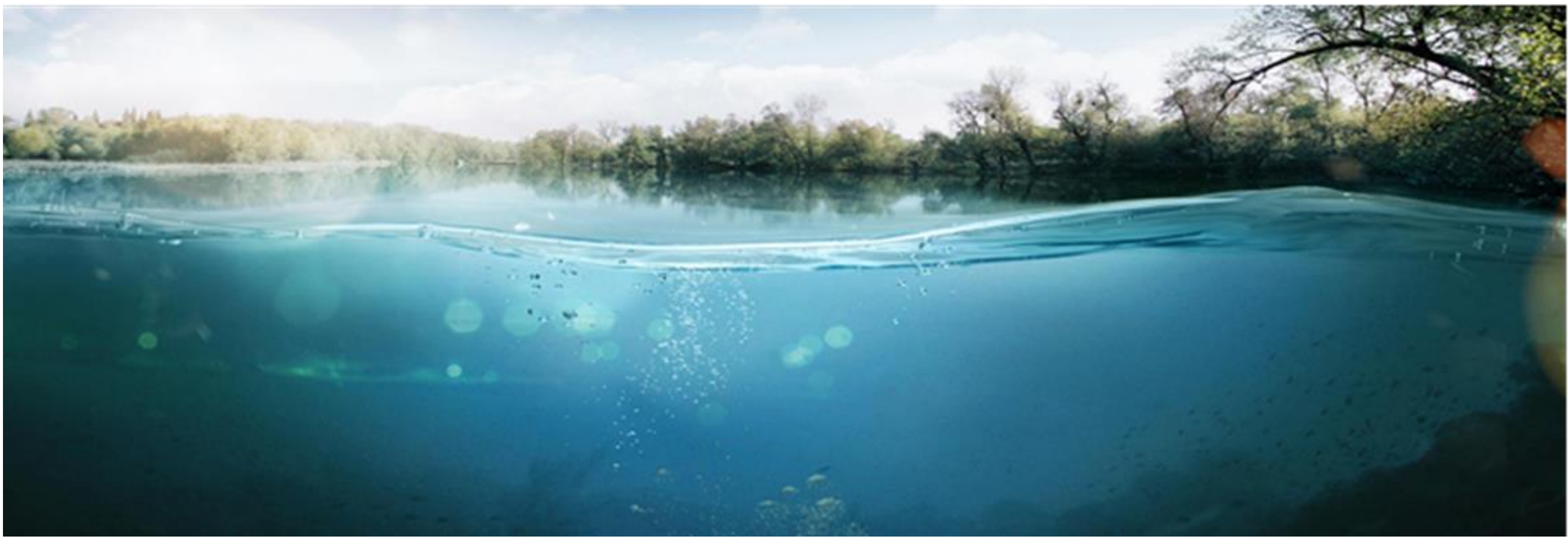
# Nicole
## INNOVATION AWARD 2017



iFLUX

# Integrated passive groundwater mass flux sampling technology

envision groundwater in motion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vito vision on technology

## *Executive Summary*

iFLUX entails a proven innovative measurement solution to explore the motion of groundwater pollution. The patented technology in combination with the specific data interpretation methodology guarantees a more accurate and complete view of water and pollution movement beneath the surface. These detailed insights enable problem owners to reduce the cost of total contaminated site remediation significantly.

The monitoring and management of soil and groundwater is a challenge. Current methods for the determination of movement of pollution in groundwater use no direct measurements but only simulations. This entails large uncertainties which cause remediation failures and higher costs for contaminated site owners. On top of that, the lack of useful data makes it difficult to get approval for a *risk-based management* approach which completely avoids costly remedial actions.

iFLUX introduces the first *modular flux sampler* operational in the market, that provides accurate in situ measures of groundwater and pollution movement. Currently, two designs have been developed: 1. the iFLUX sampler for installation in existing monitoring wells, and 2. the iFLUX Prospector for direct installation in the subsoil. The modular design enables to sample several types of pollution at the same time and for a longer period (1 week to 6 months). When installed in an existing monitoring well or directly in the saturated subsoil, it intercepts the groundwater flow and captures the compounds of interest. Lab analysis will result in time-averaged groundwater and target compound fluxes. The iFLUX technology currently comprises one Waterflux cartridge to monitor speed and direction of flow and three cartridges to monitor different sources of pollution – VOC's, heavy metals and nutrients.

