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# 1 Interactions between engineered nanoparticles and dissolved 2 organic matter: A review on mechanisms and 3 environmental effects

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## A B S T R A C T

Dissolved organic matter (DOM) is ubiquitous in the environment and has high reactivity. 18  
 Once engineered nanoparticles (ENPs) are released into natural systems, interactions of 19  
 DOM with ENPs may significantly affect the fate and transport of ENPs, as well as the 20  
 bioavailability and toxicity of ENPs to organisms. However, because of the complexity of 21  
 DOM and the shortage of useful characterization methods, large knowledge gaps exist in 22  
 our understanding of the interactions between DOM and ENPs. In this article, we 23  
 systematically reviewed the interactions between DOM and ENPs, discussed the effects of 24  
 DOM on the environmental behavior of ENPs, and described the changes in bioavailability 25  
 and toxicity of ENPs caused by DOM. Critical evaluations of published references suggest 26  
 further need for assessing and predicting the influences of DOM on the transport, 27  
 transformation, bioavailability, and toxicity of ENPs in the environment. 28

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## 80 Introduction

82 In the past decades, an intensive and growing interest has  
 83 focused on nanotechnology, and substantial advances have  
 84 been made. The small size of engineered nanoparticles (ENPs)  
 85 endows them unique physicochemical properties, which has  
 86 spurred enormous applications. ENPs are incorporated into  
 87 household goods, such as detergents, sunscreen creams  
 88 and water filters, and widely used in industry field such as  
 89 nanocatalysts, solar cells, and electronic devices (Chaudhuri  
 90 and Paria, 2012; Mahmoudi et al., 2011; Yu et al., 2013). The  
 91 significant progress in theranostics like biosensing, bio-  
 92 imaging and drug-delivery also encourages the use of ENPs  
 93 for potential treatment of tumors (Lim et al., 2015). Due to the  
 94 rapid development of nanotechnology, some scholars have  
 95 considered the current century as the “Nanotechnology Age”  
 96 (Mahmoudi et al., 2011). However, the vast production and  
 97 application of ENPs will inevitably bring their input into the  
 98 environment. In fact, commonly used typical ENPs, such as  
 99 titanium dioxide nanoparticles (TiO<sub>2</sub> NPs) and silver nanopar-  
 100 ticles (AgNPs), have already been detected in natural waters  
 101 (Gondikas et al., 2014; Pasricha et al., 2012; Wen et al., 1997).  
 102 Although the predicted concentrations of these ENPs in  
 103 aquatic systems are currently orders of magnitude lower  
 104 than those that are known to have environmental effects on  
 105 aquatic biota (Batley et al., 2013), the concentration would  
 106 change with the proliferation of ENPs in various applications  
 107 in the future, leading to public concerns of their potential risks  
 108 to the aquatic organisms and human health.

109 Once released into natural systems, ENPs may interact with  
 110 dissolved organic matter (DOM) in the environment, which  
 111 would greatly influence the final fate, transport, transforma-  
 112 tion and the bioeffects of ENPs. DOM, mainly derived from  
 113 slow microbial decomposition of animal residues, plants and

microorganisms, is ubiquitous in the natural environment. 114  
 The sources, properties and characterization methods of DOM 115  
 have been thoroughly discussed in previous review papers and 116  
 books (Chen and Hur, 2015; Connell, 2005; Mopper et al., 2007; 117  
 Nebbioso and Piccolo, 2013). The DOM concentration in 118  
 aquatic ecosystems depends on biogeochemical conditions 119  
 and climate, but typically ranging from 0.1 to 10 mg/L DOC 120  
 (dissolved organic carbon). Rather than a single compound, it 121  
 can be regarded as a pool of abundant substances with low 122  
 molecular weights (MW, less than 2000 Da) and high MW (up 123  
 to 10,000 Da), and contains numerous functional groups, such 124  
 as thiols, phenolic-OH, quinones, aldehydes, ketones, car- 125  
 boxyls and methoxyls (Aiken et al., 2011; Nebbioso and Piccolo, 126  
 2013). Consequently, DOM can chelate with metals and adsorb 127  
 organic toxicants, which play important roles in the cycle 128  
 and transport of inorganic and organic molecules and ions. 129  
 Interactions of ENPs with DOM may result in a DOM coating on 130  
 ENP surfaces, thus modifies the surface properties, solubility, 131  
 stability and toxicity of ENPs (He et al., 2016; Hou et al., 2017; 132  
 Lowry et al., 2012; Philippe and Schaumann, 2014). Modifica- 133  
 tion of ENPs may make them behave differently from the ENPs 134  
 originally prepared in laboratories. A thorough understanding 135  
 of the ENP–DOM interaction is of great importance to evaluate 136  
 and predict the possible fate, transport and toxicity of ENPs. 137

138 Studies on understanding the ENP–DOM interactions and 138  
 their effects on the environmental behavior of ENPs have been 139  
 reported quite extensively in recent years, with substantial 140  
 information scattered in hundreds of research papers based 141  
 on laboratory experiments and model predictions. Very 142  
 recently, a few excellent papers reviewed or discussed part 143  
 of this topic, including a review on interactions of DOM with 144  
 natural and engineered inorganic colloids (Philippe and 145  
 Schaumann, 2014); a feature article about the impacts of 146  
 DOM on the fate of metals, nanoparticles (NPs) and colloids in 147

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