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The huge number of chemicals (metallic, synthetic or from biological origin) used for human activities leads to their dispersion in the environment where they can have adverse effects on wildlife and humans. With the emergence of new products (e.g. nanoparticules, pharmaceuticals, biopesticides...), new questions are popping up for research in terrestrial and aquatic ecotoxicology. In that context, this Special Issue of *Environmental Science and Pollution Research* highlights selected results of research, and activities from members of the network of terrestrial and aquatic ecotoxicology, ECOTOX (http://www6.inra.fr/ecotox_eng). A previous issue published two years ago (see Mougin et al., 2016, DOI 10.1007/s11356-015-5948-7) presented the network and its main objectives. Here we highlight some points discussed during the last scientific seminar of the ECOTOX network hold in Alixan (France) in December 2017, co-organised with the Rovaltain Scientific Foundation (http://www.fcsrovaltain.org/).

To address the new questions for terrestrial and aquatic ecotoxicology, the ECOTOX network, leaded by INRA and IRSTEA, interacts with several other networks at national and international level with specific scientific focus (non-exhaustive list: ECOBIM, RTP EcotoxicoMic (https://ecotoxicomic.org/), GDR Ecotoxicologie animale, Réseau Antiopes, GIS Médicaments...). Some non-academic structures, as the Rovaltain Scientific Foundation, aims to develop cross-cutting works between human toxicology and ecotoxicology. If, on one hand, France appears as a fertile ground for ecotoxicology given the number of networks showing the dynamism of researches in this field of research, the risk of balkanisation can be seen on the other hand with a threat of fragmentation of ecotoxicology which intrinsically requires multidisciplinary. Therefore, in this context rich of different initiatives, and taking into

account the example of the Canadian network in Ecotoxicology (EcotoQ; <u>http://ecotoq.ca/</u>) presented at the seminar, the ECOTOX network launches a formal call to develop a common playground made of platforms gathering and sharing scientific priorities, resources and expertise in order to increase national and international visibility of our researches. Some questions in terrestrial and aquatic ecotoxicology were highlighted during the seminar.

The first one concerned biocontrol, biopesticides and ecotoxicology. The main aim of biocontrol is to offer a safe alternative to agrochemicals to control pests and diseases and to allow the development of agroecology. As with conventional pesticides, biocontrol agents reduce the size of pest populations to release the negative pressure exerted by pests or weeds on the crops or cattle. Macro-organisms, micro-organisms or natural substances can be used as biocontrol agents. Biocontrol is considered today to be among the safest, most environmentally benign, and most cost-effective available methods for pest control. Nevertheless, as encountered with conventional (synthetic) pesticides, one can expect side-effects of biocontrol agents. Thus, the following questions are asked: who is experienced in ecotoxicology in relation with biocontrol? To what extend would it be useful to use ecotoxicology and ecology concepts in biocontrol? What is the fate of biopesticides in the environment? What role could we cast to ecotoxicology in biocontrol regulations?

A second concern for terrestrial and aquatic ecotoxicology is related to model species that can be used for ecotoxity assessment, especially in soils.

Enchytraeids are soil annelid Oligochaeta considered as key players for the soil structure dynamics, organic matter decomposition, and nutrient cycling. In addition, to their ecological importance, they are recognized as relevant indicators of soil biological activity, anthropic activities, and physicochemical stresses in terrestrial ecosystems. Until now, the reproduction was the most sensitive endpoint to assess impacts of chemicals on enchytraeids. The effects of pesticides can also be estimated by monitoring the evolution of enchytraeids feeding ability using bait-lamina test.

Earthworms are ecosystem engineers constituting the most important living biomass in terrestrial ecosystems. For many years, several standardized acute tests with earthworms (form ISO or OECD) have been developed to assess the effects of various pollutants. However, despite their undiscussable interests, these tests suffer from a poor biological relevance because

they rely on the use of *Eisenia fetida* (Savigny) or *Eisenia andrei* (Bouché 1972) which are species generally not inhabiting mineral soils and barely not found in arable fields where pesticides are applied. Here is reviewed the current knowledge on the endogeic species *Aporrectodea caliginosa* s.s which are proposed as a relevant earthworm for *a posteriori* pesticide risk assessment for soil living organism

A third concern is the development of innovative methods for early identification and diagnosis of anthropogenic pressures on natural ecosystems. Conventional biomonitoring methods are often time-consuming, require high taxonomical expertise, and remain error-prone. By contrast, the analysis of bioindicator communities with genomic tools such as DNA metabarcoding could tackle most of these limitations. The ongoing SYNAQUA research program is presented. This French-Swiss INTERREG program aims at developing and implementing eco-genomic tools for the biomonitoring of aquatic ecosystems based on a DNA-based methods.

Finally, we discussed the usefulness of two infrastructures for research in ecotoxicology that can interact with the above-mentioned networks for scientific animation.

The first one-is RECOTOX. It is a French cross-cutting initiative which aims at promoting transversal and integrated researches to answer the scientific challenges of monitoring, understanding and mitigating the environmental and health impacts of pesticides and biocides in agricultural landscapes (including water catchments). RECOTOX provides an added-value to existing Research Infrastructures for environmental researches by offering a network of *in natura* sites and by promoting a common scientific background on spatial ecotoxicology taking on board the whole chain pressure-exposure-impact of pollutants. It especially encourages transversal approaches at relevant socio-ecological system scales, by capitalizing knowledge and expertise as well as complementing existing researches of ecotoxicology. In addition RECOTOX aims to develop innovative approaches to provide data to characterize spatially and temporally animal and human exposure to chemicals, which are essential explaining parameters to perform environmental toxicology studies.