The integrated Flux Solution includes lab analysis and data interpretation in order to deliver trustworthy groundwater flux information. The end-result is an analytical report containing detailed and reliable flux data, with comprehensible graphs and maps of the designated field. This leads to a novel approach of dynamic remediation management in a more cost-effective and faster manner.

The method is validated and demonstrated at several projects in Flanders, Wallonia, France, Switzerland and the Czeck Republic. Local regulators, research institutes, consultants and problem owners were involved. The technology is on track to be accepted and recommended by environmental regulators as the number one technology for in situ mass flux determination.

Inventor and key developer of the iFLUX technology is Dr. Goedele Verreydt, who spent 8 years to optimize a flux sampler that fits market needs. Together with Tim Op 't Eyndt and Filip Meesters, they finished the iFLUX prototype and specified the business concept ready to launch commercially as a spin-off of VITO and the University of Antwerp.

## *1. Introduction*

Even though safety and environmental compliance obligations have become more stringent over the recent past, a large number of contaminated sites still prevail. Alongside this the demand for land (and groundwater) remains high, driven by population growth and continued commercial and industrial activity. Consequently, the need for remediation of contaminated sites to restore the land for future viable use is in high demand.

Deep and irregularly shaped contaminant sources typically produce widespread and dynamic plume zones that are difficult to monitor and difficult to remediate. Remedial actions often fail because of the inadequate characterization of the source zone.

Authorities and environmental consultants are well aware that it is not enough to know what is the current pollution beneath the earth surface, you also need to know how it is moving. The pollution that reaches a receptor (e.g. drinking water extraction, residential zone, river) determines the risks for that receptor and therefore should be measured. Only when this risk is in control, a risk-based management of the contamination is suggested, which is often the only BATNEEC option (Best Available Technology Not Entailing Excessive Cost).

*"It is not only about the status of pollution in groundwater,
it is about where and how it moves."*

The pollutant load or the mass of pollutant that is moving through the subsoil and the groundwater is called the *contaminant mass flux*. Current methods for the determination of mass fluxes in groundwater provide no direct in situ measures of flow.

The monitoring and management of soil and groundwater is a challenge. These methods involve individual measurements of Darcy water fluxes and contaminant concentrations. This indirect approach entails large uncertainties, especially in complex, heterogeneous aquifers and under temporally varying flow conditions. These uncertainties cause more remediation failures and higher costs for contaminated site owners. On top of that, the lack of useful data makes it difficult to get approval for a *risk-based management* approach which completely avoids costly remedial actions.

## 2. Contaminant mass flux

Contaminant mass flux is defined as the total amount of contaminant, expressed as mass, passing per unit area per unit time through a well-defined control plane or plane of compliance that is orthogonal to the mean groundwater flow direction (Basmadijan, 2004; Bear, 1988; Newman et al., 2005). $J_c = C.v = \frac{m}{A.t}$

where Jc is the contaminant mass flux [g m$^{-2}$ day$^{-1}$], C is the mean concentration of the contaminant in the groundwater [g m$^{-3}$], v is the Darcy groundwater flux [m$^{3}$ m$^{-2}$ day$^{-1}$], m is the mass of contaminant [g], A is a well-defined plane of compliance, orthogonal to the groundwater flow direction [$m^2$] and t is the time [day].

