

The coming of age of microbial ecotoxicology: report on the first two meetings in France

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Context and objectives

Microorganisms are ubiquitous in soil, air, and water ecosystems, where they are key players of ecosystem services. Microbial ecotoxicology is an emerging interdisciplinary area of research which aims at investigating the impact of human activities on the diversity, abundance, and activity of microorganisms. In return, the results of such investigations hold the promise to provide novel ways of assessing in a sensitive way the impacts of diverse environmental disturbances and subsequent ecosystem responses. Thus and although the term itself is yet rarely encountered in the scientific literature, microbial ecotoxicology already addresses an increasing political and societal demand. In the French scientific landscape, which often mimics the famous (but sometimes indigestible) “mille-feuilles” pastry, microbial

34 ecotoxicologists are scattered across many different research centers belonging to different
35 research organizations and universities. This research field has thus lacked any visibility and
36 remained unorganized until now. Formal organization of scientific activities may be
37 considered a typical ‘froggies’ concern (or ailment). Nevertheless, it is rather surprising that
38 scientific journals and significant international conferences specifically devoted to microbial
39 ecotoxicology have been missing so far, especially considering the plethora of journals
40 and congresses devoted to microbial ecology and ecotoxicology. With these considerations in
41 mind, the idea of organizing the French research community of microbial ecologists around
42 concepts of ecotoxicology made its way, with the aim of sharing the necessity to overcome
43 artificial boundaries that prevent progress in this promising field.

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45 ***Coming out: the 1st meeting on Microbial Ecotoxicology, Lyon-Villeurbanne, France, 20-***
46 ***22 March 2013***

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48 This meeting was organized by Drs Stéphane Pesce (Irstea UR MALY, Lyon-Villeurbanne)
49 and Fabrice Martin-Laurent (INRA, UMR Agroécologie, Dijon) in March 2013 at Irstea in
50 Lyon-Villeurbanne.

51
52 *Objectives*

53 The main objectives of this first meeting were i) to identify and bring together researchers,
54 lecturers and professors in the field of microbial ecotoxicology, in order to establish an
55 overview of the state of the art of research and teaching in microbial ecotoxicology in France,
56 and ii) to initiate a collective brainstorming to identify future challenges of microbial
57 ecotoxicology. The ultimate goals were to define and successfully implement a collective
58 approach to design, evaluate and support investigations in the field of microbial
59 ecotoxicology.

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61 *Developing active participation in the research community: the “World Café” approach*

62 A key challenge was to choose an optimal way to involve all potentially interested researchers
63 in the process of defining the community of ‘microbial ecotoxicologists’. The organizers
64 decided to apply a participative approach coupled with a ‘world cafe’, a technique originally
65 developed for meetings in which different interest groups confront their views and discuss
66 common future activities (e.g. Jorgenson and Steier, J. Appl. Behav. Sc., 2013, 49:388-405).
67 First, all potentially interested researchers were contacted before the workshop and asked to

68 respond to an online questionnaire designed to provide an initial inventory of the strengths,
69 weaknesses, wishes and development potential of microbial ecotoxicology, also taking the
70 French and international research contexts into account.

71 Answering the questionnaire was a pre-requisite for effective inscription to the meeting. In
72 total, 46 researchers and lecturers from 25 different laboratories affiliated to different
73 institutes and universities in France responded to this solicitation, and 35 of them eventually
74 participated to the workshop.

75 The results of this questionnaire as well as the results of bibliometric study on microbial
76 ecotoxicology were presented to the participants of the workshop as an opening lecture, and
77 provided the framework to develop subsequent exchanges. Keynote lectures were delivered
78 by Drs Jeanne Garric (Irstea), Christian Mouglin (INRA), Philippe Garrigues (CNRS) and
79 Edward Topp (Agriculture and Agri-Food Canada), who all gave their respective vision about
80 the main challenges facing ecotoxicology in the light of the worldwide environmental fate and
81 dispersion of chemicals as a result of human activities.

