REMTECH expo 2009
REMEDIATION TECHNOLOGIES
Ferrara Fiere Congressi
23-24-25 Settembre 2009

International Symposium on Contaminated Soils and Sediments

Inhalation of contaminated vapor in indoor air: analysis of the relationship between soil-gas concentrations and the related contamination sources in soil

M. Morando, E. Leide, F. Faimani - NCE Srl

Session on:

Remediation technologies, soil reclamation and risk assessment

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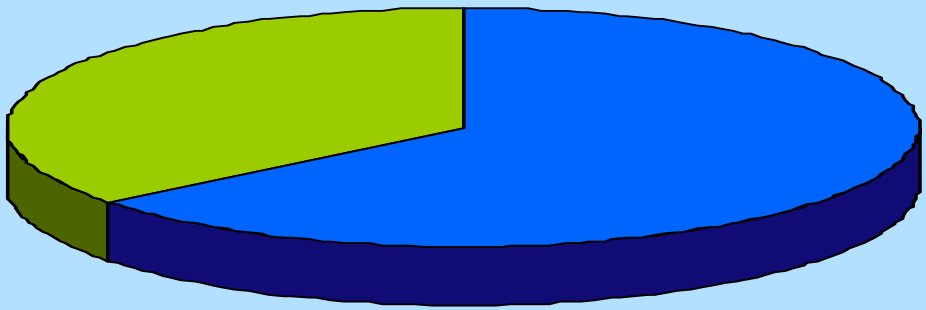
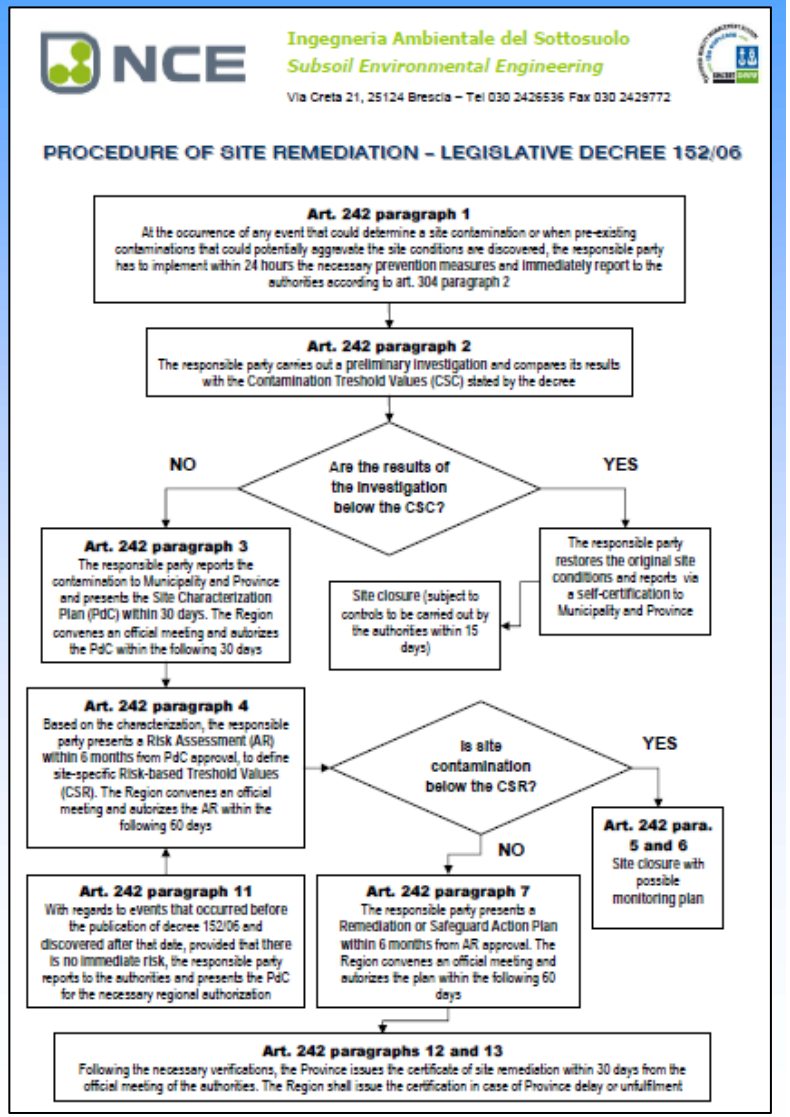
Introduction

Soil and GW Risk-based Target Levels (CSRs) are defined by means of a site specific Risk Assessment (L.D. 152/06, Part 4th, Title V)

The CSRs definition is often dominated by the exposure pathway "Inhalation of contaminated vapor in indoor air"

NCE's projects

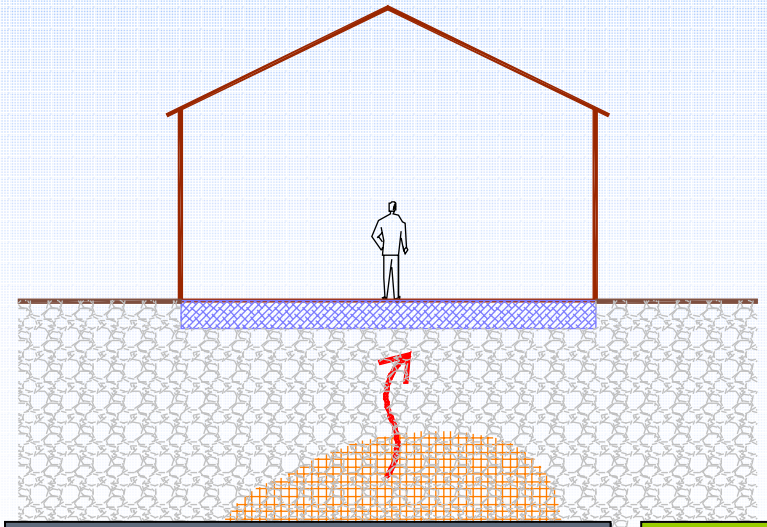




Introduction

The *indoor* pathway is simulated by means of algorithms (e.g. Johnson and Ettinger Model) generally affected by a tendency to overestimate the contaminant concentrations.

