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DOC trend in Arctic lakes as a response to air pollution reduction by Kola North Smelter, Russia (1980-2018): possible mechanisms of transformation of organic substances

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The phenomenon of increasing DOC levels in water systems over the last decades is confirmed by numerous studies (Driscoll et al., 2003; Stoddard et al., 1999; Skjelkvale et al., 2001a; Montein et al., 2007; Evans et al., 2008; Clark et al., 2013). The increasing of organic matter content in lake waters is being also observed for the totality of lakes in the Kola North, more markedly in forest and water-logged subregions. This conforms to the data reported by Skjelkvale et al. (2001a) which demonstrates the significant increase of DOC. Montein et al. (2007) explain the increased DOC levels by reduction in strong acid flow and return of water chemistry to its natural parameters of specifying organic matter concentrations in water.

Clark et al. (2013) demonstrated that natural humus substances are capable of producing strong organic acids and increase water acidity. It is known that DOC level has a direct relationship with water color. In analyzing long-term study data with regard to the group of 75 lakes (obtained during 1990-2010) DOC is increased year-over-year, but the color decreased.

More evident dependence the increasing the content of DOC on reduced color from year to year (Fig.). The following chemical processes developing in water can explain this phenomenon.

Figure. The correlation between the change of DOC (ΔDOC) and color (ΔColor) - file

The water color is predominantly determined by large molecules of humus acids which molecular weight >1000 Da. Macromolecular organic substances of humus type can be dissociated in water with formation of a free proton, as well as enter into reactions of decomposition (hydrolysis) and disproportionation with formation of low-molecular weight fragments. Its fragments also are dissociated of proton (see the diagram below). The above processes may be catalyzed by non-organic strong acids supplied from anthropogenic and natural sources. The diagram of the organic substances destruction of humus origin is given below, where R_i means non-symmetrical fragments of a natural polymer, X_iH - functional groups of organic substances of humus origin, and n - number of protons.

When strong acids get into a water environment humus acids are degraded into fractions. It could be supposed that the organic matter structure undergoes changes in natural waters, as the fraction of high-molecular weight humus acids decrease. As a consequence of interaction between humus substances and protons the humic acids precipitate to form bottom sediments, whereas fulvic acids remain in water. Fulvic acids are characterized by lower molecular weights (from 500 to 2000 Da) and exert an insignificant effect on the water color. This phenomenon is well proved in a study published by Clark et al. (2013). However, to define more exactly this phenomenon, further experimental work is required.

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