

NEWS | NOV25

Fraunhofer Institut for Molecular Biology and Applied Ecology IME

Welcome

In this issue, we would like to present our research work on the topic of "soil": the recording of soil contamination with chemicals via chemical monitoring and genetic metabarcoding. The large-scale project "BioDive4Soil", which we coordinate, investigates the state of biological diversity in our soils. In our portrait, we introduce Dr. Sebastian Kühn, head of our junior research group "B-Pol" on bioaccumulation of polymer products in soils and waters.

Yours sincerely,


Prof. Dr. Christoph Schäfers

Recording the contamination of agricultural land with biocides, pharmaceuticals, and pesticides in Germany

► Soil, along with water and air, is one of the natural foundations of life. It fulfills key functions for plants, animals, and humans and provides a habitat for numerous organisms. However, agricultural and industrial use introduces a wide variety of substances into the soil – intentionally, for example through fertilizers and pesticides, or unintentionally via air, manure, sewage sludge, or other inputs. These substances can significantly impair soil

functions and biodiversity.

Despite their importance, studies on chemical contamination of soils are rare and usually limited to individual substances. In reality, however, soil organisms are often exposed to a mixture of chemicals. Little is known about the consequences of such multiple exposures. Existing contamination, substance accumulation, or the spread of antibiotic resistance genes are also rarely taken

In this issue you can read:

- Recording soil contamination
- MetalInvert: Development of genetic methods
- BioDive4Soil: Basic survey on soil biodiversity
- Portrait:
Dr. Sebastian Kühn

into account in approval procedures.

The project, which is being carried out by Fraunhofer IME under the direction of Karlheinz Weinfurter on behalf of the German Federal Environment Agency, closes this gap by conducting a comprehensive inventory at approximately 100 agricultural locations in Germany (arable land, grassland, fruit and wine growing). Between 2022 and 2024, soil samples were taken from two depths (0–5 cm and 5–20 cm) and tested for residues of pesticides, human and veterinary medicines, biocides, and selected REACH chemicals. In addition, earthworms, springtails, and mites were sampled, and microbial activity and the presence of antibiotic resistance genes (ARGs) were analyzed.

The results show that contamination depends heavily on

land use. Hardly any residues were found on grassland, while several active substances of pesticides were regularly detected on arable land, orchards, and vineyards. Drug residues occurred only sporadically on arable land. There were few differences between the upper and lower soil layers, with slightly higher concentrations tending to be found in the top layer. ARGs also occurred in both layers of fields treated with organic fertilizer and grassland areas with a similar pattern, indicating uniform distribution. In contrast, REACH chemicals were only found in low concentrations in isolated cases.

These data should help to improve the risk assessment of biocides, pharmaceuticals, and pesticides, review environmental regulations, and make future approval procedures more scientifically sound. ■

MetalInvert: Developing Standards for Genetic Methods to Include Soil Invertebrates in Monitoring Programs

► Soil invertebrates such as nematodes, enchytraeids, and microarthropods are essential for soil health. They drive nutrient cycling, organic matter decomposition, and the maintenance of soil structure. Despite their importance, they are often not included in routine monitoring programs. A key reason is that the identification of these organisms through classical taxonomic methods is extremely time-consuming and requires experts – a resource that is becoming increasingly scarce.

Molecular methods, such as metabarcoding, offer a promising solution. By analyzing DNA sequences, a rapid and accurate identification of entire communities is possible. However, a major obstacle to their broader use is the lack of standardized procedures. Without harmonized methods, results are difficult to compare across studies and countries, limiting their use in regulatory frameworks and monitoring programs.

The MetalInvert project, funded by WIPANO (Funding No. 03TN0054D), was carried out in collaboration with Senckenberg, Quodata, and Dr. Limnowak. The project aims to close the existing gap by developing standards to validate genetic methods for

characterizing soil invertebrate communities using metabarcoding. It focuses on community DNA – DNA extracted from bulk samples of animals collected in the field. This approach builds on existing sampling guidelines, making it a practical starting point for standardization.

The project has focused on establishing pre-analytical requirements for metabarcoding and defining the basic conditions for barcoding PCRs. In the first phase, test collections of organisms were carried out and protocols were refined, which led to the design and implementation of a ring test involving eleven laboratories - seven international and four national.

“The results are very promising,” says Dr. Cecilia Díaz from Fraunhofer IME and member of DIN (NA 119-08-04 AA Biologische Verfahren), “and represent a tremendous milestone that provides a strong basis for the preparation of



an ISO draft to be formally presented to the committee in March 2026.” At the same time, she emphasizes that in the context of standardizing molecular methods, much remains to be done - particularly with workflows starting directly from soil-extracted DNA (eDNA), which would greatly expand soil monitoring by enabling the inclusion of organisms that are otherwise difficult to collect or identify.

With the progress achieved so far, we are one step closer to making genetic methods a reliable tool for soil biodiversity assessment. Ultimately, this will support the integration of soil invertebrates into long-term monitoring programs and provide a stronger scientific basis for soil protection. ■

BioDive4Soil - How much life is in our soils?