This tendency is frequently amplified using extremely conservative input parameters



NCE presented a study which confirmed this tendency to overestimate the observed values (Remtech 2008, Convegno L'Ambiente)

Concentrazione indoor MISURATA

$C_{TRICLOROETILENE} = 8{,}5 \cdot 10^{-3}$ mg/m³

$C_{TETRACLOROETILENE} = 7{,}0 \cdot 10^{-4}$ mg/m³

Concentrazione indoor SIMULATA

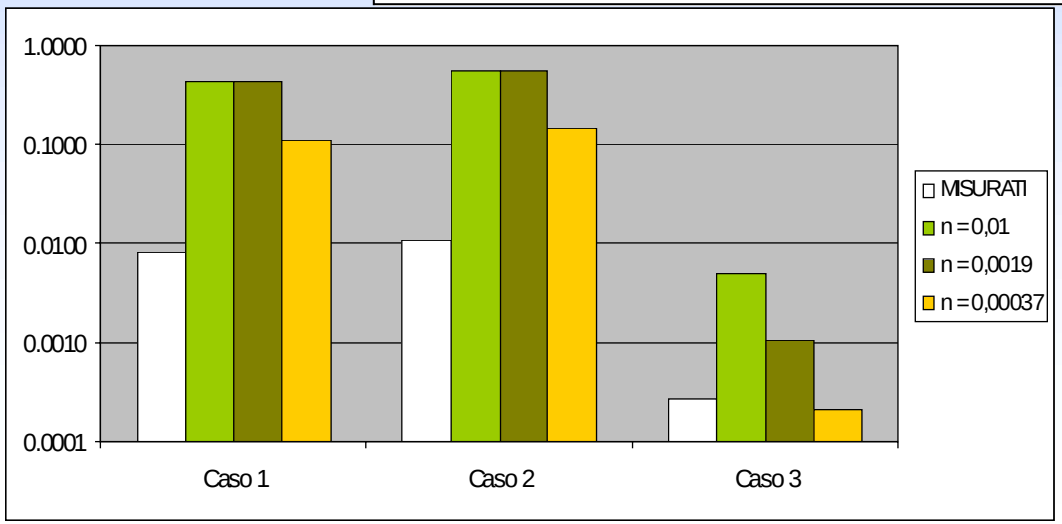
$C_{TRICLOROETILENE} = 4{,}2 \cdot 10^{-1}$ mg/m³

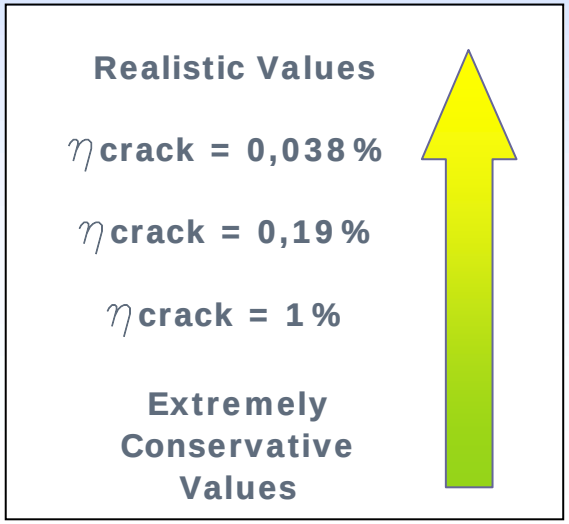
$C_{TETRACLOROETILENE} = 4{,}6 \cdot 10^{-3}$ mg/m³

Introduction

The 2008 NCE study included a limited sensitive analyses, focused on the “foundation crack ratio”, which showed the following results:

- ηcrack = 1%: systematically overestimates the observed values, up to two orders of magnitude;
- ηcrack = 0,19%: (EPA “conservative” value) resulted to be sufficiently "conservative" for all the sites;
- ηcrack = 0,038%: (EPA “typical” value) provided the most realistic air indoor values.





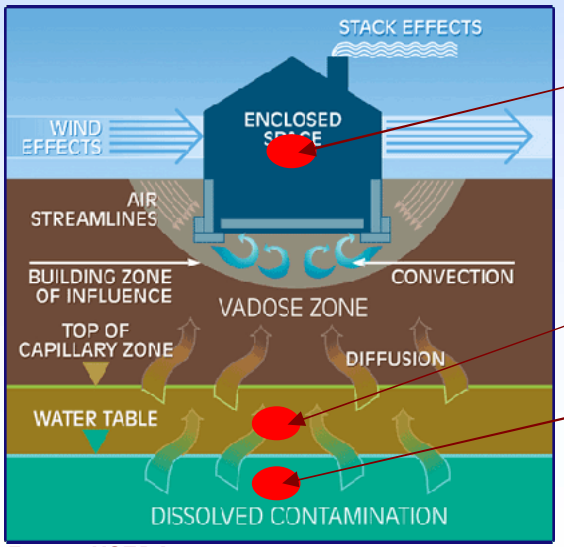
Introduction

In order to obtain additional information about the vapor indoor exposure pathway

and

Considering that the prediction of indoor air starts from the calculation of the soil-gas concentration

The present study is focused on
the analysis of the relationship between soil-gas concentrations and the related contamination sources, comparing data observed and calculated at 5 sites contaminated by volatile HC



