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ORIGINAL ARTICLE

Change of water properties during the process of floodplain vegetation destruction

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The destruction of plant residues of floodplain vegetation in the aquatic environment was studied. The objects of study were three herbsspecies dominant in the Ob floodplain: *Inula salicina, Calamagrostis purpurea* and *Carex atherodes.* Dissolved organic matter (DOM), which plays a significant role in the aqueous environment, was studied carefully. As a result of the work, there was revealed the species specificity in the leaching processes of major elements,trace elements and organic matterfrom herbs. It has been established that the motley grasses samples are primarily affected by the destruction process. The growth of dissolved organic carbon, aromatic substances, condensed carbon fragments in the structure of DOC components in the studied waters was observed in the first fifty hours of the experiment, then the corresponding indicators decreased, probably due to the mineralization of organic substances.

Key words: destruction, flood, water properties, dissolved organic matter.

Introduction

The Ob floodplain landscape soccupy a significant part of the territory of Western Siberia and play a special role in the carbon cycle as the richest habitats (Vorobyev et al., 2019). Compared to non-floodplain spaces, these territories are better provided with moisture, heat, and mineral nutrition. However, until now, the studies of the Ob floodplain were mostly devoted to production processes in these territories (Shepeleva, 2018), while the process of degradation of floodplain vegetation during the spring flood remains extremely poorly studied. Meanwhile, significant attention is currently being paid to biological and photolytic degradation in the world (Moran, Zepp, 1997; Hansen et al., 2016).

We studied the destruction of plant residues of floodplain vegetation in laboratory conditions; special emphasis was put on dissolved organic matter (DOM). DOM plays a significant role in the aquatic environment, providing energy to the biota, redistributing light in the water column, interacting with mineral compounds (Minor et al., 2014; Hansen et al., 2016).

Nowadays researchers consider not only the total content of organic material but also its composition that determines its position in the environment (Liang and Singer, 2003; Minor et al., 2014). The research of the composition of dissolved organic carbon in water bodies focuses on a large number of works (Smith et al., 2004, Drozdova et al., 2019, Ilina et al., 2014), which contribute significantly to the understanding of the mechanisms of ecosystem sustainability and the carbon cycle of surface waters (Drozdova et al., 2019). Optical measurements of absorbance and fluorescence are increasingly used to track DOM (Coble, 2007; Fellman et al., 2010; Gabor et al., 2014). Most often, the indicator $SUVA_{254}$ is used to assess the content of dissolved aromatic substances in waters, hydrophilicity and hydrophobicity, as well as the reactivity of DOC when interacting with coagulants and inorganic substances (Randtke, 1999; McKnight et al., 1992; Hoch et al., 2000; Weishaar, 2003). The higher is this indicator, the more aromatic substances are contained in natural waters.If the value of this coefficient is lower than 1, then low molecular weight aliphatic compounds will prevail in the waters (Weishaar et al, 2003; Chowdhury, 2013). A spectral coefficient $E_{250}:E_{365}$ is calculated to estimate the molecular weight, the content of condensed carbon fragments in the structure of the components of the DOM, and the ratio of the content of unoxidized aromatic structures to oxidized ones (Korshin et al, 1997; Peuravouri, Pihlaja, 1997). A spectral coefficient E_{254}/E_{436} is calculated to assess predominance of autochthonous or allochthonous DOM (Battin, 1998; Jaffé et al., 2004; Hur et al., 2006; Ilina et al., 2014). The wavelength ratio

E_{400}:E_{600} is calculated to understand the degree of humification of DOM and O:C and C:N atom ratio (Chin et al., 1994; Stevenson, 1994; Hur et al., 2006).

Materials and methods

The objects of there search were thre eplants species dominant in the Ob floodplain: *Inula salicina*, *Calamagrostis purpurea* and ,which were collected near the Kaibasovo research station of Tomsk State University. Work was conducted with the application of equipment of the large-scale research facilities «System of experimental bases located along the latitudinal gradient» (http://ckp-rf.ru/usu/586718/).

Prior to the experiment, plant samples were dried in an oven at a temperature of 45 °C for 36 hours to an air-dry state; then the samples were weighed under laboratory conditions. The weighed and dried plants were mixed in sterile glass containers of 1 litre with the addition of distilled water.

The containers were stored for 200 hours in a thermostat at a constant temperature of 20 °C. Measurements of pH and electrical conductivity were performed at specified intervals by Multi 3400i liquid analyzer. The collected water samples were filtered through 0.45 µm filters. The elemental composition was determined at the Tomsk Regional Center for Collective Use Tomsk State University using the ICP-MS method with the help of Agilent 7500 cx.

The research of the dissolved organic carbon (DOC), the dissolved inorganic carbon (DIC) and the structure of organic matter of tests were conducted on the basis of Forestry Institute of V.N. Sukachyov of the Siberian Branch of the Russian Academy of Science in Krasnoyarsk with use of the analyzer TOC minicube and the spectrophotometer Varian 100 UV-Vi. From the absorption spectra of water samples in the ultra-violet and visible field, the followingvalues characterizing DOM were calculated, namely $SUVA_{254}$, E_{250}:E_{365}, E_{465}:E_{665}, E_{254}:E_{436}.The $SUVA_{254}$ value was calculated as the 254 nm absorption ratio (mg^{-1} m^{-1}) to the DOC content of the sample. We used statistical packages of the program "Statistica 6.0" to process the obtained results.