Fraunhofer IME leads the research consortium investigating biological diversity in Germany's soils

▶ Although 60 percent of the Earth's total biodiversity is found in our soils and these soil organisms are responsible for fertile soils and clean drinking water, humus formation and pollutant degradation, little is often known about the status of these microorganisms and the biological diversity and performance of soils in Germany.

For this reason, the German Environment Agency (UBA) has launched a research program in collaboration with the Fraunhofer-Gesellschaft and ten other institutions, which is funded by the Natural Climate Protection Action Program (ANK) of the Federal Ministry for the Environment (BMUKN).

The world of soil organisms often remains hidden, even though it is essential for humans. Soil biodiversity ensures the functioning of our ecosystems: soil animals and microorganisms control nutrient cycles, store carbon, mix soil layers, and help with rainwater storage. “Ecosystem engineers” such as earthworms and ground-nesting wild bees depend on healthy soils. However, pollution, unsustainable use, and climate change are threatening soil biodiversity. The BioDive4Soil research project, part of the Natural Climate Protection Action Program (ANK), is investigating the composition of soil communities in Germany. The aim is to define good biological soil condition, identify changes, and collect data on earthworms, springtails, mites, nematodes, fungi, and bacteria. To date, there is a lack of comprehensive knowledge about the biological condition of soils and how they change over time.

Over the next six years, soil ecology researchers from all over Germany will study biodiversity in different soils with different uses. Since the diversity of organisms in soils is extremely high - trillions of bacteria and several thousand representatives of different species groups can live in a single gram of soil - their reproducible recording poses a particular scientific challenge. In order to master this challenge and make it easier

to identify soil organisms in the future, the latest molecular biological methods will also be used.

The project team, led by Dr. Elke Eilebrecht and Dr. Karsten Schlich from Fraunhofer IME, will work closely with other research institutions to incorporate activities already underway. In addition to the German Environment Agency (UBA), these include the Federal Agency for Nature Conservation, the National Monitoring Center for Biodiversity, the National Soil Monitoring Center, and other institutions from monitoring networks, which will be involved, for example, in an advisory board. ■

Further information: www.ime.fraunhofer.de/en/BioDive4Soil



BioDive₄Soil



"Only when we understand how polymer products behave in biological systems can we better protect people and the environment."

Dr. Sebastian Kühr...

► Dr. Sebastian Kühr studied chemistry and biology at the University of Siegen to become a high school teacher and wrote his state examination thesis at Fraunhofer IME on the effect of silver nanoparticles in wastewater on the freshwater amphipod *Hyalella azteca*. In his subsequent doctoral studies at Fraunhofer IME (2018–2020), he investigated the bioaccumulation of nanomaterials in invertebrate organisms and developed test and assessment concepts for their regulatory evaluation. From 2021 to 2025, he conducted postdoctoral research at the Norwegian Institute for Water Research (NIVA) and

in the particle laboratory at Eawag (Switzerland) with international partners such as Imperial College London (UK) on the transformation, bioaccumulation, and toxicity of nanomaterials in the environment, as well as plastic additives in marine invertebrates and *in vitro* systems.

Since June 2025, he has been leading the "B-Pol – Bioaccumulation of Polymer Products" group as part of the Fraunhofer "Attract" program.

Almost 500 million tons of polymers are produced annually – for use in packaging or car tires, for example. During their manufacture, use, and disposal, micro- (100 nm–5 mm) and nanoparticles (<100 nm) enter the environment. In addition to the possible uptake and accumulation of these particles in the food chain, polymer additives such as metals and organic compounds also pose a challenge, as they can be washed out in humid or aqueous environments.

Although polymers are subject to the REACH regulation and their bioaccumulation potential must be assessed, existing guidelines for conducting studies on these substances are currently not very suitable.

The aim of the Attract group "B-Pol" is therefore to develop test and evaluation concepts for the regulatory bioaccumulation assessment of polymer products. The test guidelines to be developed should not only enable a reliable assessment of the particles and released additives, but also avoid the use of vertebrates.

For concept development, Fraunhofer IME will initially use radioactively labeled polymers synthesized there in nano- and microplastic sizes. These will be used to investigate uptake pathways in various invertebrate organisms and collect data on bioaccumulation. Based on this data, suitable test organisms will then be identified and adapted test systems developed and optimized. Their suitability for various polymer products will be determined by testing typical everyday products.

The methods, which are being further developed in collaboration with partners within and outside the Fraunhofer-Gesellschaft, are intended to help better identify current environmental impacts and reduce future risks through improved regulation. ■

IMPRINT

Published by
Fraunhofer Institute for
Molecular Biology and
Applied Ecology IME

Division Applied Ecology
Auf dem Aberg 1
57392 Schmallenberg
Germany

Phone +49 2972 302-0
www.ime.fraunhofer.de/en/ae

Director
Prof. Dr. Christoph Schäfers

Editing, Design & Layout
Julia Karbon, Dorothea Weist

Translation
Dr. Terry Clark

Production
Schäfers Druck GmbH,
Schmallenberg
100% Recyclingpaper

Read more about our research activities here:

www.ime.fraunhofer.de/en/ae