Fonte: USEPA

C_{IN} [mg / m³]

C_G [mg / m³]

C_S [mg / kg or ug / l]

Algorithms, Materials and Methods

Johnson and Ettinger Model (Air Indoor), hypothesis:

- The transport mechanism is one-dimensional and steady-state
- Capillary zone/unsaturated soil: diffusive; near foundations: convective;
- Source is infinite (then checked by a total mass balance equation)
- The source is characterized by an homogeneous contamination;
- Soil is an homogeneous layer with isotropic properties;
- Partitioning equilibrium among gas, adsorbed and dissolved phases;
- Contribution of vapor phase is significantly higher than other phases
- Gas-phase contaminants enter a building through cracks
- Chemical and biological reactions are neglected

Soil source (Δp = 0)

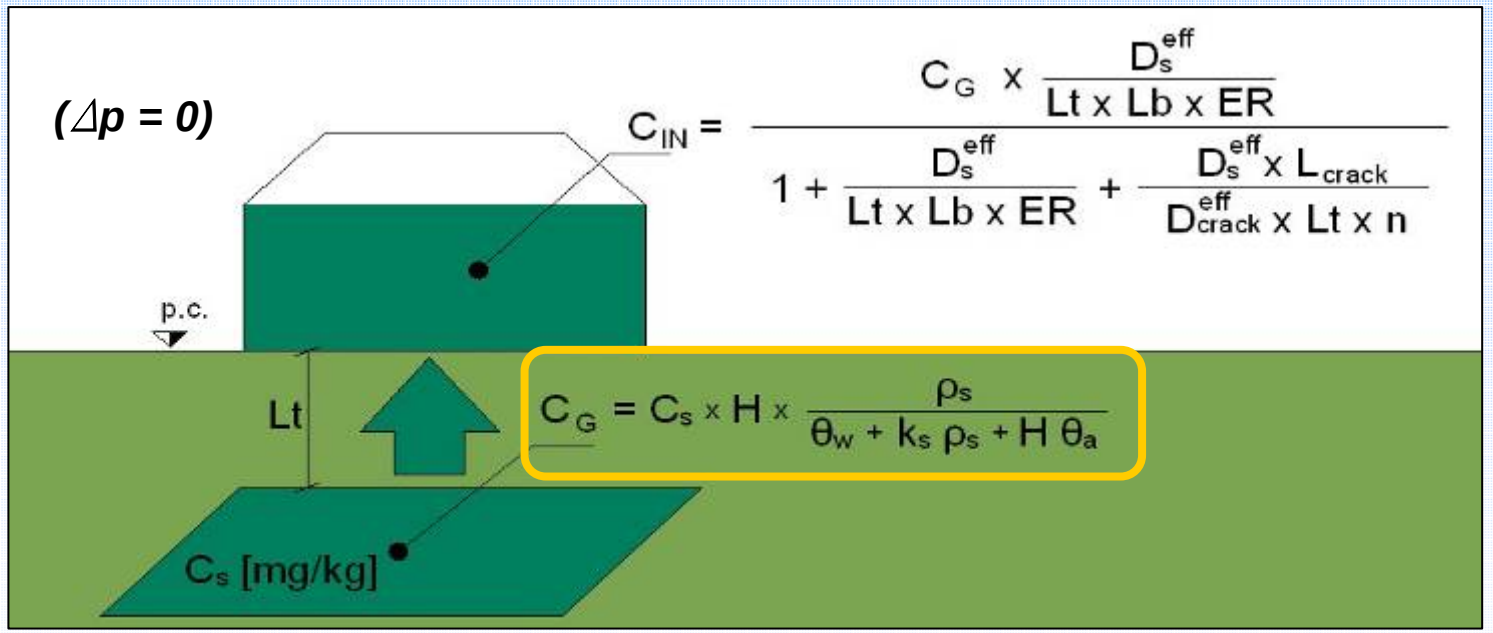
$$VF_{sesp} = \frac{C_{poe}}{C_s}\left[\frac{\frac{mg}{m^3 - aria}}{\frac{mg}{Kg - suolo}}\right]$$

$$VF_{sesp}(1) = \frac{\frac{H\rho_s}{(\vartheta_w + k_s\rho_s + H\vartheta_a)} \cdot \frac{D_s^{eff}}{L_T L_b ER}}{1 + \frac{D_s^{eff}}{L_T L_b ER} + \frac{D_s^{eff} L_{crack}}{D_{crach}^{eff} L_T \eta}} \cdot 10^3$$

$$VF_{sesp}(3) = \frac{\rho_s \cdot d_s}{L_b \cdot ER \cdot \tau} \cdot 10^3$$

Algorithms, Materials and Methods

Soil-gas Model



where:

ρ_s = Soil dry bulk density [ton/m^3] Θ_w = Soil water-filled porosity [-]

Θ_a = Soil air-filled porosity [-] foc = Soil organic carbon weight fraction [-]

H = Henry's law constant K_{oc}= Soil organic carbon partition coeff [cm^3/g]

