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Biochem-Env: a platform of biochemistry for research in environmental and agricultural sciences

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Abstract

Biochemical indicators are potent tools to assess ecosystem functioning under anthropic and global pressures. Nevertheless, additional work is needed to improve the methods used for the measurement of these indicators, and for a more relevant interpretation of the obtained results. To face these challenges, the platform Biochem-Env aims at providing innovative and standardized measurement protocols, as well as database and information system favouring result interpretation and opening. Its skills and tools are also offered for expertise, consulting, training and standardization. In addition, the platform is a service of a French Research Infrastructure for Analysis and Experimentation on Ecosystems, for research in environmental and agricultural sciences.

Keywords

environment; agriculture; ecotoxicology; biochemical markers; enzymes; environmental stressors; land use; survey; agrosystems; microorganisms; soils; sediments; invertebrates; information system; open science; indices

Introduction

Our environment is a heritage to be protected for the future generations. It comprises several types of ecosystems that are essential for human societies, by providing well recognized services (Millenium Ecosystem Assessment, 2004). To produce these services, the ecosystems mobilize key resources, which are non-renewable at a human time scale. Resources include living organisms, micro-organisms, fauna and plants, as a basis for biodiversity. It is now admitted that ecosystems and their biodiversity are impacted by increasing anthropic (crop and forest production, land use, peri-urban and urban development, chemical pollution...) and global pressures, with possible consequences for human well-being (Balmford and Bond, 2005).

To set, follow and ensure protection and managements actions on ecosystems, either natural or cropped or urbanized, it is necessary to develop indicators responding to functional disturbances. Monitoring of environmental quality can draw on two approaches, of physical-chemical or biological nature. The first one deals with the knowledge of threshold levels for pH, temperature, organic matter content, oxygen saturation, nitrogen, phosphorus and ion concentrations, contaminants... that affect life. The second one concerns biological indicators that offer the advantage to integrate a large set of stresses reflecting the global state of the ecosystems, and of their functioning. They are measurable at various levels of biological organization (individual, population, community levels). Among these biological indicators, biochemical indicators are used for a long time as tools to assess molecular, biochemical, cellular or physiological changes that may reveal exposure of organisms to environmental modification (i.e. biomarkers: Lagadic et al. 2000). However, interferences with natural environmental factors or endogenous parameters affect the interpretation of their responses. Therefore, although measured for many decades (i.e. soil enzymatic activities: Caldwell,

2004), they have not been commonly applied in long-term observation, environmental risk assessment (ERA) or for regulatory purposes (Jemec et al., 2010). In that context, the platform Biochem-Env (<https://www.biochemenv.fr/>) behaves as an innovative tool for providing an increased knowledge on biochemical indicators, as developing skills and services to support researchers from academia, but also from industry and forces of civil society.

What is Biochem-Env?

Biochem-Env is a technical platform allowing the development and the measurement of biochemical indicators in the environment and associated living organisms. The missions of the platform are: i) to provide equipment and skills for analysis to hosted users and service delivery, ii) to contribute, as a scientific partner, to research projects for observation and experimentation on ecosystems, iii) to develop innovative methodologies and protocols, and 4) to carry out expert missions (consulting, training..., Fig. 1). In the environment (i.e. soils and sediments), the platform performs the measurement of enzymatic activities involved in the biogeochemical cycles and the metabolism of macromolecules, and/or reflecting the overall metabolic activity of these media. It achieves also the measurement of biochemical indicators of benthic and terrestrial invertebrates, such as energetic reserves and macromolecules, oxidative stress, detoxification mechanisms, exposure to environmental contaminants... Examples of biochemical indicators actually provided by the platform are presented Table 1.

Biochem-Env is also a structure offering to the scientific community open datasets on biological indicators in relation with the functional biodiversity of ecosystems. To reach that objective, the platform actually develops an Environmental Information System centered on a database gathering its measurements, results and associated metadata. Rigorous quality

standards are a prerequisite for that system, which will be interoperable with other French environmental databases. The information and knowledge gain obtained by the platform will allow the development of mathematical and modeling approaches to evaluate and predict the impacts of environmental hazards on functional biodiversity.

In relation with activities related to its scientific and technical objectives, the platform operates expertise, consulting and training (academic students from 2 to 5 years after bachelor degree, and Ph.D), as well as scientific watch. It also aims at valorizing its produced results (scientific and transfer publications, participation in scientific or professional congresses and workshops) and developed protocols (international standardization).

Biochem-Env is a service of the Research Infrastructure for Analysis and Experimentation on Ecosystems (AnaEE-France, <https://www.anaee-france.fr/en/>), which is an integrated network of the major French experimental, analytical and modelling platforms dedicated to the biological study of continental ecosystems (aquatic and terrestrial)(Mougin et al., 2015).

