

„Soil Vapour Intrusion“ – A new model for the determination of indoor air concentrations

THOMAS PUTZMANN; CECILIA DE BIASE; SARAH LOECHEL; MARTIN BITTENS;
HOLGER WEISS

Resumo

As emissões de contaminantes voláteis provenientes de fontes subterrâneas para a qualidade do ar interior (intrusão de vapor) representam um risco significativo sobretudo em ambientes urbanos. Intrusão de vapor simulada em experimento de laboratório e sua aplicação em um módulo de campo em locais contaminados ajudaram a compreender os mecanismos de transporte por difusão e por convecção de poluentes na zona insaturada do solo e, ainda, através de concretos como barreiras de difusão. Com os dados dos experimentos de laboratório e de campo, uma nova ferramenta de previsão para estimar as concentrações do ar interior foi desenvolvida. O modelo, Intrusão de Vapor no Solo (SVI), pode ser utilizado para cálculos diretos e inversos e, também, para integrar o comportamento difusivo através de materiais de vedação.

Palavras-chave: solo contaminado, intrusão de vapor, ar de interiores, modelo de previsão

Abstract

Emissions of volatile organic compounds (VOCs) from groundwater sources to indoor air (vapour intrusion) represent a relevant risk driving process in urban environments. Simulated vapour intrusion in lab scale experiments and the application of a field module at contaminated sites help to understand the mechanism of diffusive and convective transport of pollutants in the unsaturated soil zone and through concrete as diffusion barrier. With the data sets from lab and field scale experiments of the UFZ, a new prediction tool for the estimation of VOC concentrations in indoor air was developed. The model, Soil Vapour Intrusion (SVI), can be used for forward and backward calculations of VOC concentrations and also integrates the diffusive behaviour through sealing materials.

Keywords: contaminated soil, vapour intrusion, indoor air, prediction model

corresponding author: Thomas Putzmann, Ph.D student;
Helmholtz-Centre for Environmental Research – UFZ; Permoserstrasse 15;
04318 Leipzig, Germany;
Phone: +49 341 235 1674; E-mail: thomas.putzmann@ufz.de

1 – INTRODUCTION

The inhalation of contaminants due to vapour intrusion into buildings is often the main pathway to the exposure of humans at sites contaminated with Volatile Organic Compounds (VOCs). For such sites the quantification of pollutant concentrations in indoor air is essential while assessing the risks for human health.

To calculate the risk of indoor air concentrations it is necessary to obtain field and lab data. A novel Bench-Scale-Module was used for lab experiments. Also a field module was built in the framework of UFZ's SAFIRA II research program allowing the determination of transfer rates of VOC from the unsaturated soil zone through diffusion barriers – such as concrete used for bottom plates in private houses – into indoor air.

The data sets of the several experiments in the lab were used for the optimization of the field scale investigations. Finally the data sets were also used for the development, verification and sensitivity analysis of a new UFZ prediction tool, called "Soil Vapour Intrusion (SVI)".

2 – LAB AND FIELD SCALE

2.1 – Lab scale experiments

The Bench Scale Module, shown in Figure 1, used for the intrusion scenarios in the lab was developed by the UFZ. The module was a modified dehydrator and could simulate diffusive and convective behaviour of pollutants in the unsaturated soil zone and through diffusion barriers like bottom plates. It is separated into two sections; the lower part being used for the pollutant source and for the unsaturated soil zone and the upper part being used to simulate an indoor space. Between the two glass envelopes it is possible to fix a specimen e. g. a tight interlayer or different types of concrete. In the lower part there are two openings used for taking different soil gas samples. The pollutant source was also inserted in the lowest part of this module. The ports in the upper part are for ventilation. At the top the connection to the GC-FID-system (gas chromatography-flame ionization detection) is positioned.

With this configuration it is possible to simulate the vapour intrusion in several types of soil and concrete with different pollutant mixtures.

Advantages of this module are that a large variety indoor air concentration with different soil materials or diffusion barriers can be measured under lab conditions. The determination of effective diffusion coefficients and diffusive mass flows (Fick's 1st law) can also be performed with this module. Several settings of the lab experiments were transferred into the field scale experiments.

