediation works

- **Outdoor areas**
  - removal of all waste from on-site disposal area ➔ excavation to 11 m depth
  - redefinition of future use ➔ parking areas, green areas

- **Indoor areas**
  - building specifications ➔ presence of crawl space, technical galleries, air renewal rate…
Optimization of the global project after several evolutions and simulations

Initial risks

Initial project

Final risks

Final project
- Final redevelopment optimized based on risks
- Construction specifications (crawl space and minimum air renewal rates)
- Clean top spoil layer of 50 cm in green areas
- Recycling of demolition materials as backfill for delineated areas
- Precise definition of areas to excavate (by grid)
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**BUYER/REDEVELOPPER**

6 – Redevelopment

Use of GIS & Database

Field observations
4. Remediation works

Demolition

Excavation of former on-site disposal area

Grinded concrete

Material sorting and segregation
4. Remediation works
GIS & Risk module

- **Use of GIS & Risk module during work phase**
  - Continuous update of database as works are being performed
  - Responsiveness to “surprises” (identification of new hot spot, backfill, etc.) and manage quickly excavated material
  - Traceability of excavated material
  - As work progressed, the tool enabled the use of real time data to confirm the results of the risk assessment
5. Deed restrictions

- Groundwater use beneath the site is limited/restricted
- Access to monitoring wells for surveillance
- Former on-site disposal area redeveloped as a parking
- Sensitive buildings have basements where air renewal rates > 3 changes per hour
- Utility corridor (air renewal rates > 2 changes per hour)
- Clean top layer of soil (50 cm)
- Any modification (new construction or modification of redevelopment project) is subject to a new risk assessment
Conclusion

- The GIS & Risk module tool has proven to be efficient
  - In the early project phase
    - To carry constructive discussions with the redeveloper to define and validate a final optimized redevelopment plan
    - To manage and archive extensive data
  - During the work phase
    - To quickly address “surprises”
    - To guarantee a complete traceability of performed operations, in particular backfilling with site demolition material and delineation of contaminated areas
  - Along the whole project
    - Establishment of trust relationships with third parties (administration, expert advisor, redeveloper, …)
    - Readiness and easiness for simulation (prospective risk assessment along the project)
    - Ability to meet the deadlines