82 Following these presentations and on the basis of the contextual elements that were identified,
83 a collective prospective discussion followed, with three successive stages:

- 84 i) identification of the main stakes of microbial ecotoxicology;
- 85 ii) definition of objectives and associated courses of action;
- 86 iii) determination of the priority levels of actions.

87 In line with the chosen participative approach to promote interactive exchanges among all
88 participants, moderation of the “World Café” was ensured by RCT Territoires
89 (<http://www.rct-territoires.com>), a consulting business whose team designed and implemented
90 structured conversational processes in which groups of researchers discussed a topic along
91 several stations, with groups of researchers switching tables periodically and getting
92 introduced to the previous discussion by a “station host”. Giving their expertise in
93 ecotoxicology, Drs Ed Topp and Philippe Garrigues acted as ‘Witness Experts’, moving from
94 station to station to give advices and an external perspectives on the ongoing discussions.

96 *Main conclusions*

97 Four types of issues were defined:

- 98 i) social (i.e. how to promote interactions between research in microbial ecotoxicology
99 and society?);
- 100 ii) scientific (i.e. how to better assess the effective biological and ecological “impact” of
101 toxicants in complex environments?);

- iii) technology transfer (i.e. how to go from scientific knowledge to political decisions?);
- iv) organizational (i.e. how to improve synergies between research groups and gain in visibility and readability?)

For each of them, concrete objectives were defined and courses of action were identified. Some of these actions were implemented quickly, thanks to the positive dynamics resulting from this workshop.

With regard to the organizational issue, the most concrete actions that were implemented were:

- i) the setting-up of a website dedicated to microbial ecotoxicology (<http://ecotoxicomic.irstea.fr>), and of an associated mailing list to exchange information on microbial ecotoxicology (Fig. 1),
- ii) the writing of a collectively reviewed and publicly available report on the microbial ecotoxicology website.
- iii) the implementation of “microbial ecotoxicology” sessions in French congresses dedicated to ecotoxicology (The French Society of Ecotoxicology, SEFA, Thionville, July 2013), microbial ecology (The Francophone Association on Microbial Ecology, AFEM, Clermont-Ferrand, October 2013) and microbiology (The French Society of Microbiology, SFM, Institut Pasteur, Paris, April 2014),
- iv) the scheduling of a first French scientific conference entirely devoted to Microbial Ecotoxicology (see below)
- v) the implementation of ‘microbial ecotoxicology’ sessions in international congresses (XIVth International Congress of Bacteriology and Applied Microbiology, IUMS 2014, Montreal, Canada, July 27 - August 1, 2014)

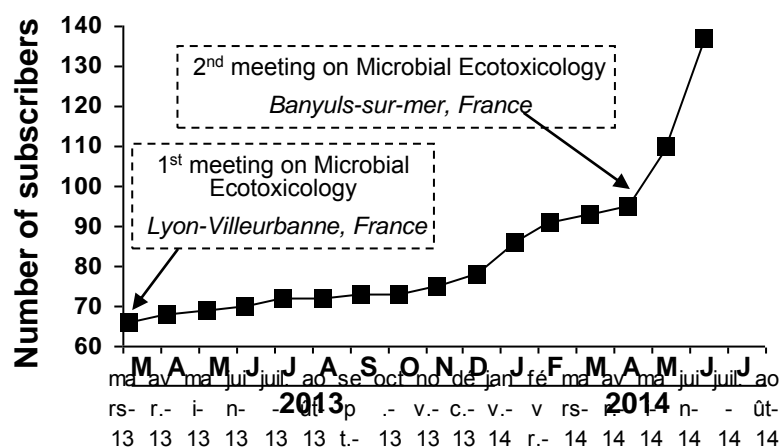


Fig. 1: Evolution of subscribers to the “ecotoxicomic” mailing list

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2 138 **From “World Café” to Science: the 2nd meeting on Microbial Ecotoxicology, Banyuls-sur-**
3 139 **mer, France, 21-23 May 2014**

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7 141 *Objectives and organization*