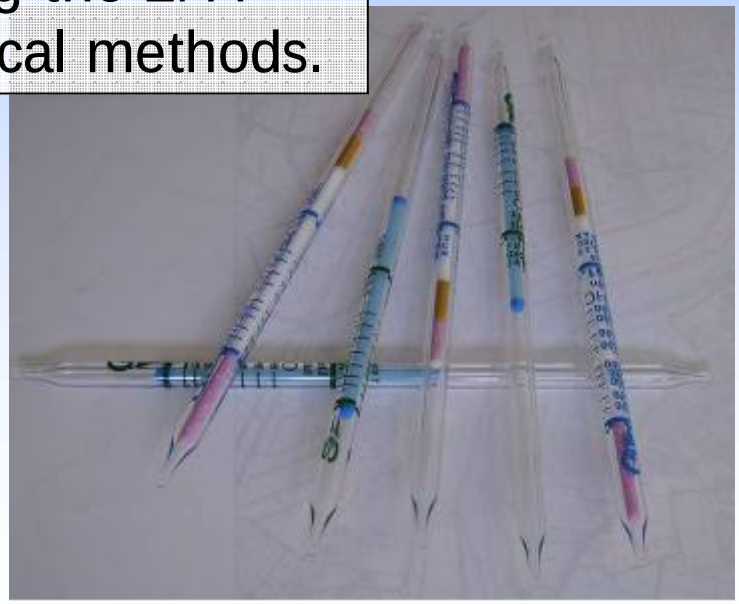
K_s = Soil-water partition coefficient [cm^3/g] (for organic compounds: K_{oc} x foc)

Algorithms, Materials and Methods

Soil-Gas Sampling and Analyses

The soil-gas sampling was conducted as follows:

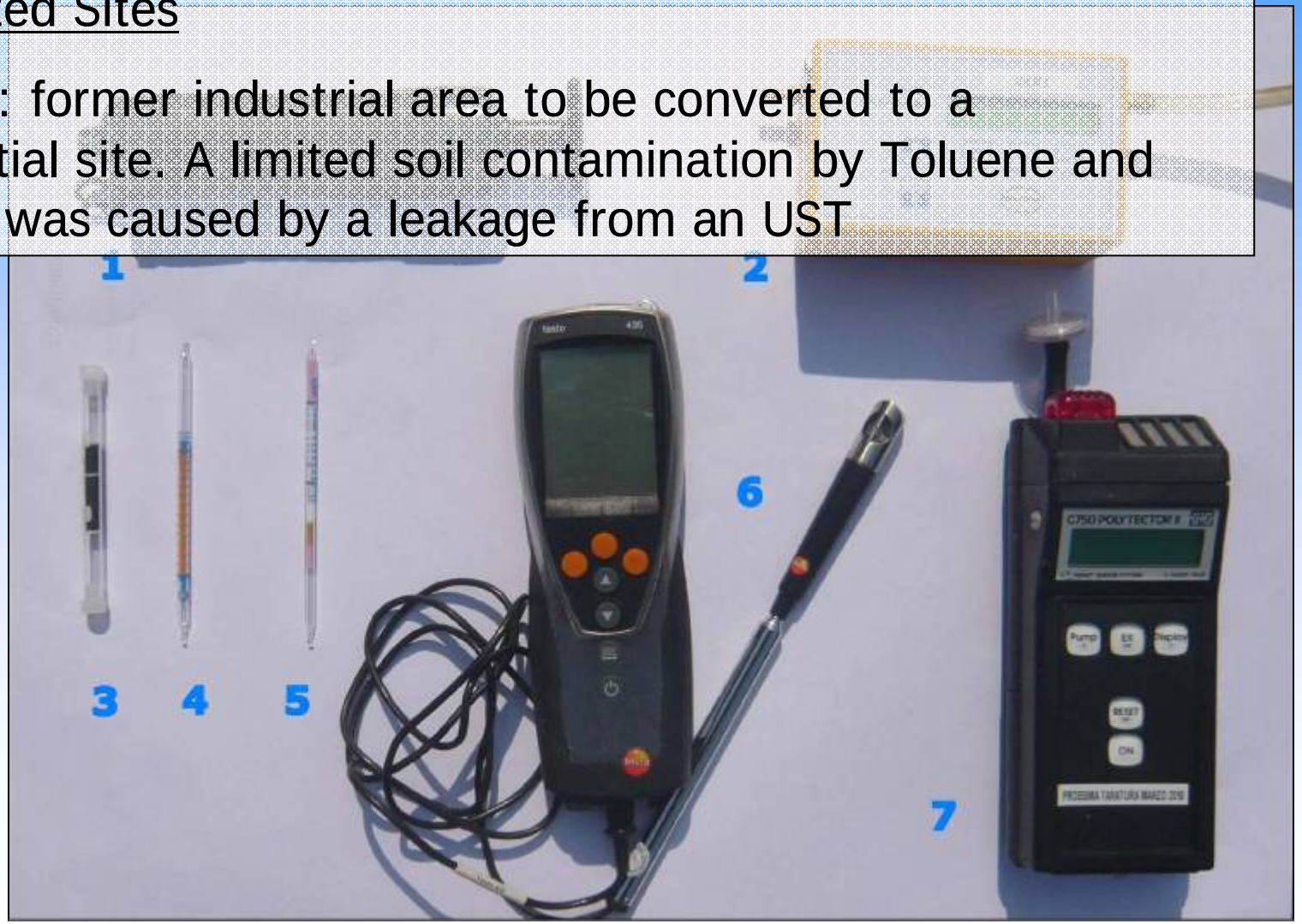
- Fixed monitoring probes installed inside source
- Activated carbon tubes with personal sampling units
- Volume ranged from 5 to 180 liters
- Soil-gas samples were analyzed following the EPA 8015D 2003/UNI EN 13649:2002 analytical methods.