Contaminant mass discharge ($M_d$) is the spatial integration of the contaminant mass fluxes (i.e., the sum of all mass flux measures across an entire plume) and thus represents the total mass of any contaminant transported by groundwater through a defined plane. Contaminant mass discharge is expressed as mass per time.

$$M_d = \int_A J_c dA$$

where A is the area of the plane of compliance [$m^2$] and $J_c$ is the spatially variable contaminant flux [g $m^{-2}$ $day^{-1}$].

## 3. Technology

The iFLUX technology includes an *in situ* measurement device for capturing dynamic groundwater quality and quantity, and an associated interpretation and visualization method. Currently, two iFLUX designs have been developed: 1. the iFLUX Sampler for installation in existing monitoring wells, and 2. the iFLUX Prospector for direct installation in the saturated subsoil.

The basics of the three designs are the same. They all are modular systems that include catridges, specific to measuring water flux or capturing the contaminants of interest. The catridges, when exposed to the groundwater flow, provide in situ point determinations of a time-averaged target compound mass flux and water flux.

### *iFLUX cartridges*

The iFLUX catridges are permeable cartridges which are each packed with a specific sorbent matrix. The sorbent matrix of the water flux cartridge is impregnated with known amounts of water soluble resident tracers. These tracers are leached from the matrix at rates proportional to the groundwater flux. The measurements of the contaminants and the remaining resident tracer are used to determine groundwater and target compound fluxes. Exposure times range from 1 week to 6 months, depending on the expected concentration and groundwater flow velocity. Four types of cartridges are currently available: volatile organic compounds, metals & heavy metals, nutrients and water flux. Several cartridges can be superimposed to realize vertical flux differentiation

### *iFLUX Sampler*

The iFLUX Sampler is the device that can be installed in existing monitoring wells. The cartridges are superimposed on rods (typically on waterflux catridge combined with one or more contaminant cartridges) that can be connected to form a long sampling chain. The ease of use and installation is the main advantage of this design.