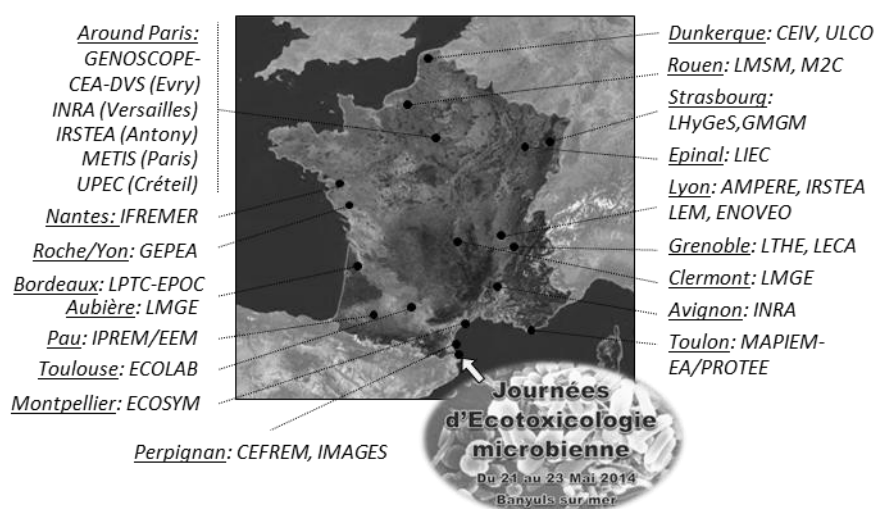
8
9 142 The 1st prospective meeting on microbial ecotoxicology in Lyon in 2013 generated quite some
10 143 interest in the microbial ecology, ecotoxicology and environmental chemistry fields, and
11 144 prompted us to organize a scientific conference dedicated to the topic, to assess whether a
12 145 community of microbial ecotoxicologists could emerge beyond day-to-day *ad hoc* contacts
13 146 and collaborations between individual researchers.

14 147 This 2nd meeting and scientific conference on microbial ecotoxicology was organized by Dr
15 148 Jean-François Ghiglione (CNRS, Laboratoire d’Océanographie Microbienne LOMIC – UMR
16 149 7621) and took place in May 2014 at the Observatoire Océanologique de Banyuls, France.
17 150 This meeting was sponsored by the government research organizations in charge of the main
18 151 national reference laboratories involved in microbial ecotoxicology, i.e. CNRS (National
19 152 Center for Scientific Research), IFREMER (French Research Institute for Exploitation of the
20 153 Sea), INRA (National Institute for Agronomic Research), IRD (Research and Development
21 154 Institut) and Irstea (National Institute for Scientific and Technological Research for the
22 155 Environment and Agriculture). The meeting was organized under the auspices of the
23 156 Francophone Association for Microbial Ecology (AFEM), which aims to organize meetings in
24 157 the field of microbial ecology (<http://mio.pytheas.univ-amu.fr/AFEM>). A scientific committee
25 158 composed of the authors of the present report and of the AFEM administrative board
26 159 validated the scientific program and abstracts, which are available on the conference website
27 160 (<http://www.obs-banyuls.fr/AFEM5>).

28 161 In total, 70 researchers attended the meeting, and 36 scientific teams, coming from all over
29 162 France, were represented (Fig. 2). Thus, the main goal of the meeting, i.e. to federate and
30 163 organize the French community, was fulfilled. Most notably, PhD students and postdocs were
31 164 in strong attendance although they had not been particularly targeted in meeting
32 165 announcements. In our view, this testifies of the strong interest of the emerging generation of
33 166 scientists for the interdisciplinary approach of microbial ecotoxicology.

34 167 The meeting included four sessions, with a total of 30 oral presentations, 10 poster
35 168 contributions and 3 keynote lectures by Drs Philippe Garrigues, Jean-François Ghiglione, and
36 169 Stéphane Pesce. On the first day, a round table moderated by the members of the scientific
37 170 committee allowed initiating the discussion on possible ways of promoting and developing

171 this specific scientific community. The four sessions were rather ambitious in their scope,
 172 addressing most of the identified key questions in the field (see below for a detailed
 173 description of each session). In order to avoid fragmentation of the community on the basis of
 174 their preferred ecosystem, special care was taken to distribute reports on freshwater, marine
 175 water, sediment and soil ecosystems across the four sessions of the meeting.



