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## Environmental significance of dissolved organic matter in soils: A review

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### Abstract

Dissolved organic matter (DOM) is an important constituent of soil solution that plays a role in many chemical and biological processes in soils. Dissolved organic matter (DOM) is defined as the organic matter fraction in solution that passes through a 0.45 mm filter. It has important roles in the biogeochemical cycles of carbon, nitrogen, phosphorus, sulphur, etc. so that increasing attention has been paid on the study of soil DOM. The effects of DOM on environmental behaviours of nutrient elements, heavy metals, agrochemicals in soils were related to the physico-chemical characteristics of these substances, DOM, and soil. The present review aims to investigate the environmental significance of dissolved organic matter in relation to the mobilization of nutrients, complexation of heavy metals, partitioning of organic pesticides, gaseous emission and environmental pollution.

**Keywords:** Dissolved organic matter, mobilization of nutrients, heavy metals, organic pesticides, gaseous emission, pollution

### Introduction

Dissolved organic matter (DOM) represents one of the most mobile and reactive organic matter fractions, which represent less than two per cent of the total soil organic matter and it can control number of physical, chemical and biological processes in both terrestrial and aquatic environments. It is one of the operationally defined phase of total dissolved organic matter in solution that can pass through a 0.45 µm filter. True dissolved organic matter which is not bounded to the colloidal particles can be separated with 0.2 µm filter (Dafner and Wangersky 2002) [3]. Dissolved organic matter (DOM), consisting of a complex, heterogeneous continuum of water soluble soil organic matter (SOM) molecules, plays a central role in regulating soil health, contaminant behaviour, and biogeochemical cycles. Aridity and clay content can account for the majority of the variations of DOM chemical composition (Ding *et al.*, 2020) [4]. It is originated mainly from the decomposition of soil organic matter that had accumulated through vegetation and the addition of biological waste materials. In the soil, DOM availability depends on its interactions with mineral components (e.g., clays, Fe and Al oxides) modulated by adsorption and desorption processes (Saidy *et al.*, 2015) [18].

DOM plays a significant role in ecosystem by influencing carbon and nitrogen cycles. Various biotic and abiotic processes, such as degradation, mineralization, partitioning, dissolution, and aggregation, are associated with the dynamics of DOM (Inamdar *et al.*, 2012) [11]. Dissolved organic matter (DOM) can respond rapidly to external interference and is of great importance to soil carbon cycling. It is strongly affected by water erosion and can be an effective indicator for predicting the SOC stability feedback to erosion (Zang *et al.*, 2018) [24]. Aggregate stability is one of the most important factors in soil conservation and maintenance of soil environmental functions. In soils with a higher carbon content (Humaquepts and Haplosaprists), stabilization is predominantly conferred by the aliphatic groups, which is probably due to the structural protection offered by the hydrophobic organic groups (Hanke *et al.*, 2017) [7].

The present review aims to delineate the impacts of DOM on the environment by expediting mobilization of nutrients, Complexation of heavy metals, Partition of organic pesticides and gaseous emission and environmental pollution.

### Mobilization of nutrients

Organically bound nutrients can contribute largely to the export of N, P, and S from soil into aquatic systems. (Kaiser *et al.*, 2001) [12] suggested that one possible determinant for the

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losses of dissolved organic nutrients could be their distribution between DOM fractions of different mobility in soil. They determined the concentrations and fluxes of DOM and dissolved organic N, P and S in soil water under a Scots pine (*Pinus sylvestris* L.) and a European beech (*Fagus sylvatica* L.) forest. The dissolved organic nutrients were mainly concentrated in the hydrophilic DOM fraction which proved to be more mobile in mineral soil pore water than the hydrophobic one. (Donald *et al.*, 1993) <sup>[5]</sup> noticed that phosphorus in the hydrophobic neutral fraction of DOM from boreal forest soils constituted 64 per cent of the total P measured in various fractions. The high P content and low sorption of the hydrophobic neutral fraction suggests that the leaching of these fractions may be a possible mechanism for the redistribution and loss of P in these soils. Similarly, (Vance and David 1992) <sup>[21]</sup> suggested that DOM can influence the mobility and sorption of inorganic solutes in soils. In the presence of DOM (5.6 mmol C/L),  $\text{SO}_4^{2-}$  sorption by three Spodosols decreased. Although DOM reduced the amount of  $\text{SO}_4^{2-}$  adsorbed by each soil, the great affinity that mineral horizons have for DOM can rapidly reduce DOM concentration in soil leachates. This would decrease the competitive DOM effect on  $\text{SO}_4^{2-}$  sorption, resulting in their retention in lower mineral horizons. Furthermore, the overall  $\text{SO}_4^{2-}$  budget may also be influenced by the release of  $\text{SO}_4^{2-}$  through organic decomposition.