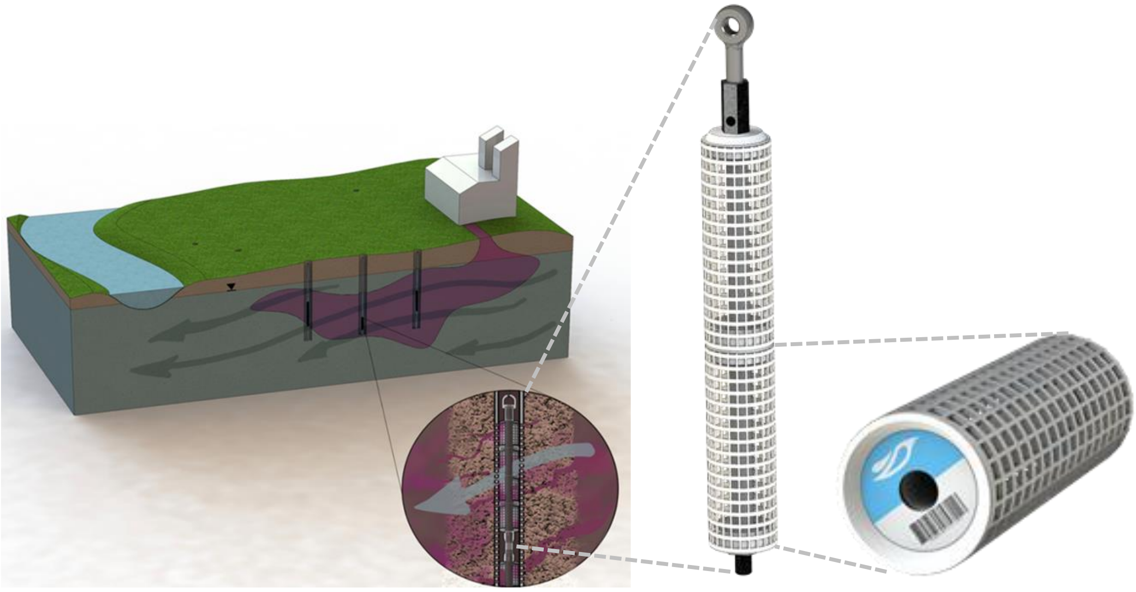


*Figure 1 - iFLUX sampler: Field concept – sampler assembly – sampler cartridge*

## *iFLUX Prospector*

The iFLUX Prospector modules are designed to create a string of stainless steel modules to install into the soil by the use of machine drilling rig or by hand drilling.  The weight and dimensions are designed to make the installation a one man job. Every sampling module can contain several iFLUX cartridges. Figure 2 shows the installation of the iFLUX Prospector system using a machine drilling drig. Advantages of this system are the no need for monitoring tubes where it is not desired and the minimum groundwater flow field distortion as the cartridges are in direct contact with the surrounding soil material.

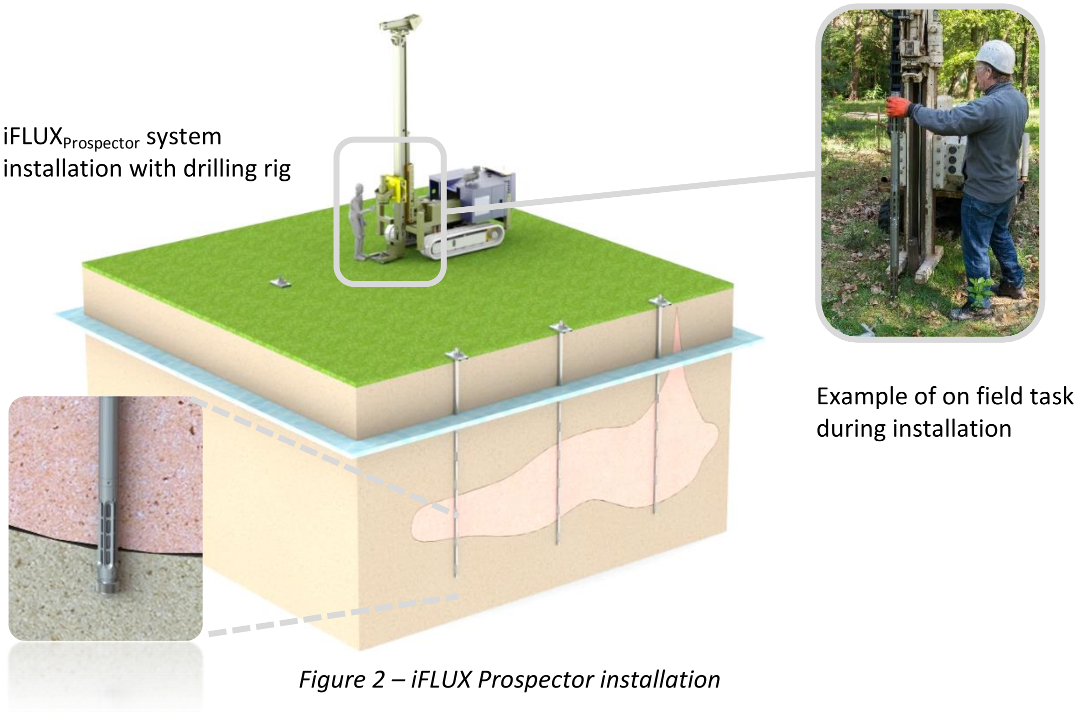



*Figure 2 – iFLUX Prospector installation*

## 4. When to apply?

- *More accurate characterization*
  Executing the remediation based on accurate data that can also indicate the mobility of contamination is of invaluable importance. Therefore it is crucial to map out clearly the spreading risks of groundwater contamination.
- *Design remediation plan*
  High flux zones can be indicated and in situ remediation techniques can be dimensioned based on the actual and local pollutant load.
- *Determine remediation urgencies and priority source zones*
  Differences in source strength can be determined from the flux results, which localizes the most hazardous sources. This can be put to immediate use in the remediation plan.
- *Follow up of remediation efficiency*
  Follow-up of the efficiency of these remediation measures is more accurate as well. This can be done by following the decrease in pollutant load and pollutant flux, typically downstream from the treated source or plume zone.
- *Monitoring of Natural Decomposition*
  The natural decomposition or the decrease in pollutant loads can be calculated by the difference in total pollutant load between two cross sections of the contamination plume. Monitoring of decomposition parameters, nutrients and fluxes to subsidiary products also results in highly valuable information.
- *Risk-based management of contamination*
  Flux sampling offers a reliable basis for risk management. The actual mass and speed with which a contamination reaches a receptor, evaluates precisely the risks for this receptor.