The second is the Biological Resource Centre for the Environment BRC4Env. It is a network of Biological Resource Centres (BRCs) and collections. Their leading objectives are to improve the visibility of genetic and biological resources maintained by its BRCs and collections, and to facilitate their use by a large research community, from agriculture research to life sciences and environmental sciences. Its added value relies on sharing skills, harmonizing practices, triggering projects in comparative biology, and ultimately proposing a single entry portal to

facilitate access to documented samples, taking into account the partnership policies of research institutions as well as the legal frame which varies with the biological nature of resources. BRC4Env currently includes 3 BRCs: the Centre for Soil Genetic Resources of the platform GenoSol (https://www2.dijon.inra.fr/plateforme_genosol/en) in partnership with the European Conservatory of Soil Samples, the Egg Parasitoids Collection (EP-Coll) and the collection of ichthyological samples, Colisa. BRC4Env is also associated to several biological collections: microbial consortia (entomopathogenic bacteria, freshwater microalgae...), terrestrial arthropods, nematodes (plant parasitic, entomopathogenic, animal parasitic...) and small mammals. The BRCs and collections of BRC4Env are involved in partnership with academic scientists, as well as private companies, in the fields of medicinal mining, biocontrol, sustainable agriculture and additional sectors. Moreover, the staff of the BRCs is involved in many training courses for students from French licence degree to Ph.D, engineers, as well as ongoing training.

We hope that you will enjoy reading this Special Issue, presenting some challenging questions in ecotoxicology, from bioavailability of pollutants to remediation and ecological engineering.

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Christian Mougin, PhD, is a senior scientist at the National Institute for Agricultural Research (INRA) in the "Functional Ecology and Ecotoxicology of Agro-Ecosystems" joint research unit in Versailles, France. His main interests combine the fate of contaminants (metals, pesticides, cyanotoxins and emerging compounds) in soils, and the responses of microorganisms and macrofauna exposed to these chemicals,

both in situ and through laboratory experiments. His work focuses actually on the development of innovative tools for the biochemical characterizations of soils, sediments, and living micro-macro-organisms, in relation to the assessment of ecosystems functioning under anthropic constraints. Christian Mougin is in charge of French research platforms open to research in ecotoxicology, and leads the network of terrestrial and aquatic exotoxicology, ECOTOX (http://www6.inra.fr/ecotox_eng/).



Agnès Bouchez, PhD, is a senior scientist at the National Institute for Agricultural Research (INRA) in the "Alpine Center for Research on Lake Ecosystems and Food Webs" (CARRTEL) joint research unit in Thononles-bains, France. She is mainly involved in the functional evaluation of the ecological quality of lakes and rivers using genomic, taxonomic and

ecotoxicological tools. Based on these tools, she develops innovative metrics and methodologies to assess the impacts of xenobiotics on the structure and functioning of freshwater microbial communities. Her work focuses on bringing more ecological realism in risk or impact assessment, regarding contaminants (low doses, mixtures), biological organisms (species or communities from the environment) and experimental approaches in micro-mesocosms or in the field. Agnès Bouchez is vice-chair of the DNAqua-Net COST action (CA15219) and co-leading the network of terrestrial and aquatic ecotoxicology, ECOTOX (http://www6.inra.fr/ecotox_eng/).



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samplers. She is working on diffuse contamination of agro-ecosystems and also manages transfer projects with technical institutes and participates to the management of the RMT QUASAPROVE. She teaches the terrestrial ecotoxicology at Bordeaux University, in the Master "Ecotoxicology and environmental chemistry" and is member of the INRA's national network of Ecotoxicologists, ECOTOX. Laurence Denaix is co-leading the network of terrestrial and aquatic ecotoxicology, ECOTOX (<u>http://www6.inra.fr/ecotox_eng/</u>).



Jeanne Garric, PhD, is a senior scientist at The National Institute of Science and Technology for Environment and Agriculture. For several years she led the team of ecotoxicology in Irstea Lyon and the Irstea's research group dealing with exposure analysis and assessment of the effects of organic and

inorganic chemicals in freshwater ecosystems, as well as tools development for bioindication using algae and plants. Her main interest focus on the contamination and the effect of chemicals on fish and invertebrates. She is also involved in scientific or technical expertise activities dealing with ecotoxicology and environmental toxicology. She is currently co-leading the network of terrestrial and aquatic ecotoxicology, ECOTOX (http://www6.inra.fr/ecotox_eng/).



Fabrice Martin-Laurent, PhD, is a senior scientist at the National Institute for Agricultural Research (INRA). He is adjunct director of the Agroecology research unit in Dijon, France where he is the chief of the BIOmE department (Biology and Ecosystem Functions of Soils). He is leading a research team studying microbial ecology of agricultural

chemicals including both fertilizers and pesticides. His main interest is focused on the pesticides microbial ecotoxicology. On one hand, his work is aiming at developing innovative approaches based on molecular approaches to assess the ecotoxicological impact of these chemicals on the composition, abundance, diversity and activity of soil microbial community. On the other hand, his is studying the processes responsible for the selection in the soil environment of

microorganisms able to rapidly biodegrade pesticides. Fabrice Martin-Laurent is co-leading the network of terrestrial and aquatic ecotoxicology, ECOTOX (<u>http://www6.inra.fr/ecotox_eng/</u>), and is the co-creator of the French Network of Microbial Ecotoxicology which led recently to the creation of the International Network on Microbial Ecotoxicology (.