AnaEE-France aims at understanding and predicting ecosystem dynamics under global changes. It offers three main kinds of services open to national and international research on ecosystems: access i) to experimental and analytical facilities, instruments, and modelling platforms, and ii) to large data sets. AnaEE-France will provide the best tools to conduct innovative fundamental research on gene-environment interactions, biodiversity, biotic interactions and ecosystem functioning, and eco-evolutionary processes. Biochem-Env is also an associated analytical platform of the Biological Resource Centre for the Environment (BRC4Env, <https://www.brc4env.fr/>), for the characterization of samples of environmental biological resources. BRC4Env is an element of the French infrastructure Agricultural Resources for Research (RARE-AgroBRC), a network of Biological Resource Centres and collections, that can be used to collect, distribute and secure biological resources sampled during environmental and agricultural studies.

Biochem-Env has been involved in numerous French and international research projects. Examples deal with the assessment of the impact of toxic elements and chemicals (metals, antibiotics, pesticides...) on soils (de Santiago et al., 2013; Corbel et al., 2014, 2015 a and b; Joly et al., 2015) and on earthworms (Beaumelle et al., 2014, 2016; Nélieu et al, 2016; Pelosi et al., 2016), the effects of repeated organic amendment applications on agricultural soils (Obriot et al., 2016). They concern also the role of biological adaptation in ecosystem responses to global changes, the impact of agricultural practices on the taxonomic and functional diversity of the soil communities and their consequences on the soil functions, the valorization of contaminated soils, the agroforestry in Africa...

Why does the platform Biochem-Env respond to actual and future needs in environmental biochemistry?

Biochem-Env offers several advantages for the research in environmental biochemistry by the continuous fulfilment of its missions at the highest quality and impact level.

-It is closely associated to the Joint Research Unit “Functional ecology and ecotoxicology of agroecosystems” (Ecosys, http://www6.versailles-grignon.inra.fr/ecosys_eng/) that host relevant scientific skills in environmental sciences, functional ecology and ecotoxicology. Several experienced scientists, engineers and technicians are involved in the design, implementation and monitoring of experiments, analysis, and in data processing and interpretation.

-The platform aims at improving a battery of biochemical tools by developing innovative and standardized protocols. One main development concerns the automation of analyses to ensure reliability, repeatability and high-throughput of the measurements, by using robotics (Fig. 2) and miniaturized devices (multi-well microplates).

-Today, multiple methods exist for enzyme activity or biomarker measurements, and the use of different (often non-international) units to express them, make difficult, even impossible, the comparison of the data produced by different laboratories worldwide. To overcome that situation, Biochem-Env contributes to French (AFNOR) and international (ISO) standardization processes. Actually, it deals with the achievement of the ISO 20130 standard “Soil quality - Measurement of enzyme activity patterns in soil samples using colorimetric substrates in micro-well plates”. In that context, it managed in 2016 an international ring-test co-funded by ADEME (French environment & energy management agency). The staff of the platform is also involved in the systematic review of standards related to its missions, i.e. the measurement of dehydrogenase activity in soils, the sampling of soil or invertebrates, the measurement of the impact of contaminants on the feeding activity of soil dwelling organisms...

-Biochem-Env has deployed a quality management system based on the internal referential of INRA, which ensures traceability and reliability of its activities. It is currently engaged into the ISO9001:2015 certification. That policy is applied to all activities of the platform, including management, development, analysis and training. Since 2015, the platform is permitted to import, handle and analyze quarantine materials such as soils from non-European or non-continental countries. In early 2017, that agreement has been extended to the transfer of sterilized materials to the Platinaae platform (<http://www6.inra.fr/platinaae>), dedicated to physical-chemical and chemical analyses on soils, waters, residual organic products, plants and small animals.

-In addition to Platinaae, Biochem-Env develops also scientific and functional interactions with the platform GenoSol (https://www2.dijon.inra.fr/plateforme_genosol/en/presentation-genosol), involved in the conservation of microbial genetic resources and the molecular characterization of the microbial metagenome. Together, they develop a common Laboratory

Information Management System (LIMS) as a basis for shared sample management and traceability (barcoding), and data/results exchanges.

-Biochem-Env develops also its database and Information System with the respect of interoperability with existing ones, data quality, sharing and security, in a context of open science and open data. A partnership agreement will be established for all projects involving the platform. Access policy to the platforms actually includes a single access point through its ISIA web portal (<http://isia-biochem-env.anaee-france.fr/>), to register and manage the submitted projects, and evaluate if necessary their scientific and technical relevance.