Dissolved organic matter- associated nutrient loadings resulted in substantial increases in nitrogen and phosphorus in seepage lakes and could account for nutrient concentrations in the lake (Corman *et al.*, 2018) <sup>[2]</sup>. The application of superphosphate with or without dung to a low P-sorption soil under pasture and irrigation which led to substantial quantities of P being leached to depth. The proportion of P leached as dissolved organic phosphorus over dissolved reactive phosphorus was greater at 50 cm than 30 cm depth (Mc Dowell *et al.*, 2021) <sup>[15]</sup>.

### Complexation of heavy metals

The transport of heavy metals in water and soil can be strongly influenced by their complexation with DOM. (Businelli *et al.*, 1999) <sup>[1]</sup> compared the Cu binding ability (maximum complexing capacity - MCC) of the DOM from pig slurry with that of humic (HA) and fulvic (FA) acids extracted from a clay-loam soil. Gel filtration chromatography showed that the DOM from pig slurry was mainly composed of a fraction with an apparent molecular weight higher than 5000 Da and the Cu naturally present in the slurry was completely complexed by this fraction. The MCC of pig slurry DOM and soil HA, which contained a similar concentration of carboxylic groups, were analogous, while MCC of soil FA, which contained double the concentration of carboxylic groups, was higher. (Laurent *et al.*, 2020) <sup>[13]</sup> suggested that increased soil pH and dissolved organic matter after a decade of organic fertilization mitigate copper and zinc availability despite contamination. Increased application of crop residues for longer period of time increase dissolved organic matter and there by its aromaticity. Concentration of Cu in soil solution is directly correlated with DOM and thereby it will form a complex with DOM and concentration of Cu will be reduced in soil solution whereas concentration of Zn depends on the pH. Increase in the pH reduces Zn content in soil solution.

The presence of dissolved organic substances significantly reduces heavy metal sorption onto pine bark. The order of

sorption efficiency of the considered metals decreases in the order: Zn > Ni > Pb > Cu. Sorption of copper is the most sensitive to DOC content, while Zn is the least sensitive. DOM can potentially enhance the transport of Hg in flood plain soil, fresh water, and sediment pore water either by limiting adsorption onto solid phases or enhancing the solubility of Hg precipitates (Haitzer *et al.*, 2002); (Ravichandran 2004); (Wallschläger *et al.*, 1996) <sup>[6, 17, 22]</sup>.

Groundwater DOM was comprised of protein, polysaccharide and lignin-like substances derived from organic fertilizers. Protein-like substances accounted for the binding of CO, Ni, and Fe, while polysaccharide and lignin like substances were mainly responsible for Cr and Mo complexation (He, 2020) <sup>[8]</sup>.

### Partition of organic pesticides

(Herbert *et al.*, 1993) <sup>[9]</sup> quantified the interactions between pyrene and fractions of DOM, HA, and FA using fluorescence-quenching spectroscopy. Pyrene partition coefficients to the smaller DOM fractions varied between  $4.1 \times 10^3$  and  $6.8 \times 10^3$  L/kg, while partition coefficients (Kdoc) for the largest fraction of DOM, HA, and FA were  $1.5 \times 10^4$ ,  $1.7 \times 10^5$ , and  $1.1 \times 10^4$  L/kg, respectively. Pyrene partitioning data to the largest DOM fraction suggest that the presence of colloidal organic matter suspended in the soil solution may have a large influence on non-ionic organic compounds transport.

According to (Wu *et al.*, 2018) <sup>[23]</sup> combined practice of application of organic amendment like compost along with MCPA (4 Chloro-2-methyl phenoxy acetic acid) enhance the environmental risk of phenoxyacetic acid herbicide leaching in to ground water. DOM and surfactant were able to enhance the transfer of atrazine in both soil and plant. Application of DOM and surfactant decreased atrazine sorption and increased desorption in soil (Tian, 2019) <sup>[20]</sup>.