Input Parameters

Investigated Sites

- Site #1: former industrial area to be converted to a residential site. A limited soil contamination by Toluene and Xilenes was caused by a leakage from an UST



Input Parameters

Investigated Sites

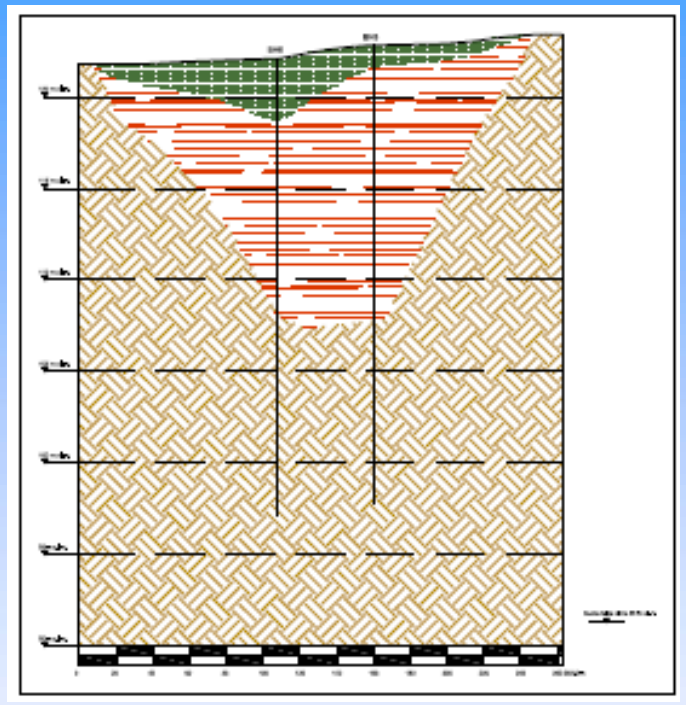
- Site #2: portion of a former manufacturing gas plant, where a significant soil contamination by BTEXS was detected

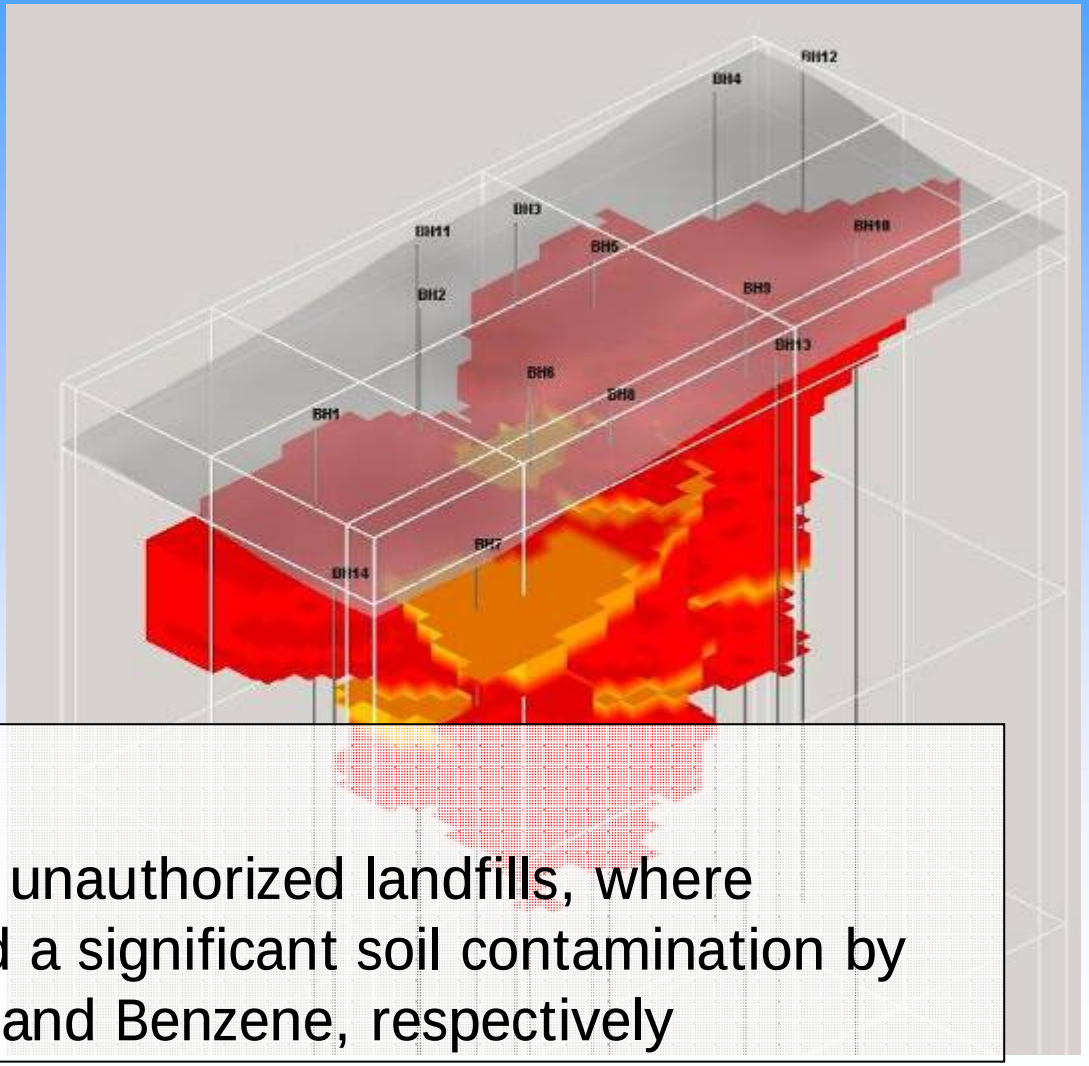
Input Parameters

Investigated Sites

- Site #3: active industrial site, where a damaged UST caused a significant contamination by Petroleum HC;

Input Parameters





Investigated Sites

- Site #4 and Site #5: two unauthorized landfills, where dumping activities caused a significant soil contamination by Petroleum Hydrocarbons and Benzene, respectively

Input Parameters

All the subject sites have the following characteristics:

- Contamination limited to deep soil (> 1 m bgs)
- No shallow soil nor groundwater is contaminated
- Coarse Soils ("Sandy Loam" to "Sand“)
- Contaminants: Volatile Petroleum Hydrocarbons
- Soil-gas collected from monitoring points inside sources

