Centro Regionale di Competenza
Analisi e Monitoraggio del Rischio Ambientale

Università degli Studi di Napoli Federico II
Dipartimento di Ingegneria Chimica

Mesocosm

Technical manual edited by:

Guido Greco

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Foreword

Soil and groundwater pollution brought about by natural and/or human events affects approximately twenty million square kilometers of the earth surface.

Polluted areas increase by 1% each year.

Remediation costs of Western Europe polluted sites can be estimated in approximately 500 G€, i.e. in 5% of the GNP.

The Italian situation closely parallels the European one, with more than 500 M€ required for the remediation of just the main polluted sites.

In Southern Italy, soil and groundwater are heavily polluted because of innumerable urban waste disposal sites and of dismissed industrial locations. Furthermore, huge amounts of toxic wastes , in many instances produced elsewhere, are dispersed in the environment illegally, to a still largely unknown extent.

In order to cope effectively with the needs of soil and groundwater remediation and to prevent further environmental damages, a multidisciplinary network of scientists and technicians is mandatory, together with advanced scientific infrastructures.

AMRA scarl entirely fits within this strategy since it connects the best part of the environmental scientists working in Campania and operates a mesocosm, probably one of the most advanced in Europe, that enables to:

- carry on research projects in cooperation with Public Research Institutes, Universities and industrial partners,
- develop new remediation techniques,
- set up environmental remediation strategies according to specific needs arising in private and public sectors,
- train qualified technicians providing them with high-level expertise in soil and groundwater remediation.

Why a mesocosm?

The genesis and evolution of soil and groundwater pollution are reported schematically in Figure 1.

The pollution source can consist in a liquid that had been spread accidentally or in a solid waste, leaking liquid pollutants, both directly or under the action of surface waters and rain.

Pollutants percolate through soil, simultaneously releasing into the gas-phase volatile components, if any, that can also diffuse back to the atmosphere.

Once the capillary fringe has been reached, the water-soluble pollutants are dispersed into the groundwater. The insoluble pollutants either stop or keep carrying on their vertical motion if their density is less or greater than that of water, respectively. In the former instance, a pollutant lens is formed, that floats on top of the groundwater table and follows its seasonal level-variations. In either case, the soluble components are released into the groundwater.

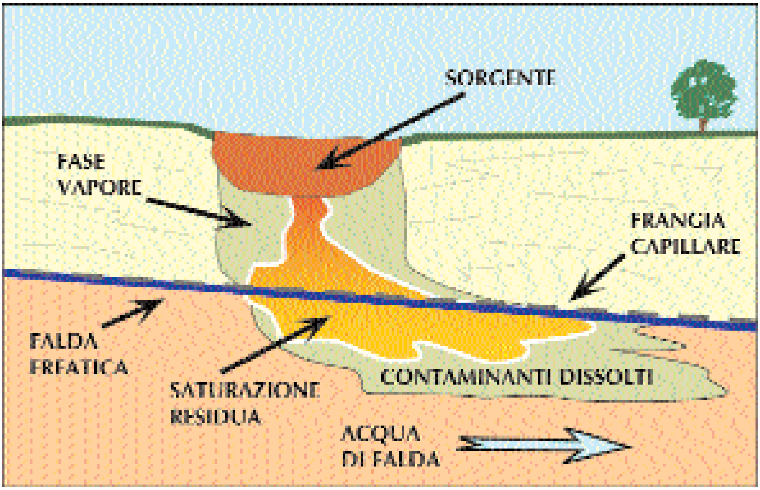

Fig. 1.

The space-scales of the pollutant dispersion phenomena are of the order of:
- kilometers: aquifer;
- meters: macroscopic soil- and aquifer-structure;
- centimeters: soil local heterogeneities;
- millimeters: soil macroporosity;
- micrometers: soil microporosity.

Pollutant percolation, in both its vertical and horizontal components, is dictated by soil texture, at all the scale levels above.

The time-scale of pollutant dispersion falls within an interval bound between days (percolative phenomena) and years (pollutant release into the water table).

The external environmental variables affecting the system are:
- rainfalls;
- seasonal and daily variations in room temperature;
- ventilation;
- biological activity of vegetables, insects, micro-organisms;
- fluctuations in water-table level.

A lab-scale system yields informations that can be hardly scaled-up to the real situation, because an artificial soil/water-table system built-up manually is necessarily oversimplified. The same applies to any tentative simulation of the external environmental effects above.

Obviously, performing the experiments directly in the field, i.e. in the real system, would overcome all these drawbacks.

Further, though different, difficulties arise, however, in dealing with field experimentation.

Firstly, an open system does not allow to perform the required mass balances.

Secondly, crucial parameters such as:
- the vertical distribution of water tension and volumetric fraction,
- the vertical distribution of the gas-phase composition,
- the flow-rate of percolating liquid/s,
- the fast fluctuations in water-table level,
- mass variations in the control volume,

are hardly measurable, if at all.

Last but not least, direct dispersion of pollutants into the soil (in order to simulate a pollution event) is obviously illegal. Indeed, severe limits exist for the introduction of xenobiotics into the environment, even of potentially amending nature, unless their absolute harmlessness has been completely acknowledged.
All these general remarks have been taken into account in defining the layout of the AMRA mesocosm. It consists in a confined system of the same dimension as that of the characteristic scale of the aquifer (meters); it is filled up with unperturbed-soil samples; it is directly exposed to all the external environmental agents (Figures 2 and 3). Programmable hydraulic systems are provided to simulate the fluctuations in water-table level, as well a complete set of sensors that enable the continuous monitoring of all the crucial parameters, including the soil sample mass.
The system is confined, thus overall mass balances can be performed; xenobiotics can be freely dispersed into the soil for

Fig. 2.

