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Review

Eutrophication: A new wine in an old bottle?

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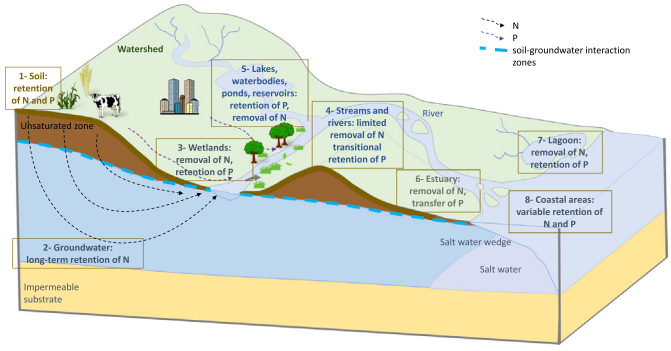
HIGHLIGHTS

- Eutrophication in the 70ies was related to point source pollution, mainly phosphorus.
- Eutrophication is pervasive in many lakes, coastal areas and rivers of the world.
- Diffuse nitrogen and phosphorus losses are now the main drivers of this new wave of eutrophication.
- It is a wicked problem as a consequence of multiple, often cumulative actions other large spatio-temporal scales.
- Solutions to tackle eutrophication need to address the entire land-sea continuum.

GRAPHICAL ABSTRACT



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ABSTRACT

Eutrophication is one of the most common causes of water quality impairment of inland and marine waters. Its best-known manifestations are toxic cyanobacteria blooms in lakes and waterways and proliferations of green macro algae in coastal areas. The term eutrophication is used by both the scientific community and public policy-makers, and therefore has a myriad of definitions. The introduction by the public authorities of regulations to limit eutrophication is a source of tension and debate on the activities identified as contributing or having contributed decisively to these phenomena. Debates on the identification of the driving factors and risk levels of eutrophication, seeking to guide public policies, have led the ministries in charge of the environment and agriculture to ask for a joint scientific appraisal to be conducted on the subject. Four French research institutes were mandated to produce a critical scientific analysis on the latest knowledge of the causes, mechanisms, consequences and predictability of eutrophication phenomena. This paper provides the methodology and the main findings of this two years exercise involving 40 scientific experts.

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Contents

1. Introduction

Eutrophication is one of the most common causes of water quality impairment of inland and marine waters (Vitousek et al., 1997; Smith et al., 1999; Bennett et al., 2001; de Jonge et al., 2002; Smith, 2003). It is generating major disruptions to aquatic ecosystems and has impacts on related goods and services, on human health and on the economic activities of the territories where they occur. A large amount of research has been conducted during the 1970ies and 80ies to understand the causes and mechanisms underlying the process of eutrophication which was spreading in the Northern Hemisphere's lakes (Vollenweider, 1968; Schindler, 1974; Dillon and Rigler, 1974; Hecky and Kilham, 1988). These researches clearly pointed out the key role of phosphorus point source pollutions and spectacular recoveries, at least at the time, were monitored following a reduction of point source phosphorus pollution.

Yet, today eutrophication is pervasive in many lakes, coastal areas and rivers of the World. In some areas, these environmental crises have become an urgent societal issue, involving a wide variety of stakeholders with contrasting values and interests (Rabalais et al., 2002; Smetacek and Zingone, 2013). Diffuse nitrogen and phosphorus pollutions are now the main drivers of this new wave of eutrophication (Beusen et al., 2016). We argue with this diffuse context of nutrient pollution that this new eutrophication crisis can be considered as a "new wine in an old bottle". We consider that it is an "old bottle" because the consequences, i.e. algal bloom, anoxia are similar as those encountered in the 1970ies and 80ies. Yet, this is a "new wine" because this diffuse propagation forces to address: i) the long term cumulative impact of far reach anthropogenic activities, ii) the consequences of multiple, and often cumulative, actions which can be very distant both in space and time, iii) the difficulty to disentangle past and present causes from past anthropogenic legacy. The consequence of multiple, often cumulative actions, which can be very remote both in space and time from the visible impact, the uniqueness of each aquatic ecosystem, its resistance, resilience and trajectory, the difficulty to disentangle past and present causes from legacy of the past anthropogenic activities fulfil many attributes of a wicked or complex problem facing society (Thornton et al., 2013). Indeed, there is no single answer applicable to resolving eutrophication, no true-false answers, and there is no end point in implementing a solution. Moreover, there is no a priori understanding of the outcomes associated with interventions intended to solve eutrophication. Furthermore, the application of one intervention to resolve a specific case of eutrophication may have a different outcome when applied to a similar problem in a different location. Yet, the planner has no right to be wrong (Thornton et al., 2013). The development of eutrophication exemplifies the linkages between physical and biogeochemical processes along the land-sea continuum. However, from headwater catchments to coast areas, several often antagonistic interests prevail, while scientists are often specialized in one domain, with limited interactions and shared methods, tools or models. There is a need for interdisciplinary approach calling for several disciplines of agronomy, engineering, biogeochemistry, ecology, hydrology, economy, political sciences and sociology to provide ways and approaches for aquatic ecosystems remediation from this world-wide and pervasive problem of eutrophication.

This manuscript brings together the reviews undertaken by a set of French scientists who were requested from the French ministries in charge of environment and agriculture to provide the state-of-the-art on eutrophication. The following papers of the special issue on "eutrophication: a new wine in an old bottle" gather interdisciplinary research on eutrophication with special emphasis on land-water interactions along the land-water-sea continuum.

2. Method

The joint scientific appraisal is an institutional, scientific and collective expertise. It consists in collating the international scientific literature on a given topic and extracting points of certainty and uncertainty, knowledge gaps and any questions that are the subject of scientific controversy. The purpose of a joint scientific appraisal is to provide the public authorities and all the stakeholders with a base of certified scientific knowledge on which to build a political science-based decision-making process. This state of knowledge is not intended to provide expert advice or turnkey technical solutions to the issues faced by administrators, but to identify levers for action.