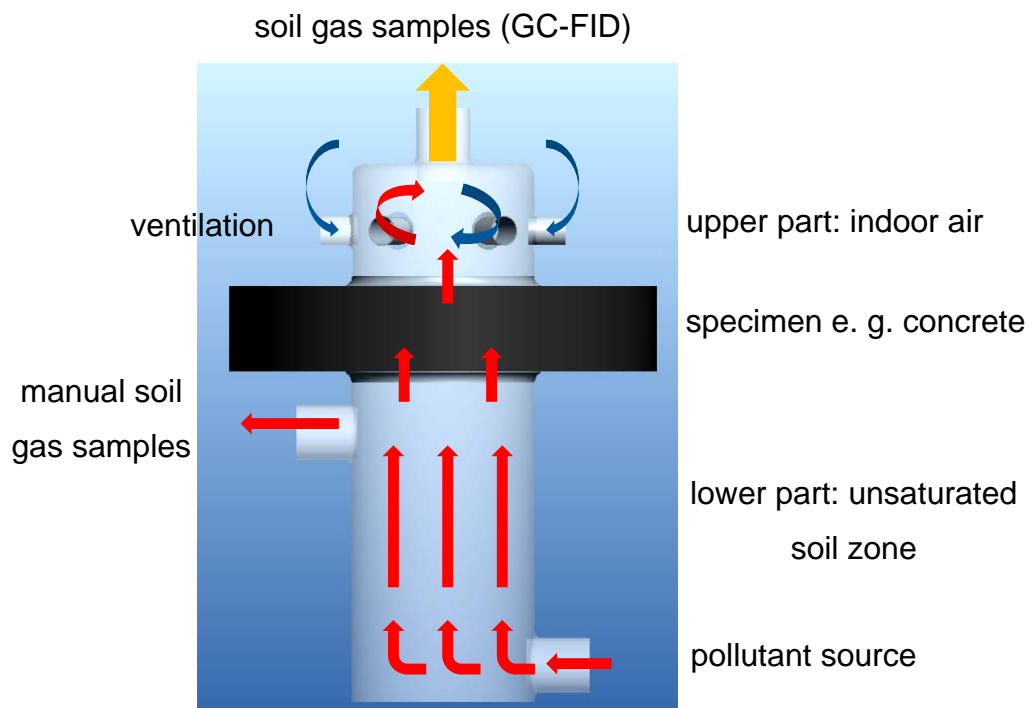


Figure 1: Bench-Scale-Module for vapour intrusion

2.2 – Field scale experiments

Field scale investigations have been executed at the Bitterfeld megasite in Saxony-Anhalt. At this site the groundwater is contaminated extremely with VOCs such as trichloroethene, *cis*-1,2-dichloroethene or 1,1,2,2-tetrachloroethane. The field module was used for the determination of transfer rates of VOCs through different bottom plates into ambient air with simultaneous analysis of soil gas. Long term tests of several concrete specimens were also performed with this module. Inside of the module were four test chambers for different intrusion scenarios. The mechanism of a test chamber is shown in Figure 2. The specimen was fixed directly on the soil simulating a bottom plate. Inside of the test chamber it was possible to regulate manually the air exchange rate ($0\text{--}2.5\text{ h}^{-1}$) and the pressure difference ($0\text{--}100\text{ Pa}$) to simulate different intrusion scenarios. Next to the test chambers soil gas sampling stacks at several depths were allocated. The soil gas samples were analysed by a mobile on-line GC-FID-system with automated air sampling and integrated thermo-desorption. The meteorological parameters such as soil temperature, soil moisture, air pressure as well as the depth of groundwater table were automatically recorded.

The field module offers a simple method to simulate the migration of soil gas pollutants from the groundwater through the soil gas and diffusion barrier into ambient air. The transfer rates of VOCs as well as the diffusive and convective behaviour of pollutants through concretes could be determined.

The data yielded from the several intrusion scenarios of the field module were implemented in the novel prediction tool. So the model was evaluated with a real data set.

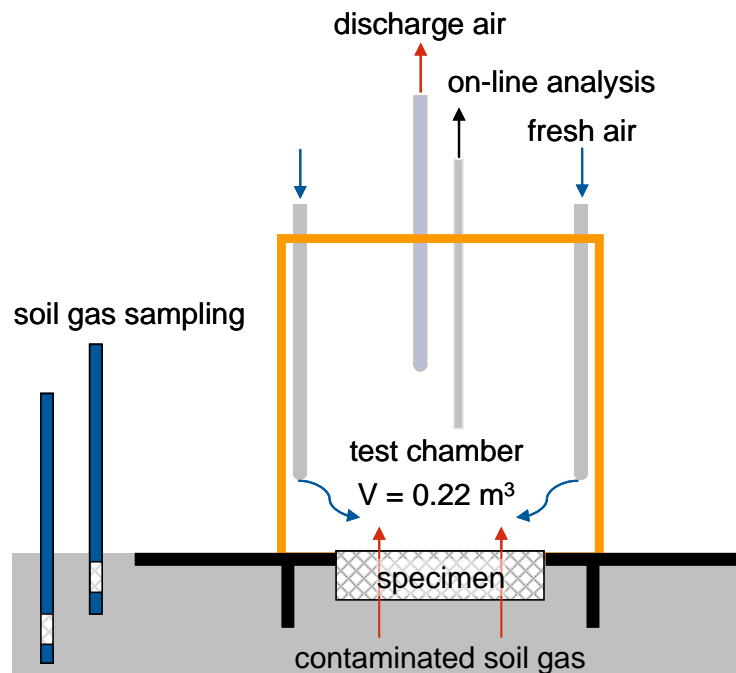


Figure 2: Flowchart of a test chamber used in the field module

3 – THE MODEL

A number of risk assessment models for indoor air concentrations are currently used in practice (e. g. Johnson & Ettinger 1991, Volasoil, 1996), but they have been proven to underestimate indoor air concentrations significantly compared to the actual measurements. Therefore a new model, the Soil Vapour Intrusion (SVI) model, was developed by the UFZ. The SVI was based on the model from the 1991 Johnson & Ettinger but with major improvements. Some advantages of the new model are the implementation of 10 soil layers and 10 compounds and the calculation of the diffusive transfer through different sealing materials. Other benefits of the new model are the possibility of forward and backward calculations from groundwater and/or soil gas to indoor air concentration as well as the production of concentration profiles at any depth. Finally the model is an important tool to consult when improving the indoor air situation at contaminated sites.

The first set of calculations with field data from the field module at Bitterfeld site showed an outstanding comparison between measured soil gas concentration and ambient air to the SVI values. The calculations for groundwater values varied only with one order of magnitude.