(Seol and Lee 2000) <sup>[19]</sup> examined the effect of atrazine and prometryne association with DOM extracted from municipal wastewater, swine-derived lagoon wastewater, and HA on sorption by two soils. Pesticide association to DOM normalized to organic matter ranged from 30 to 1000 L/kg DOM. DOM sorption by soil ranged from 1.5 to 10 L/kg, with a silt loam having a higher affinity for the DOM than the sandy loam. DOM up to 150 mg DOM/L did not significantly suppress sorption by soils of either atrazine or prometryne. Lignin- and polysaccharide- like substances in dissolved organic matter play a key role in the binding of pesticide (i.e., dichlorodiphenyltrichloroethane [DDT], endosulfan,  $\gamma$ -hexachlorocyclohexane [ $\gamma$ -HCH], monocrotophos, chlorpyrifos, and chlorfenvinphos), rendering the conversion of  $\gamma$ -HCH to  $\beta$ -hexachlorocyclohexane ( $\beta$ -HCH) and the degradation of DDT to dichlorobenzene dichloroethylene (DDE) ineffective. However, the presence of protein-like substances in groundwater benefited the degradation and conversion of  $\gamma$ -HCH and  $\alpha$ -endosulfan. (He, 2020) <sup>[8]</sup>.

### Gaseous emission and atmospheric pollution

Occurrence of readily decomposable organic matter such as DOM in soil is critical in controlling gaseous emissions from soils through its influence on denitrification of nitrogen and methylation reactions of metal(loid)s such as As, Pb, Hg, and Se. The presence of ample carbon substrate can also result in rapid  $\text{O}_2$  consumption and possible  $\text{O}_2$  depletion, which may then indirectly enhance the potential for denitrification and methylation.

Volatilization of metal (loid)'s occurs through microbial conversion to their respective metallic, hydride or methylated forms. Microbial dissimilatory iron reduction (DIR), a key process of soil biogeochemical cycle, is closely related to the migration and transformation of heavy metals and causes the release of DOM by carbon-ferrihydrite associations. The effect of DOM on microbial DIR is specifically manifested as driving force properties, coprecipitation, complexation, and electronic shuttle properties (Li and Gong 2021) <sup>[14]</sup>. Methylation is considered to be the major process of volatilization of As, Hg, and Se in soils and sediments, resulting in the release of poisonous methyl gas. Although methylation of metal(loid)s occurs through both chemical (abiotic) and biological processes, biological methylation (biomethylation) is considered to be the dominant process in soils and aquatic environments. For example, biological methylation is effective in forming volatile compounds of As such as alkylarsines, which could easily be lost to the atmosphere.

(Zhang and Frankenberger 1999) <sup>[25]</sup> observed that the application of both insoluble (casein) and soluble (casamino acids) organic amendments to selenium (Se) contaminated soil enhanced dimethyl selenide (DMSe) production and removal of Se from soil through volatilization. Similarly, (Michalzik *et al.*, 2007) <sup>[16]</sup> and (Holloway *et al.*, 2009) <sup>[10]</sup> observed a positive relationship between DOM and methylation of Hg and organo-metal(loid) compounds, respectively. Accumulation of algal biomass derived bio-labile DOM resulted in enhanced outgassing of ebullitive CH<sub>4</sub> from the shallow lake mesocosms (Zhou *et al.*, 2019) <sup>[26]</sup>.

### Conclusion

DOM is considered the most mobile and reactive component of the SOM pool despite its occurrence in only small quantities in soils. As such, it regulates major physical and biogeochemical processes not only in soils but also in aquatic ecosystems. It is quite evident that DOM can affect biogeochemical processes from micro- to macroscale. On a global scale, DOM can also play a vital role in the degradation of endogenous and exogenous organic matter affecting C sequestration and N and P transformation and mobility in soils. It also resulted in the emission of green house gases and interplay in the global climate change. This literature demonstrated environmental significance of dissolved organic matter in relation to the mobilization of nutrients, complexation of heavy metals, partitioning of organic pesticides, gaseous emission and environmental pollution. Thus DOM can be viewed to serve a dual function in the environment- as a link and as a bottleneck for various ecological processes.

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