-The governance of the platform Biochem-Env is actually shared between two committees. The Platform Local Committee comprises the staff of the platform, and is its decision-implementing body. Chaired by the scientific and technical directors of the platform, it is in charge of the operational management of all its activities. The Committee also includes the support staff (chemometry, quality, metrology, health and safety, information system, management...). The Scientific Strategic Committee comprises leaders of the scientific community covering expertise in the topics supported by the platform, from different institutes and universities. Chaired by a recognized scientist, it provides a strategic feedback regarding the platform project, and proposes new avenues of development and investigation. A Stakeholder Strategic Committee will be set-up in 2018.

Conclusion

Biochem-Env offers to the international community of environmental and agricultural scientists a set of biochemical protocols for studies on environment and organisms, as well as database and tools for their interpretation. The platform actually gains standards for its international recognition. Yet, by its contribution to AnaEE-France, designed in line of AnaEE-Europe

Infrastructure currently on the ESFRI roadmap (<http://www.anaee.com/>), Biochem-Env will enlarge its activities to an international range of partners.

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Table 1. Biochemical indicators actually provided by the platform Biochem-Env

Biochemical indicators measured in soils and sediments
<i>Biogeochemical cycles and metabolism of macromolecules</i> Lignin and chitins: laccase, Manganese and lignin-peroxidases Polysaccharides: cellulase, α -amylase, α and β -glucosidases, α and β -galactosidases, α and β -xylanases, xylosidase Phosphate esters: total, acidic-alkaline phosphatases, phosphodiesterase Sulfur esters: arylsulfatase Proteins and nitrogen: arylamidase, urease, aminopeptidase <i>Metabolic activity</i> Dehydrogenase and fluorescein diacetate hydrolysis Microrespirometry
Biochemical indicators in invertebrates (earthworms, beetles, spiders, amphipods...)
<i>Energetic reserves and macromolecules</i> Total lipids, carbohydrates, glycogen and proteins amounts <i>Oxidative stress</i> Catalase and superoxide dismutase activities, lipid peroxidation <i>Detoxification mechanisms</i> Glutathion-S-Transferase

Fig. 1. Activities carried out by the platform Biochem-Env

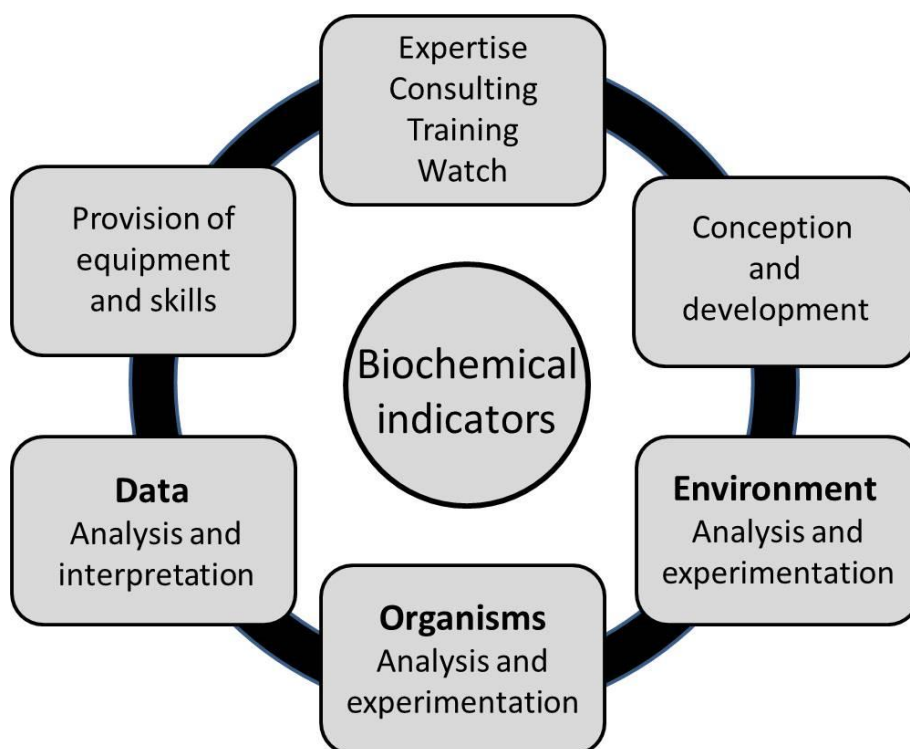


Fig. 2. Automated chain for the measurement of soil and sediment enzymatic activities, including micro-well plate handler, incubator, centrifuge and plate reader.