Fig. 3.

both the simulation of pollution and the implementation of remediation strategies; phytoremediation can be analyzed, as well, by sowing amending crops onto the exposed surface of the mesocosm.

The technical solution adopted in the AMRA mesocosm is that of a multiple-lysimeter station. It consists in eight units that operate individually and simultaneously. The multiplicity enables a reference situation to be always at hand.

Each lysimeter is a soil-filled steel vessel of 1.14 meters in diameter and of 2 meters in height (Figure 4).

Soil samples have been collected into each single lysimeter in such a way as to keep the natural texture unperturbed, in terms of local heterogeneities, macrostructure, microstructure (Figures 5 and 6).

As of now, four units contain an agricultural soil and four an industrial soil that has undergone co-pollution by organics and heavy metals. The latter is fairly common in many dismissed industrial sites.

In case specific needs should arise to analyze an individual remediation strategy, the necessary number of lysimeters can be emptied and filled-up again with ad hoc soil samples, drawn from the site.

Fig. 4.

Fig. 5.

Fig. 6.

Technical description

Site

The Mesocosm is located in Piana di Monte Verna, within the EURECO Research Center.

The monitoring system

The monitoring system of each lysimeter consists in a set of different probes placed at five depths from the external surface, namely at 10, 30, 80,120, 180 cm, in order to provide the longitudinal distribution of the relevant variables.
The latter are:
– **temperature**, measured by thermistor probes;

- **water tension**, measured by a single ceramic-membrane tensiometer placed at 180cm that enables the measurement of the hydrostatic head, as well and by soil matrix sensors at the other depths,
- **volumetric water fraction**, measured by impedance metering probes.

The overall mass of each lysimeter (approximately 3 tons) is monitored continuously by a strain gage, within ±100 g.
All sensors have been installed after the soil sample had been loaded, in order not to disturb the texture of the latter.
All sensors are connected to a data acquisition system that enables data storage and conversion into suitable formats.
Data can be retrieved by FTP.
Commands can be issued to remote actuators through the on-line connection, to perform programs such as the opening or closing of electro-valves at predetermined times, to simulate a story of water-table level fluctuations.

Sample retrieval

Gas and water samples can be gathered through sampling ports along the depth of each lysimeter (Figure 7).
Water is collected under vacuum. This operation can be actuated remotely.
Interstitial air samples are collected in the same way. As of now, this operation can only be performed manually.
Soil samples cannot be collected, in order not to perturb soil texture.
All liquid and gaseous samples are analyzed off-line.

Water-table level control system

Each lysimeter has a water-level control system consisting in two electro-valves actuated by the data-logger. The system can be programmed to supply a constant water-level, as well as to follow a complex time-profile. The water-input line is provided with a flow-rate meter.

Fig. 7.

An exit line is placed at the lysimeter bottom, provide with a remotely-actuated electro-valve and a flow-meter. This enables the simulation of conditions when the water-table level is below that of the lysimeter bottom.

Soil venting

A gas-sparging system is placed at the depth of 150 cm. It consists in a porous steel tube, coated with a porous Teflon membrane. Its length is just less than the vessel inside diameter.
Ancillary laboratories
The mesocosm is supported by ancillary laboratories providing advanced analytical facilities:

– BMG FLUORIMETER FLUOSTAR OPTIMA
  Microplate fluorimeter. It can be used for fluorescence, time-resolved fluorescence, luminescence and absorbance measurements.

– TOC/TN ANALYZER TOC-V CSH SHIMADZU
  Total Organic Carbon and Total Nitrogen Analyzer. It performs TC, IC, TOC, NPOC, POC determinations. TOC can be measured in solid samples, as well.
– ATOMIC ABSORBTION SPECTROPHOTOMETER AA-6300 SHIMADZU
  Double-beam atomic absorption spectrophotometer equipped with chopper mirror, flame (C_2H_2-Air) atomizer, titanium burner. The available lamps enable Na-K, Fe-Mn-Cr-Ni-Cu-Co, Al-Ca-Mg determinations.
– GC-MS GAS-CHROMATOGRAPH QP2010 SHIMADZU
  Mass-spectrometry/FID gas-chromatograph for capillary, wide-bore and packed columns.
– UV-VIS SPECTROPHOTOMETER UV-1700 SHIMADZU
  Double-beam UV-Vis spectrophotometer operating in the range 190-1100 nm with spectral bandwidth 1 nm.
– NEW BRUNSWICK SCIENTIFIC BIOFLO410 FERMENTER
  Fermenter with stainless steel vessel, operating volumes 2-5 L, vapor-sterilizable in situ. With a PC control system of operating parameters (pH, T, OD, liquid and foam level, mixer rpm, gas rates, medium and supplements additions, CO_2/O_2).

Applications

Analysis of soil and groundwater pollution phenomena

– Pollutant transport in soil
– Pollutant release into the groundwater table
– Pollutant degradation by the autochthonous microflora
– Variations undergone by the autochthonous microflora

Implementation of remediation techniques

– Air sparging
– Biostimulation
– Bioaugmentation
– Simulation of further, combined remediation technologies

Connections

The Mesocosm AMRA joins the “European Lysimeter Platform” (http://www.lysimeter.at/HP_EuLP/index.html) that links the european lysimetric stations to share information and experiences.

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