Input Parameters

Input parameters defined according to APAT/ISPRA (National Environmental Protection Agency) Handbook. Specifically:

- Chemical/physical parameters of COCs from ISS/ISPESL database
- Parameters generally based on site-specific observations
- If not available, parameters equal to APAT/ISPRA default values
- Source concentrations:
  - if more than 10 measurements: UCL95%
  - if less than 10 measurements: maximum value

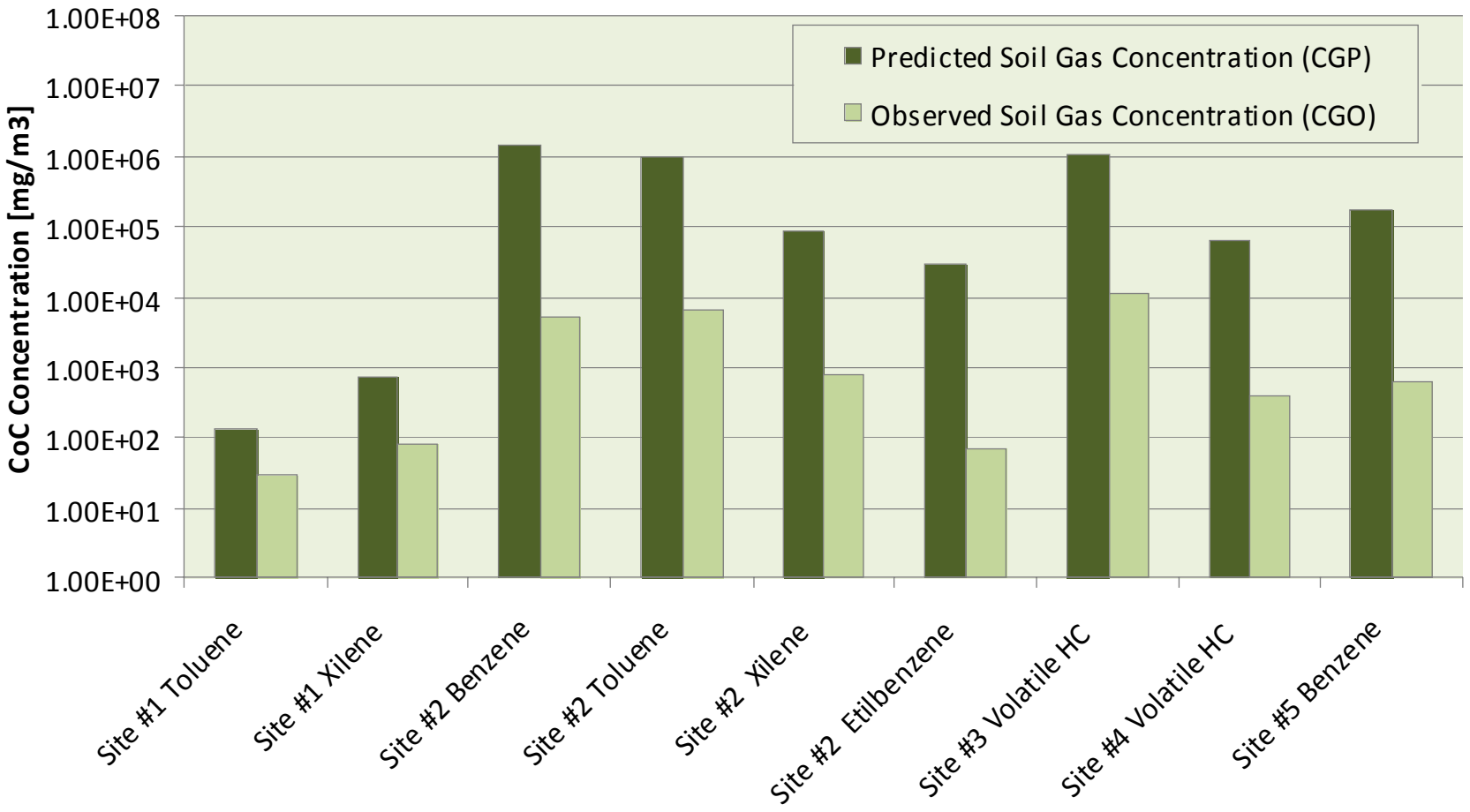
Results

Site	COCs	Conc. [mg/kg]	ρs [ton/m³]	Θw [-]	Θa [-]	foc [g/g]
Site #1	Tol	0,71⁺	*1,7*	*0,068*	*0,317*	*0,01*
	Xyl	8,61⁺				
Site #2	Ben	4300⁺	*1,7*	*0,068*	*0,317*	*0,01*
	Tol	5190⁺				
	Etyl	188⁺				
	Xyl	997⁺				
Site #3	Al C5-C8	5,54 *				
	Al C9-C18	1604,66*				
	Ar C9-C10	12,12*				
	Ar C11-C22	289,26*				
Site #4	Al C9-C18	3950*				
Site #5	Ben	546,72*				

Site	Predicted [mg/m³]	Observed [mg/m³]
Site #1 Tol	1.30E+02	2.85E+01
Site #1 Xil	7.37E+02	7.84E+01
Site #2 Ben	1.40E+06	5.09E+03
Site #2 Tol	9.47E+05	6.37E+03
Site #2 Xyl	8.53E+04	8.03E+02
Site #2 Eth	2.84E+04	6.99E+01
Site #3 HC	1.04E+06	1.15E+04
Site #4 HC	6.11E+04	4.02E+02
Site #5 Ben	1.77E+05	6.11E+02

