MODELLING MASS TRANSFER COEFFICIENTS AT LABORATORY SCALE FOR IN SITU SMARTSTRIPPING® UPSCALING

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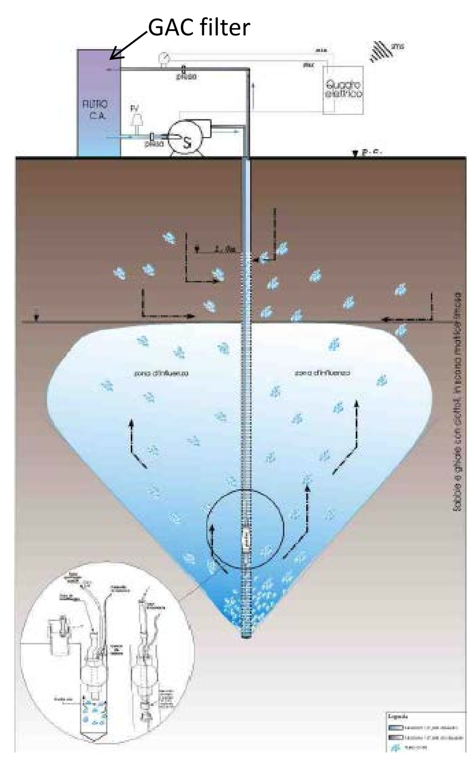
INTRODUCTION

The groundwater remediation technology called SmartStripping® is an innovative process for groundwater in-situ remediation that reduces concentrations of Chlorinated Aliphatic Hydrocarbons (CAHs) dissolved in groundwater at industrial and civil sites and especially at sites with underground storage tanks.

The process can be defined as an innovative combination of Air Sparging (AS) and Soil Vapour Extraction (SVE): groundwater remediation occurs by enabling a transfer of contaminants from a saturated zone (groundwater) to an unsaturated zone (vadose) by blowing heated air from existing wells, which then enables groundwater stripping from the aquifer. The stripping allows the separation of CAHs from groundwater that vent up to the unsaturated zone which is under a continuous vacuum status, whereby the soil vapour is extracted. Vapours are treated with granular activated carbon (GAC) adsorption filters before being re-injected into the groundwater to start the stripping process again, through a continuous closed air-cycle system.

The application of this technology in each specific site needs the use of a comprehensive modelling and lab scale experiments for an optimal design of removal of volatiles as a function of operational parameters, from which air flow is the most relevant. In the present work, a combination of hydrodynamic and mass transfer model is developed and calibrated with specific laboratory tests.

