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Abstract

This deliverable 6.7 contains popular science summaries or practice abstracts for practitioners of the major technology used in the PurPest project. They are focusing either on concentration, separation and detection of pest-induced volatile organic compounds or on integrating the technology and data analysis in a portable VOC detection unit for quick and reliable identification of pests during the import of plants.

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1 KEEP FOCUSSED! CONCENTRATE AND SEPARATE VOLATILES THAT MATTER FOR PLANT PEST DETECTION

The **PurPest** project seeks to intercept invasive plant pests by detecting odours either emitted by the pest or the attacked plant. These odours can be in the form of volatile organic compounds (VOCs). The **PurPest** project has identified several VOCs that are released from the pest or attacked plant in controlled plant experiments and is developing a **Sensor System Prototype** (SSP) to detect these. However, there are two main challenges. The first is the extremely low concentration of such VOCs and the fact that these are mixed with many other, non-target VOCs.

PurPest's approach is therefore to include two vital components in the **SSP**. The first is a **pre-concentration unit** that collects VOCs in an absorbent, after which it is released under high temperature. This increases the concentration of the collected VOC up to 1600-fold and thus lowers the limit of detection by the same factor. The second component is a **micro gas chromatograph (µ-GC),** that separates the VOCs by manipulating their various diffusion speeds through a narrow, long tube. Lighter molecules typically emerge first while heavier ones emerge later from this tube. By coating the walls of the tube with the correct material, these differences can be utilized to increase the specificity for separating the target molecules.

Both components require heat to operate and so the **PurPest** project has also focused on energy efficiency to minimise the weight of the SSP. Through innovation, we are developing a portable unit, weighing under 15 kg, that will drastically facilitate detection of invasive plant pests both at point of import and in agricultural fields.

2 SMART COATINGS FOR EARLY PEST DETECTION: CATCHING PLANT SIGNALS WITH SERS-MOF TECHNOLOGY

Surface-enhanced Raman spectroscopy (SERS) is a highly sensitive technique capable of identifying trace amounts of molecules by capturing their unique vibrational fingerprints. Detection limits can reach from the parts per billion (ppb) down to the parts per trillion (ppt), making **SERS** ideal for early-stage diagnostics. However, the technique relies on close proximity between the target molecules and a nanostructured metallic surface, which poses a challenge when dealing with volatile organic compounds (VOCs)—gaseous biomarkers emitted by plants under stress or infection.

As part of the PurPest project, **SINTEF** is addressing this challenge by developing hybrid sensing platforms that combine **SERS-active** substrates with **metal–organic frameworks (MOFs)**. **MOFs** are porous, crystalline materials with high surface area and tuneable pore structures, enabling selective adsorption of VOCs. When coated onto **SERS** substrates, **MOFs** act as molecular traps, concentrating VOCs near the metallic surface and significantly enhancing signal strength. This approach allows for rapid, reliable detection of plant pest related VOCs in real-world environments.

For growers and inspectors, this means faster decisions, healthier crops, and reduced losses—all with a compact, reusable sensor that could be deployed directly in the field.

3 PICKMOL: DOWN TO BUSINESS - PICKING UP PLANT PEST RELATED MOLECULES

PickMol™ is a recombinant technology that uses a complex approach involving photonics, nanotechnology (very small metal particles) and organic chemistry to detect specific molecules—even in extremely low amounts.

PickMol™ detection chips have a special surface made of metal nanoparticles that are designed to create favourable conditions for sensitive detection of molecules of interest. These nanoparticles are bound to specific organic linkers, which are designed by computer modelling assuring a highly specific and strong interaction with a target molecule. Once the molecule is caught on the nanosurface, the technology uses light to detect these molecules.

In the PurPest project, the **PickMol™** technology can be used to detect molecules generated by plant pests or attacked plants, because it is **highly selective** (can detect exactly what you're looking for), **very sensitive** (you can find even traces of the compound), **as accurate as, but cheaper** than expensive lab-based machines (e.g., mass spectrometry), **gives results fast** (in minutes, not hours) and works **on-site**, so the samples doe not need to be sent to an external laboratory.

4 SMELLING PLANT STRESS: AN INNOVATIVE WAY TO PROTECT CROPS

The University of Warwick's contribution to the ground-breaking "PurPest" project is to develop a new, affordable, and practical system for monitoring plant health and detecting pest attacks at an early stage. At the core of this system are two important components: a 3D-printed micro-gas chromatographic (**Micro-GC**) column and a custom-designed **array of gas sensors**.