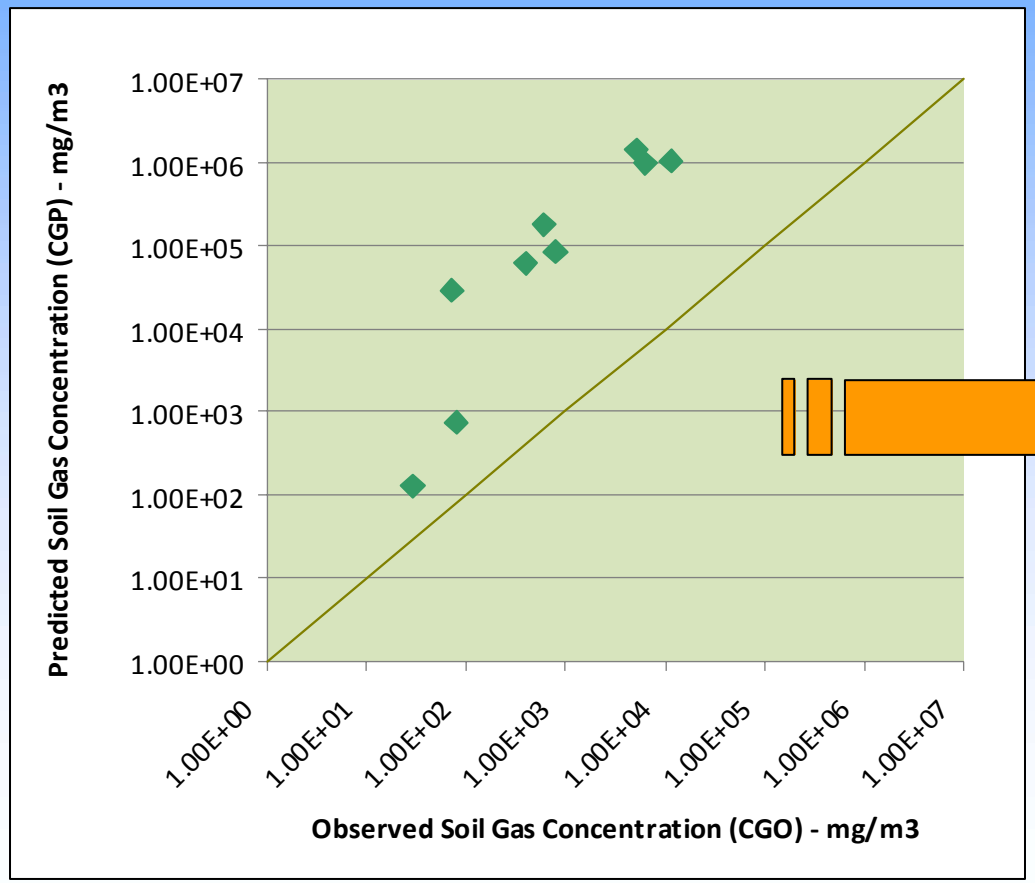
Results

Predicted and observed soil-gas concentrations on a logarithmic scale



Results

Predicted vs observed values on a bi-logarithmic diagram



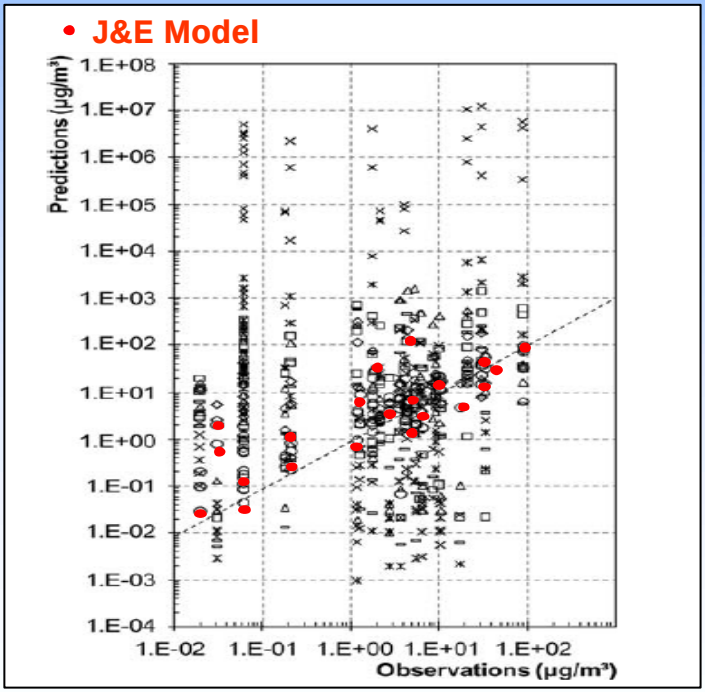
The soil-gas model has a clear tendency to overestimate the observed values.

The difference is about two/three orders of magnitude.