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 182 *Fig. 2: Map showing the location (underlined) and the acronyms of the research units (in capitals) of*
 183 *presenters of oral presentations. An arrow from the logo of the meeting indicates the location of*
 184 *Banyuls-sur-mer.*

187 *Conference sessions and highlights*

188 The first session dealt with aspects of the design and use of microbial bioassays, biomarkers,
 189 bioindicators and biosensors for environmental biomonitoring from an ecotoxicological
 190 perspective. This session made it clear that integrating ecotoxicological approaches and
 191 viewpoints in this intensively investigated field bears potential to yield new findings with
 192 particular relevance to practical applications. In this context, an environmental start-up
 193 reported a novel and promising approach to monitor environmental perturbations by chemical
 194 contamination in real-time, which exploits previous results from a partner laboratory in the
 195 field of microbial electricity generation.

196 The second session addressed fundamental aspects of adaptation and resilience of microbial
197 communities from a functional point of view. Although this often requires more
198 comprehensive investigations and time investment than currently popular high-throughput
199 sequencing approaches, functional investigations can be more easily integrated in models of
200 ecosystem functioning, most notably the still somewhat neglected yet highly promising
201 pollution-induced community tolerance (PICT) conceptual framework, and with often more
202 rewarding results.

203 The third session was dedicated to this most classical of topics in environmental
204 microbiology, bioremediation and biodegradation of contaminants. It was clearly
205 symptomatic of the shift of focus in the field afforded by the emergence of an
206 ecotoxicological perspective that this session attracted relatively few contributions compared
207 to session 4 which, as described in more detail below, proposed a new, global and frontal take
208 on the influence of pollutants, biotic and abiotic factors on microbial communities.
209 Nevertheless, very exciting contributions were proposed in this session, both on long-standing
210 environmental problems that urgently require satisfactory resolution, and on emerging and
211 possibly still underestimated issues. On the former topic, for instance, novel insights on the
212 biodegradation of chlordecone, an insecticide heavily used for decades in the French Antilles
213 to treat banana plantations, and possibly the most recalcitrant chlorinated compound known,
214 was reported. As a noted example on the latter subject, marked effects of exposure of soil
215 communities to titanium oxide nanoparticles were found using a combination of functional
216 assays and high-throughput sequence analysis.

217 The fourth session focused on the influence of pollutants, biotic and abiotic factors on
218 microbial communities in the context of multiple stresses and contaminations. This topic
219 attracted the most interest from conference applicants, resulting in a total of 17 presentations
220 covering a wide range of environments, organisms and chemicals. Microbial communities that
221 were investigated were not limited to bacteria, but also included archaea, fungi and micro-
222 algae. The aquatic (freshwater and marine) environment was the most popular, with studies
223 dealing with microbial communities from water columns, biofilms and sediments, although
224 several studies also addressed microbial communities from soil and the rhizosphere. Effects of
225 various pollutants were assessed in a variety of experimental settings, such as laboratory
226 microcosms and bioreactors, as well as *in situ*, in contaminated sites displaying different
227 levels of a wide range of pollutants, including metals, polycyclic aromatic hydrocarbons,
228 polychlorobiphenyls, pesticides, biocides and antibiotics.

229 As in all studies dealing with field experiments, interpretation of results is often complicated
1 230 by numerous environmental variables that can, because of physical and chemical interactions
2 231 that affect bioavailability of contaminants, and influence the toxicity of pollutants on
3 232 organisms, and on microorganisms in particular. Nevertheless, working on microbial
4 233 communities with relatively short generation times allows to more easily address key
5 234 questions such as the extent to which contamination history (e.g., long-term, chronic, often
6 235 low-level exposure versus short-term, high-level exposure) drives community structuring and
7 236 successions in impacted ecosystems; and the resilience of ecosystems in the face of exposure
8 237 to contaminants. In this context, this session has allowed to explicitly push forward the idea
9 238 that not only individual organisms but also microbial communities can serve as bioindicators
10 239 of the pollution-related ecological status of a given environment.