The **Micro-GC** is a small device that works like a chemical filter. When plants are attacked by pests such as insects or pathogens, they release special chemical signals called volatile organic compounds (VOCs). The **Micro-GC** separates the mixture of different VOCs into their individual components, much like a prism splitting light into a rainbow.

The **sensor array** then takes over. It is made up of small, highly sensitive devices called solidly mounted resonators (**SMRs**), which operate at very high radio frequencies (~ 2 GHz). These sensors are coated with thin special materials that absorb specific VOCs released by plants. By using different coatings, each **SMR** can be tuned to respond to a particular type of chemical compound. Working together with the **Micro-GC**, the **SMR**-based sensor array forms a so-called "**electronic nose**" that can identify the unique chemical patterns plants produce when they are attacked by pests.

To make sure the information is meaningful and useful, the system is combined with machine learning methods which will help to recognize VOC patterns and improve the accuracy of pest detection.

Because the **Micro-GC** can be **3D-printed in plastic**, it is low-cost, compact, and easy to produce at larger scales, making it possible for farmers to deploy it across commercial fields. By providing real-time, non-invasive monitoring, this technology could help farmers take quick action against pest attacks, reducing crop losses, limiting pesticide use, and supporting sustainable agriculture.

5 GAS CHROMATOGRAPH EQUIPPED WITH PHOTOIONIZATION DETECTION (PID): IDENTIFYING PEST VOLATILE PROFILE

Invasive plant pests pose a serious threat to plant health and food production, yet current analytical techniques cannot detect them reliably and cost-effectively. Detection via volatile organic compounds (VOCs) is a promising strategy, but the extremely low concentrations of pest-induced VOCs make reliable identification highly challenging. Highly sensitive and specific sensor technologies are therefore required to enable early detection of infested plants.

Within the PurPest project, a **gas chromatograph equipped with a miniaturized pre-concentration unit** and a **photoionization detector (PID)** was developed and evaluated for the characterization of pest-infested plants. The **PID** is a highly sensitive and robust detector for VOC analysis, but it lacks selectivity, as it responds to nearly all VOCs rather than specific compounds. Therefore, a chromatographic column is required to separate the compounds, enabling precise characterization of the gas sample. The analytical system was tested in collaboration with our partners in Switzerland, Germany and Italy. During these campaigns the system operated continuously over two weeks, analyzing ambient air, ambient air with healthy plants, and ambient air with pest-infested plants, autonomously. All three campaigns were successful, as the system reliably distinguished the different VOC profiles. However, it also demonstrated that detecting pest-induced VOCs is extremely challenging without pre-concentration and chromatographic separation, since the specific VOCs constitute only a tiny fraction of the total VOCs present in ambient air.

Currently, PurPest partners are working on integrating the validated analytical modules into a portable analytical system, which aims to combine high sensitivity and specificity with being deployable in the field. This will enable early detection of pest infestations in real-world conditions such as fields, greenhouses, nurseries, or container shipments, where rapid and reliable monitoring is critical for preventing the spread of invasive pests.

6 MULTIPLE SENSOR INTEGRATION: DETECTING PEST VOLATILE DATA ON THE GO!

During pest attack, plants can produce specific Volatile Organic Compound (VOC) fingerprints that can be used for pest identification and monitoring, if they can be detected with suitable sensor technologies.

Integrating multiple **field-capable sensors** into a **single portable instrument** promises cheaper and easier operating experience, while allowing to measure pest-specific VOCs. Different sensor technologies have different operating principles, with some returning changes in electric voltage, whereas others work with the principle of light detection or frequency changes. Sample handling, how VOCs are collected and sent to the sensors of choice also needs to be considered. Therefore, integrating different sensors into a single portable instrument requires **custom built broad capability electronics**.

During the **PurPest** project, **printed circuit boards** were designed to ensure voltages that are compatible with different sensor technologies and current energy consumption is being met by the instrument's power supply. Once different sensors are integrated and functional, we are developing user-friendly **software capabilities** to interpret VOC signals from examined plants. After pre-processing required by the different sensors, the extracted information is fed to a machine learning model that will recognize patterns useful for determining the health status of the plant, effectively achieving a multi-sensor predictive system. At the moment, most of the work has been focused on Proton-Transfer-Reaction-Mass Spectrometry (**PTR-MS)** and Gas Chromatography-Photoionization detector (**GC-PID)** technologies, for which smoothing, baseline-removal, normalization, and peak and compound detection methods have been developed.