## 5. Reference projects

Multiple reference projects within different application scopes have been and are still being perfomed. As an example, we will show some results of two recent projects: 1. Vertical stratification of VOCs in groundwater (Czeck republic), and 2. PASSIFLUX phase 1-2 (Switzerland).

### *Reference 1: Vertical stratification of VOCs in groundwater (Czechia, March-May 2017)*

*Background*

It concerns an active industrial site in Czechia. The site is contaminated with petroleum hydrocarbons, chlorinated solvents and pharmaceutical products. The flux field campaign focuses on the vertical spreading of mainly the chlorinated solvent compounds.

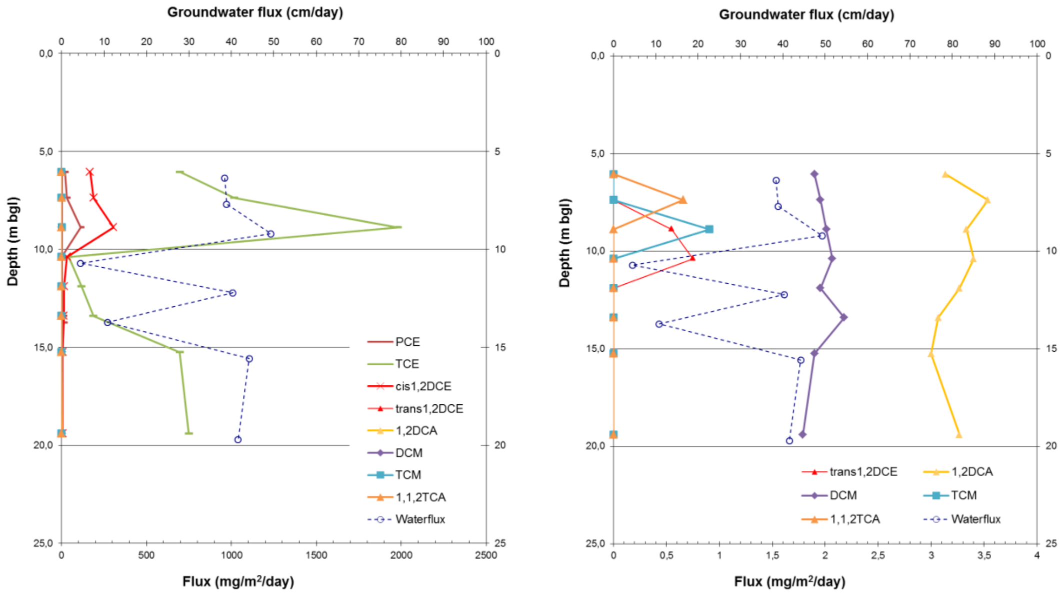
*Challenge*

The challenge within this project is to determine the vertical stratification of the residual deeper pollution in a very heterogeneic subsoil. A fully screened deep large diameter well is used for the measurements.

*Solution*

16 iFLUX cartridges were installed in one large diameter well between 6 and 19 meter below ground level. The mass flux data determine the vertical spreading and therefore stratification of the residual VOCs in the subsoil.