11 240 The data presented in this session also spelt out some commonly known but still unresolved
12 241 issues. First of all, working with micro-organisms remains a challenge because of the high
13 242 level of biological complexity associated with community level studies, and the resulting
14 243 difficulties in data interpretation. For instance, a large proportion of phylotypes continue to
15 244 lack physiologically characterized representatives, so that their roles, functions and
16 245 interactions with the rest of the community remain unknown. The session made it clear that
17 246 microbial ecotoxicology approaches may provide novel and important contributions to
18 247 understand the effects of pollutants on the structure, function and dynamics of microbial
19 248 communities. In particular, several contributions demonstrated how recent technological
20 249 advances, particularly on molecular tools such as high-throughput sequencing, are providing
21 250 decisive support. On the other hand, the need for sensitive but also robust approaches was also
22 251 made evident. Indeed, techniques should be able to detect early disturbances at the level of
23 252 global communities that i) can be measured in terms of function, and ii) cause detectable if
24 253 even slight modifications of their structure. In both cases, however, the specific contribution
25 254 of a given physico-chemical or specific biotic factor or organism to the “good state” or “good
26 255 functioning” of the community will often be difficult to identify. Thus, key questions are still
27 256 difficult to address at present, such as the definition of criteria to characterize disturbances of
28 257 community structure and functions, and of microbe-based models to define normal operating
29 258 range for microorganisms and to predict the risks of chemical contamination for ecosystem
30 259 functioning through time, on different scales of size and in different geographical
31 260 localizations. However, such questions were clearly central in current experimental designs of
32 261 the participants of the meeting, so advances along these lines can reasonably be expected in
33 262 the near future.

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2 264 *Conference outcomes*

3 265 This 2nd meeting allowed us to gain a better insight on the forces in the field of microbial
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5 266 ecotoxicology in France, on specific research areas, and on the geography of the related
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7 267 network of laboratories involved in such research. Activities are clearly spread out all over the
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9 268 national territory and carried out by scientists belonging to research teams which generally do
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11 269 not identify microbial ecotoxicology as their core activity. Nevertheless, the feeling of
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13 270 belonging to a community was evident to all in the very rich discussions that took place all
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15 271 along the meeting. The wish of most participants to be a member of this community is also
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17 272 testified by the increase in the number of subscribers to the mailing list “ecotoxicomic” after
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19 273 the meeting in particular (Fig. 1).

20 274 A debate arose during the round table on the pertinence of creating a new of Francophone
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22 275 Microbial Ecotoxicologists, to facilitate organization of further meetings, sharing of
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24 276 knowledge and technical skills, and to make visible the vitality and the specificities of
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26 277 microbial ecotoxicology studies for colleagues and citizens. It was decided, as a concrete first
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28 278 outcome of the meeting, to take steps towards proposing and setting up a Pluridisciplinary
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30 279 Thematic Network (RTP) on microbial ecotoxicology to be hosted by the CNRS in
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32 280 conjunction with IFREMER, IRD, INRA, Irstea and other governmental research
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34 281 organizations for the next few years. In addition, the community of Microbial
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36 282 Ecotoxicologists is expected to reconvene in two years for the 3rd meeting of Microbial
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38 283 Ecotoxicology, to be held in Clermont-Ferrand, France. Clearly, the field of microbial
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40 284 ecotoxicology has the potential to answer the wishes and needs of many scientists at the
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42 285 interface of microbial ecology, ecotoxicology and analytical chemistry, not only in France but
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44 286 also internationally. In this context, a special issue on microbial ecotoxicology will be
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46 287 proposed soon in ESPR in order to document this emerging field. We also strongly encourage
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48 288 authors of publications in the field to use the term “microbial ecotoxicology” as keyword, to
49
50 289 increase the visibility of the international community of microbial ecotoxicologists.

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53
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