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Review

Dynamic exchanges between DOM and POM pools in coastal and inland aquatic ecosystems: A review

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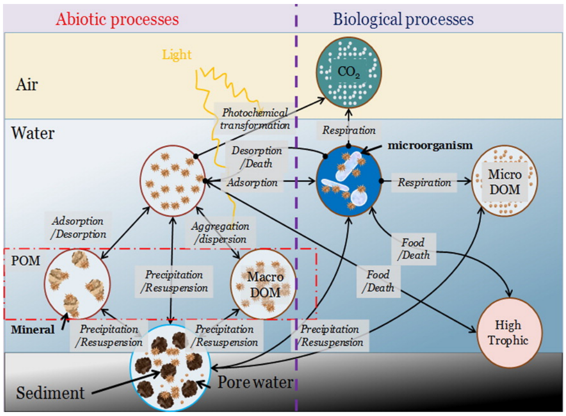
HIGHLIGHTS

- DOM-POM exchanges are dynamic with various ecosystem processes involved.
- A micro-spatial mechanistic schema is clearly presented for the complex phenomena.
- Influencing factors are critically evaluated from ecological and molecular perspectives.
- A unified conceptual model based on exergy theory is proposed to integrate all processes.

GRAPHICAL ABSTRACT



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ABSTRACT

Dynamic exchanges between dissolved organic matter (DOM) and particulate organic matter (POM) plays a critical role in organic carbon cycling in coastal and inland aquatic ecosystems, interactions with aquatic organisms, mobility and bioavailability of pollutants, among many other ecological and geochemical phenomena. Although DOM-POM exchange processes have been widely studied from different aspects, little to no effort has been made to date to provide a comprehensive, mechanistic, and micro-spatial schema for understanding various exchange processes occurring in different aquatic ecosystems in a unified way. The phenomena occurring between DOM and POM were explained here with the homogeneous and heterogeneous mechanisms. In the homogeneous mechanism, the participating components are only organic matter (OM) constituents themselves with aggregation and dissolution involved, whereas OM is associated with other components such as minerals and particulate colloids in the heterogeneous counterpart. Besides the generally concerned processes of aggregation/dissolution and adsorption/desorption, other ecological factors such as sunlight and organisms can also participate in DOM-POM exchanges through altering the chemical nature of OM. Despite the limitation of current analytical technologies, many unknown and/or unquantified processes need to be identified to unravel the complicated exchanges of OM between its dissolved and particulate states. Based on the review of several previous mathematical models, we proposed a unified conceptual model to describe all major dynamic exchange mechanisms on the basis of exergy theory. More knowledge of dynamic DOM-POM exchanges is warranted to overcome the potential

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problems arising from a simple division of OM into dissolved versus particulate states and to further develop more sophisticated mathematic models.

Contents

1. Introduction

Natural organic matter (NOM) is ubiquitous on Earth, including approximately 662 Gt of dissolved organic carbon stored in the ocean (Hansell et al., 2009). This total amount of aquatic NOM rivals the carbon storage in terrestrial soil environments (1200–1600 Gt) (Post et al., 1990). Due to climate change caused by anthropogenic activities, stocks of aquatic NOM are showing increasing trends with the primary sources of NOM originating from land although it is leveling off in the Northern hemisphere (i.e., allochthonous NOM) (Evans et al., 2005; Roulet and Moore, 2006; Monteith et al., 2007; Oulehle and Hruška, 2009). Global stock changes of NOM in aquatic ecosystems (marine, estuarine, riverine, and limnic ecosystems, etc.) are expected to lead to variations of carbon transport and aquatic productivity (Bacastow and Maier-Reimer, 1991; Kepkay, 1994). As part of the sources from living organisms' exudation and detritus (Wetzel, 1995; Passow, 2002), NOM plays a “bridging” role between living and nonliving systems (Verdugo et al., 2004; Azam and Malfatti, 2007), contributing to the maintenance of the aquatic food web by providing foods and energy to heterotrophic microorganisms (Grossart and Simon, 1998; Zimmermann-Timm, 2002; De La Rocha et al., 2008). NOM also influences environmental behaviors of pollutants by affecting their solubility, toxicity, bioavailability, mobility, and ultimate fate (Eadie et al., 1992; Eriksson et al., 2004; Hassett, 2006), and attenuates harmful light by scattering and absorbing (Schindler and Curtis, 1997).

In practice, NOM is often categorized and quantified as dissolved organic matter (DOM) or particulate organic matter (POM) based on filtering. A filter pore size of 0.45 μm is typically utilized to set the operational boundary between DOM and POM, although various researchers may use filter pore sizes ranging from ~0.1 to ~0.7 μm (Verdugo et al., 2004; Roulet and Moore, 2006; Azam and Malfatti, 2007). In the oceans, estimated stocks of carbon from DOM and POM are 662 Gt and 30 Gt, respectively (the conversion factor is variable between 1.5 and 6 to convert POC or DOC into POM or DOM) (Hansell et al., 2009; Post et al., 1990). The dynamic exchanges between DOM and POM plays critical roles in organic carbon cycling (Chin et al., 1998; del Giorgio and Duarte, 2002; Verdugo et al., 2004; Hopkinson and Vallino, 2005), interactions with aquatic organisms (Simon et al., 2002; Azam and Malfatti, 2007; Mayer et al., 2011), bioavailability of pollutants (Eadie et al., 1992; Eriksson et al., 2004), and oceanic aquatic phenomena such as mucilage events and marine snow (Smith et al., 1992; Giani et al., 2005; Mecozzi et al., 2005). Some exchange pathways such as aggregation can sequester carbon in sediments and facilitate the settling flux of POM in deep lakes and the open oceans (Grossart and Simon, 1998; Simon et al., 2002; Engel et al., 2004; De La Rocha et al., 2008; Passow, 2012; Zielińska et al., 2014), and they also serve bacteria a colonization area and provides nutrition to living organisms (Azam and Malfatti, 2007; Mayer et al., 2011). And the abiotic conversion of micro-DOM to the macro-aggregates is of great ecological importance because it occurs without carbon losses from the water column (Kerner et al., 2003). The carbon flux from the hydrosphere to the atmosphere is also affected by the exchange efficiency of labile DOM from POM in the riverine systems like the Amazonian rivers (Mayorga et al., 2005). The interactions between terrestrial NOM (mainly POM) and aquatic NOM (mainly DOM) are also involved in the dynamic exchange (Schwesig et al., 2003; Remington et al., 2007; Perez et al., 2011). In addition, NOM can also be categorized into humin, fulvic acid, and humic acid according to its behavior, nature, and structure. This categorization is mainly based on NOM solubility as a function of pH, which was reported to affect the photo-reactivity of DOM as well (Timko et al., 2015).

In previous review articles, aggregates and their formation mechanisms have been extensively discussed (Passow, 2002; Zimmermann-Timm, 2002; Burd and Jackson, 2009) and the roles of organisms have been emphasized (Simon et al., 2002; Azam and Malfatti, 2007). A conceptual model based on the interactions between minerals and OM has also been proposed to explain the exchange pathway via adsorption (Kleber et al., 2007). However, most related studies have focused only on unidirectional processes. Although there have been some studies addressing bidirectional and/or multi-mechanism processes, the major findings have been mostly deduced from indirect supporting data (Wells, 1998; Simon et al., 2002; Hwang et al., 2006; Yoshimura et al., 2010; Helms et al., 2013). We noted that most previous review articles did not delineate a mechanistic and micro-spatial schema for the complex exchange processes to combine all the associated aspects. Despite