Fate and effect of pollutants in rivers: from analysis to modeling

The long march of ecological stress assessment in rivers

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Received: 6 December 2016 / Accepted: 9 December 2016 / Published online: 20 January 2017
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The urban, agricultural and industrial developments generate many pollutant emissions, in increasing quantities and of a highly variable nature, in aquatic environments (nutrients, pesticide residues, heavy metals, pharmaceutical residues...). This global statement covers notable differences between countries. On the one hand, the sometimes alarming river pollution levels in developing countries (hyper eutrophication, toxic substances...) are mainly due to the lack or low efficiency of waste treatment plants, and on the other hand, the so-called developed industrialized countries have established efficient wastewater treatment infrastructures, with restrictive regulations (e.g., European Water Framework Directive, WFD) and technical and financial resources to carry out recovery plan actions. In addition to chemical releases, other pressures also impact the river's quality: suspended solid and sediment from land erosion, hypoxia (or anoxia) during the microbial degradation of algal blooms or of organic matter, reduction of flows increasing pollutant concentrations, and increase in water temperature. Lastly, the many interactions between contaminants/pollutants and environmental factors control the expected stresses and their effects on water uses and aquatic biodiversity.

Aquatic pollution—whether widespread or occasional and chronic or accidental—is often the result of a complex mixture of substances and environmental factors, making risk assessment particularly difficult and increasing uncertainty about the forecasted effects. With the exception of heavy metals, organic pollutants or toxic compounds are degradable, sooner or later, due to the various natural attenuation processes: photodegradation, biodegradation... These processes are however likely to affect the bioavailability and toxicity of substances and globally reduce the toxic load over time. But for this to happen, the biodegradation potential of the river must not be exceeded by excessive pollutant loads, which is often the case given the continuous inputs along the river and the upstream-downstream transfer of pollution: a watercourse is not and should never be considered as an annex of a wastewater treatment plant.

The induced environmental effects are also multiple and can be evaluated at different overlapping degrees, making a meaningful assessment of in situ induced effects extremely complicated: from the individual to communities/acute or chronic effects, direct or indirect (domino effect); physiological and/or genetic effects (multigenerational and transmittable)... From a scientific point of view, all these issues are brought together within a thematic/new discipline called stress ecology, making it possible to formalize pressure-impact relationships, whatever the causes of environmental stress are. Numerous methods of bioindication and ecotoxicology are available on the market, standardized or not, regulatory or not, that enable us to classify hazardous substances, evaluate potential impacts, and highlight the deterioration or renovation of aquatic environments. Many national or European guidelines exist to assess the effect of substances (e.g., REACH Directive) or environmental quality (e.g., WFD) but without solving the issue. One of the current challenges, despite the growing number of studies, is the development of in situ ecological assessment approaches especially those able to assess the effects of a low level of contaminants. These

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approaches are based on the so-called “weight of evidence” and remain a posteriori assessments, enabling us to report on the state of the environment, but without providing predictive elements on which a forward planning policy could be based.

This difficulty converges with the other great challenge in stress ecology, which is modeling, an indispensable tool for generalizing all the biophysicochemical processes in rivers related to the fate and effects of substances. Numerous models already exist, especially for hydrology or self-purification processes in rivers relating to organic substances and nutrients. Regarding micropollutants, many models have also been developed, from biogeochemical models describing the transformation of molecules in aquatic environments, via toxicokinetic models describing the entry, processing, and intracellular effects of toxic molecules, to the substance effect assessment models on biological communities (e.g., PICT model, pollution-induced community tolerance, or SSD model, species sensitivity distribution). In fact, one of the challenges of scientific activity centered around modeling is to anticipate the resilience of natural and anthropogenic environments that water systems very often are.

Last but not least, our ability to predict and control the release of contaminants and their environmental effects is also based on a close dialog between scientists and managers with, on the one hand, the need for incorporating scientific knowledge into tools to aid public decision and, on the other hand, the ability to translate management issues into scientific issues.

The I.S. River Conferences (integrative sciences and sustainable development of rivers) thus aim to promote and amplify these essential interactions and to create cross discussions between research and practices on the world’s large rivers, whether natural or strongly anthropic; this is not only in terms of ecological functioning, evolution, and interactions at the interfaces (with coastal or groundwater) but also in terms of management and engineering policies. In particular, the 2015 Conference, with its six scientific topics, had two major objectives:

To promote multidisciplinary approaches

- To identify and discuss the most recent scientific advances regarding the complexity and diversity of rivers, in particular functioning, ecological services, stakeholder involvement, and management strategies
- To share experiences of research and practices, implementation of local policies at different levels and within various human and geographical contexts: hydrographic districts, corridors, large cities, transition zones, and estuaries

To engage all stakeholders and to build links

- To gather highly skilled professionals from various fields of activity, in order to promote knowledge transfer

between scientists, river managers, consultants, residents, and varied users

- To stimulate European and international collaborations between scientists and river managers for the purpose of improving decision support and practices

The conference among other things led to this special issue “Fate and effect of pollutants in rivers: from analysis to modeling” published by ESPR Journal. In this very broad theme, as mentioned in the previous paragraphs, four sections illustrate specifically the points relating to the fate of contaminant or hypoxic stress in fluvial ecosystems. Despite their ancient recognition as major water contaminants, heavy metals still raise many scientific and management questions, in terms of identifying sources and divergence with regional geochemical background (cf paper of Li et al.). Metal inputs from major urban areas are not constant over time and exhibit seasonal variations, and their water-sediment partition is controlled by changes in pH and oxygen levels: this happens in the river Saigon Ho Chi Minh City, as demonstrated by the paper of Strady et al. Metals are also known for their ability to bioaccumulate in organisms with a differentiation according to the organ. In this way, the paper of Adel et al. shows an increasing accumulation respectively in the muscle, liver, and shell of the turtle *Mauremys caspica* in the Caspian Sea. Finally, the article of Schmidt et al. addresses the issue of oxic stress in an estuary (La Gironde, Bordeaux, France), showing that the resuspension of sedimentary particles linked to the movement of the tides can create hypoxic conditions up to 100 km upstream from the river mouth.

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