*Results*




*Figures 3 a & b - iFLUX mass flux results in one monitoring well, showing different scales*

## Reference 2: PASSIFLUX phase 1-2 (Switzerland & France – 2015/2018)

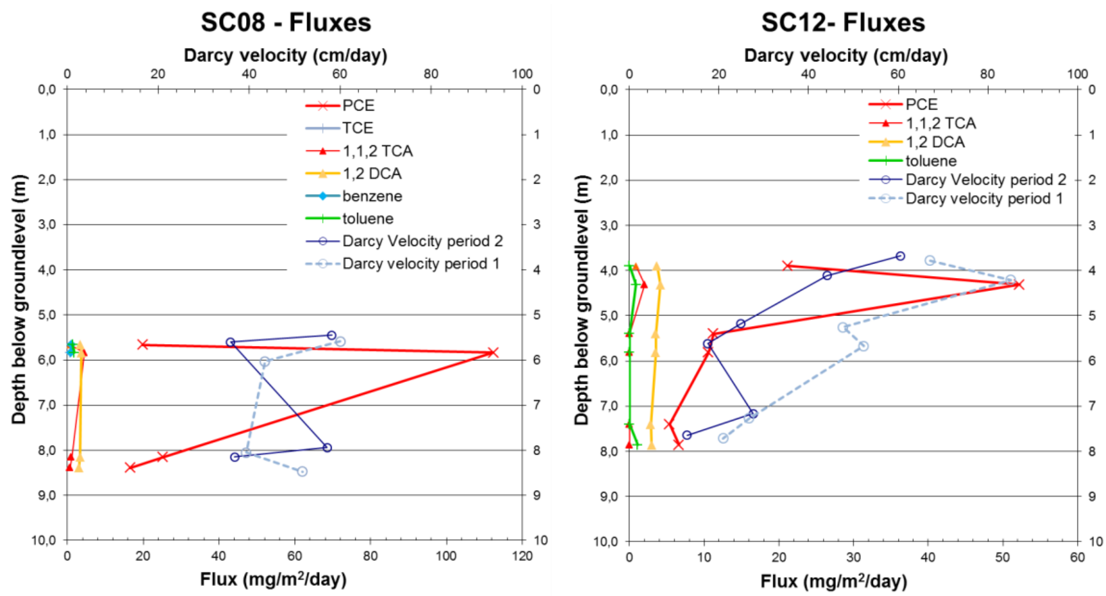
*Background*

This study comprises the application of passive flux samplers for the measurement of halogenated volatile organic compound mass fluxes and Darcy water fluxes in groundwater at a field site in Switzerland and in France. It frames in the PASSIFLUX project which aims the preparation of a 'Code of Best Practices for Passive Flux Samplers', that includes the evaluation and testing of the performance of several types of passive flux methodologies for groundwater.

*Challenge*

Flux samplers are installed in different situations, with different target pollutions, in source and plume zones, under low and high water fluxes and varying contaminant mass flux loads.

*Results*




*Figures 4 a & b - iFLUX mass flux results in two monitoring wells*

*Solution*

The project consists of four phases. In the first two phases we installed 22 flux samplers (2 cartr./sampler) in 6 different monitoring wells. After retrieval (1-3 months exposure), the cartridges were analyzed for VOCs and tracers. Results are compared with other passive sampling methods and traditional soil and groundwater sampling methods.

## *6.Prospects & discussion*

The in situ monitoring of the movement of the groundwater pollution is unique and very promising in contaminated soil and groundwater management.

The proposed technology fits within the procedures and principles formulated in the proposed EU Soil Framework Directive, the EU Water Framework Directive, the Industry Emissions Directive and the Flemish Soil Decree. The implementation of this flux-based strategy requires the participation of the local authorities to accept mass flux measurements as an additional or in some cases better alternative monitoring method to conventional concentration measurements.

The Flemish, French and Suisse authorities have already taken the first step toward possible mass flux targeting instead of concentration targeting by implementing the iFLUX technology and by performing pilot studies to validate the technology and pubish it for the environmental sector as a Code of Best Practice for passive flux measurements in groundwater (Pilootstudie Polluentfluxen – OVAM, 2017, PASSIFLUX Project – ADEME & INERIS, 2015-2018).

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