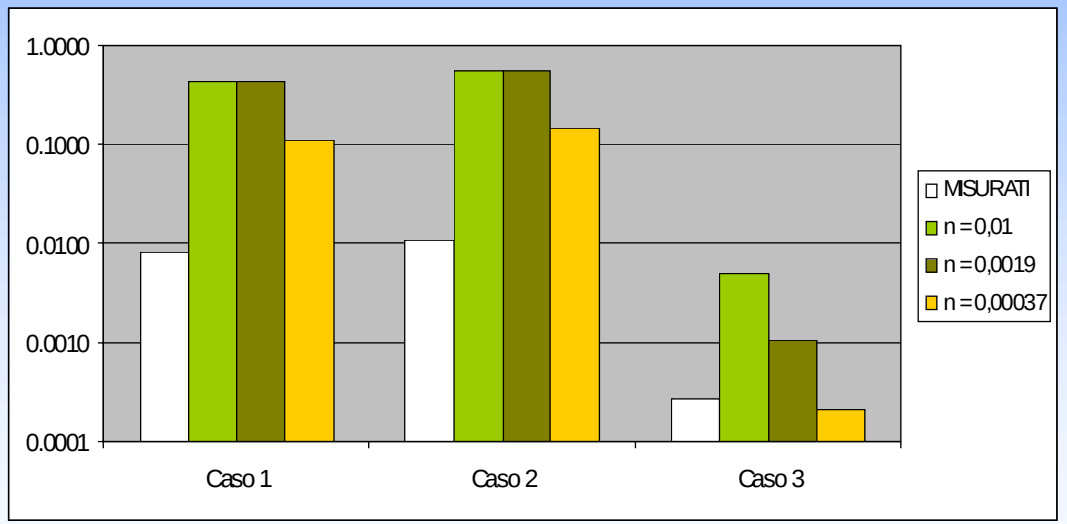
Only for low soil concentration the difference was limited to one order of magnitude.

Discussion and Conclusions

Several studies investigated the accuracy of the Johnson and Ettinger Model for predicting indoor air concentration and concluded that the model is generally conservative by up to one order of magnitude, as long as appropriate input parameters are used.



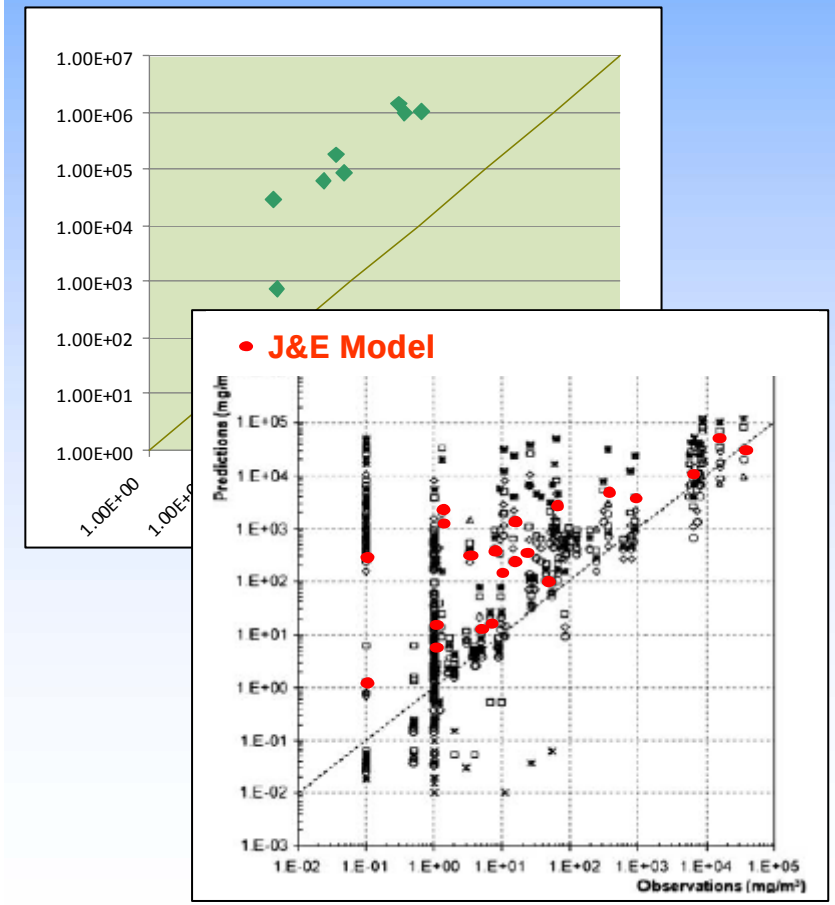
From J.Provoost, L.Reijnders et al. (2009)
Flemish Institute for Technological Research
Open University of Netherlands
National Institute for Public Health and the Environment, Netherlands



From M.Morando, E.Leide, F.Faimani - Remtech 2008

Discussion and Conclusions

Based on the results of the present study, the J&E algorithm seems to have a tendency to overestimate the soil-gas concentration, up to two/three orders of magnitude.



From J.Provoost, L.Reijnders et al. (2009)

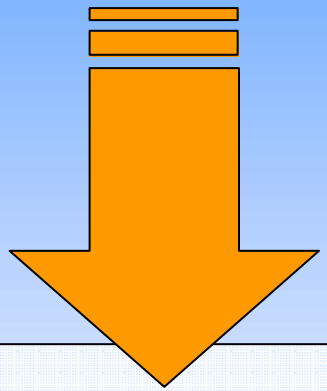
The J&E model seems to be affected by an higher overestimation tendency for the soil-gas concentrations than for the indoor air concentrations.

This conclusion is in line with the results obtained by other researchers.

Is it related to chemical and biological reactions, neglected in the J&E Model?

Discussion and Conclusions

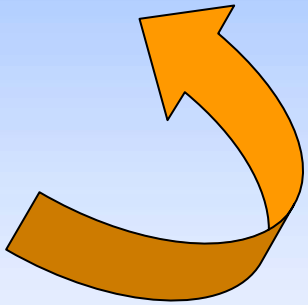
It is possible to confirm that:



A predicted unacceptable risk, associated to the "inhalation of contaminated vapor in indoor air" pathway, should always be verified by means of direct measurements of indoor gas (if possible) and/or soil-gas.

Discussion and Conclusions

Need of further studies in order to better understand the relationship among source contamination, soil-gas and indoor air (e.g. analysis of data from other sites, batch scale tests, etc.).



This would help increase the accuracy of the J&E model for predicting indoor air concentrations, based on soil gas data (especially when a direct measurements of indoor air is not possible)

Discussion and Conclusions

Thank you for your attention