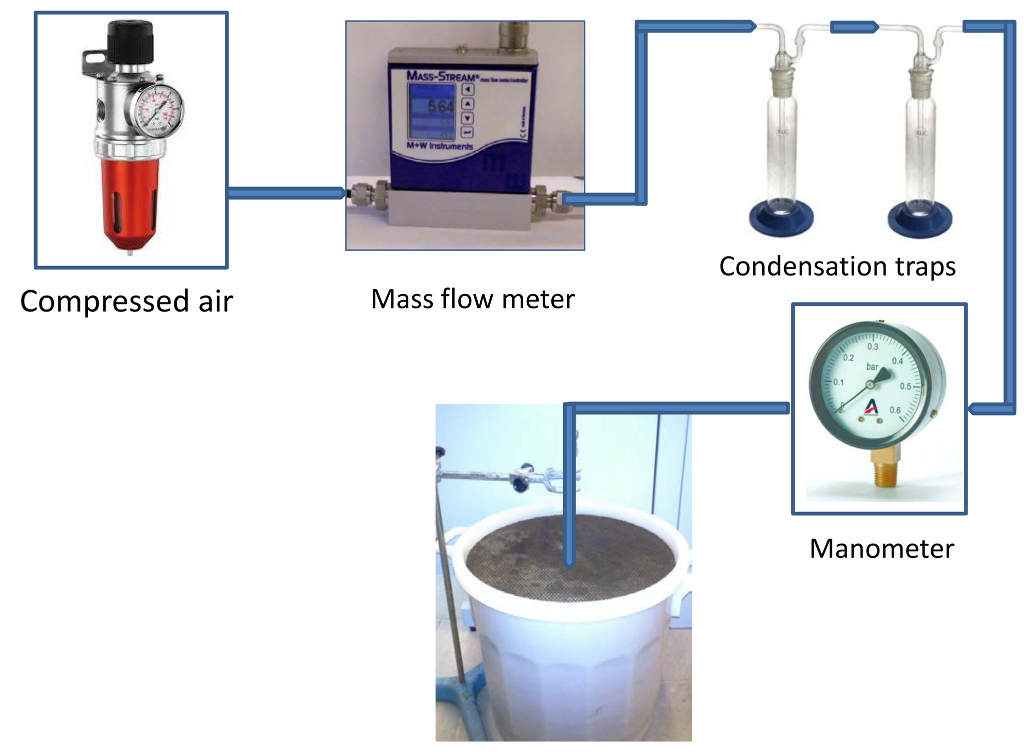


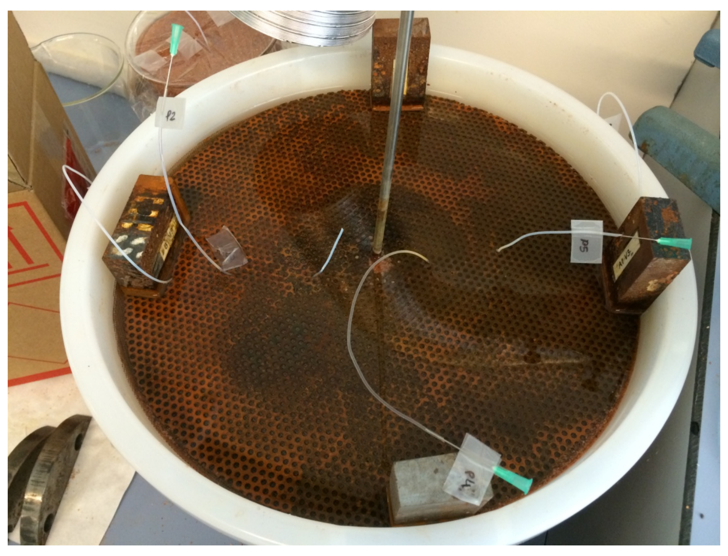
EXPERIMENTAL SETUP

<u>Experimental conditions tested:</u>

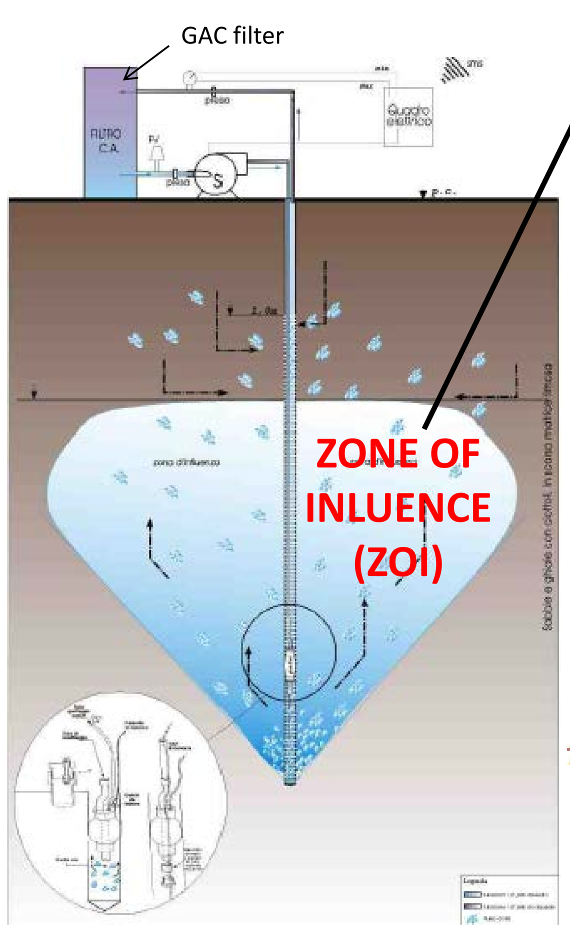
- Sand (0.50-0.80 mm) saturated with water
- Air flow (stripping) = 1.3 L/min
- Several sampling points at 26 cm below surface
- Initial contaminant concentrations
  - Experiment 1: 55 mg/L Ethanol
  - Experiment 2: 523 µg/L mix-dichloroethylene (mix-DCE)

LAB SCALE SET UP





MODELLING



MASS BALANCES INSIDE ZOI:

Diffusion from outside the ZOI

In the liquid phase:
$$\frac{dC}{dt} = \frac{S \cdot K^* \cdot (C_O - C)}{V_r \cdot \varepsilon_L} - \frac{r}{\varepsilon_L}$$

C: liquid concentration of contaminant, S: surface of the ZOI in which lateral diffusion takes place, K*: liquid mass transfer coefficient due to the lateral diffusion, C_0: Initial contaminant concentration, V_r: Volume of the ZOI, ε_L: water porosity in the ZOI

In the air phase:
$$\frac{dp}{dt} = -\frac{G \cdot p}{V_r \cdot \varepsilon_A} + \frac{r \cdot R \cdot T}{\varepsilon_A}$$

p: contaminant partial pressure, G: air flow, R: ideal gas constant, T: temperature, ε_G: air porosity in the ZOI

STRIPPING:
$$r = K_G a(p^* - p) = K_L a(C - C^*) = K_{global}(C - p/H)$$

r: rate of stripping, K_G: mass transfer coefficient in the gas phase, a: contact surface per unit of volume, p*: contaminant partial pressure in the interface, p: contaminant partial pressure in the center of the bubble, K_L: mass transfer coefficient in the interface, C: concentration in the bulk liquid, K_{global}: overall mass transfer coefficient , H: Henry's Law constant

INPUT PARAMETERS REQUIRES:

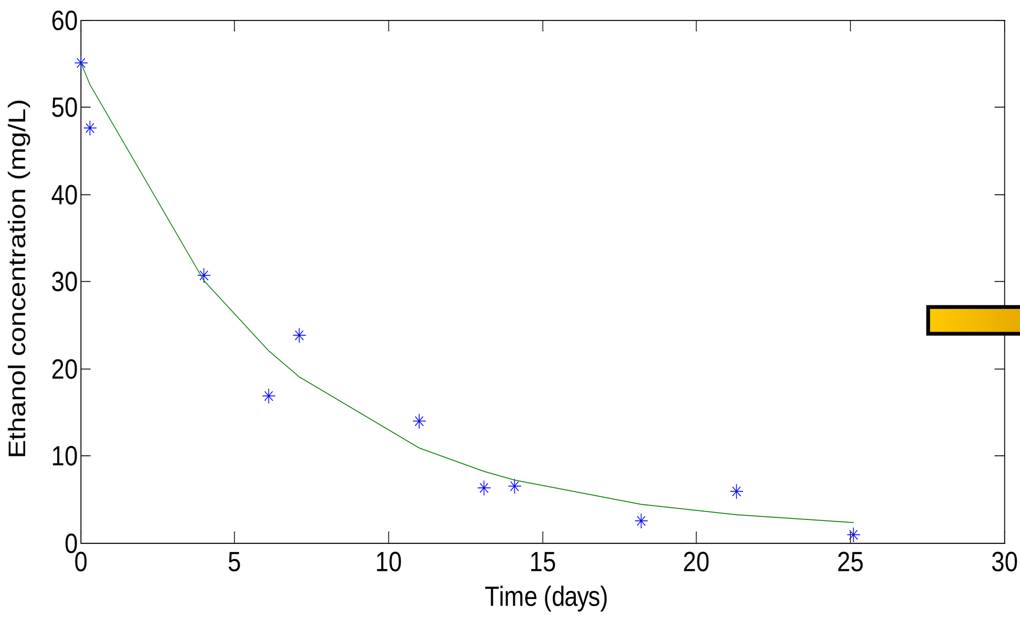
- Initial contaminant concentration in water
- Contaminant properties:
  - Henry's law constant → Bibliographic data
  - K_{global}
  - K*

  → **Parameters to be calibrated**
- Zone of influence data
  - Volume
  - Surface
  - Fraction of air
  - Fraction of water

  Obtained from hydrodynamic model developed with ANSYS-CFX® v14.0

PARAMETERS CALIBRATION

EXPERIMENT 1 – ETHANOL

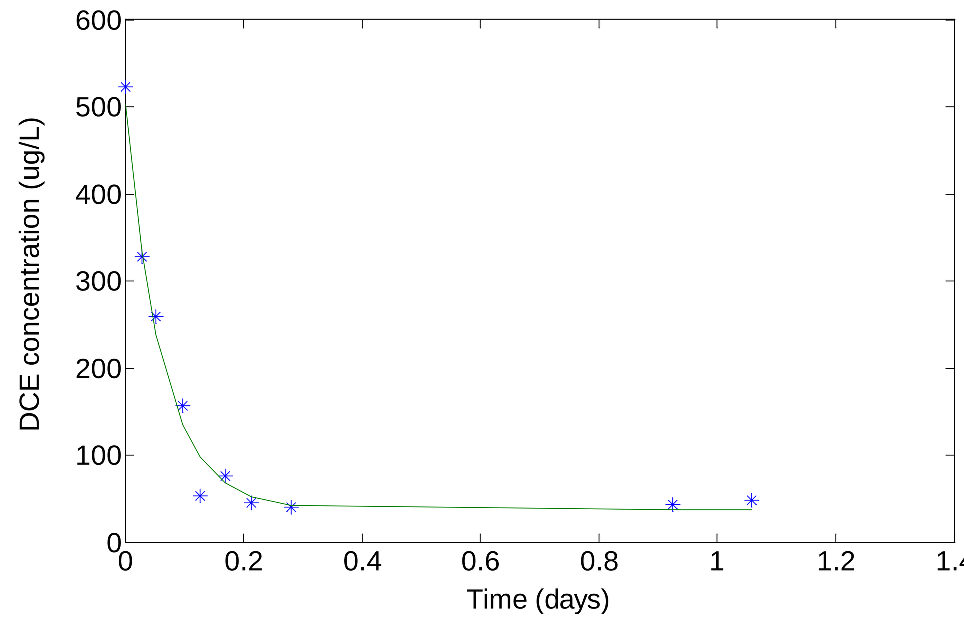


Parameters calibrated from experimental data using MATLAB® R2011a

$K_{global} = 5.2 \cdot 10^{-7}\ s^{-1}$
$K^* = 2.8 \cdot 10^{-10}$ m/s

$K_{global} = 1.2 \cdot 10^{-7}\ s^{-1}$
$K^* = 4.4 \cdot 10^{-10}$ m/s

EXPERIMENT 2 – DCE



CONCLUSIONS

- ✓ The experimental setup designed and applied in this work is useful for calibration of parameters and proper simulation of the stripping process at lab scale.
- ✓ The developed and calibrated model presented can be used to improve the knowledge of the whole stripping system at field scale.
- ✓ By means of lab experiments and modelling the optimal remediation strategy for different volatile contaminants can be designed.