Results and discussion

Substances leached from plants entered to water, which electrical conductivity naturally increased during the experiment.The maximum electrical conductivity was observed during the destruction of plant residues of motley grass samples - *Inula salicina*, which may be associated with the highest leaching of major elements during the decomposition of this species.The minimum conductivity was noticed for samples of cereals - *Calamagrostis purpurea* (Fig. 1a). During the 220 hours of leaching, plant residues lost from 11 to 30% of the mass, with the maximum losses observed for *Inula salicina* and the minimum for *Calamagrostis purpurea*. The pH of water in the first 30 hours after the start of the experiment sharply decreased in all cases (most of all, in the case with *Carex atherodes*), but then it began to increase and, starting from the hundredth hour of the experiment, a slight alkalization was observed in the water (Fig. 1b).

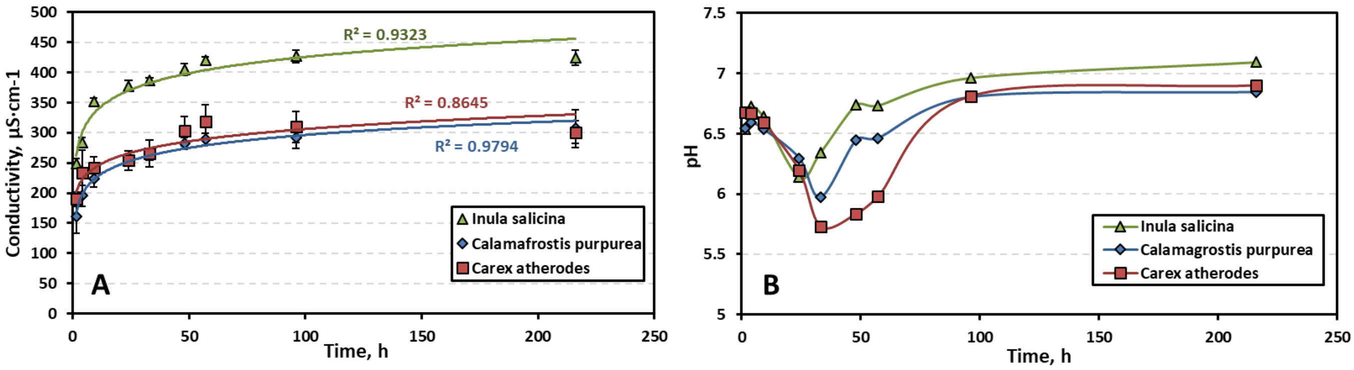

Fig. 1. Change of physicochemical characteristics. A – Conductivity, B – pH

Having studied the elemental composition of water after the experiment completion, it was established that potassium is most leached.The possible reason is that its content in the plant matter of this species is maximum (Table 1). The fact that the potassium content in herbaceous plants is usually higher than the content of other elements has been confirmed by some researchers (Covda, 1956; Archegova, 2011). Also, it is known that potassium is not a part of organic substances of plant cells, but is in free ionic form (Archegova, 2011).

Table 1. Potassium content in plants and water after the experiment, ppm

Plant species	*Inula salicina*	*Carex atherodes*	*Calamagrostis purpurea*
Potassium content in plants	30836.10	18257.39	21485.45
Potassium content in water after the experiment	217.55	138.75	122.95

For all the plants studied, the migration activity of macronutrients declining in the K >Ca> Mg > Na range. The maximum leachin of these major elements was noted for *Inula salicina*, the minimum for *Calamagrostis purpurea* (Fig. 2).

Species specificity was revealed in processes of leaching trace elements from plants. Thus, with the destruction of *Inula salicina*, Si and Rb were most actively introduced into the water, and then the entry activity decreased in the range Fe > B >Mn>Sr> Al > Zn > Ba > Cu > Ni > Se > Li. For *Carex atherodes*, this series is as follows: Si > Fe >Mn>Rb> Zn >Sr> Al > B > Ba > Cu > Ni > Se > Mo. The entry activity of trace elements for *Calamagrostis purpurea* destruction was represented by the following descending range: Mn> Si >Rb> Zn > Fe > Al > B >Sr> Ba > Cu > Ni > Se > V.

We have to note that trace elements entered the water in other ratios than these substances are found in plants; for example, the following series is characteristic of *Carex atherodes* plants: Si > Fe > Al >Mn> Ba >Rb> Zn >Sr> Ni > Cu > Ti > B > Cr >Sc> Mo; for plants *Calamagrostis purpurea*: Mn> Fe> Al> B> Si> Zn> Ti>Rb>Sr> Ba> Ni> Cu>Sr>Sn> Mo; *Inula salicina*: Fe>Rb>Sr>Mn> B> Si> Ba> Zn> Ni> Ti> Cu> Li> Cr. The largest number of major and trace elements passed into the water during the leaching of *Inula salicina*.

For the same plant species, the sharpest increase in conductivity and DIC content was noted. For all plant species, the dynamics of DIC entry into the water was close to the dynamics of electrical conductivity change (Fig. 3a), and the relationship between the increased conductivity and the content of major elements in water was also noted.

The dynamics of the intake of dissolved organic carbon is shown in Fig. 3b; it can be noted that a greater amount of DOC was released into the water during the leaching of *Inula salicina* than when other types of plants were leached. A particularly large amount of DOC in waters was revealed during the first hours of the experiment.

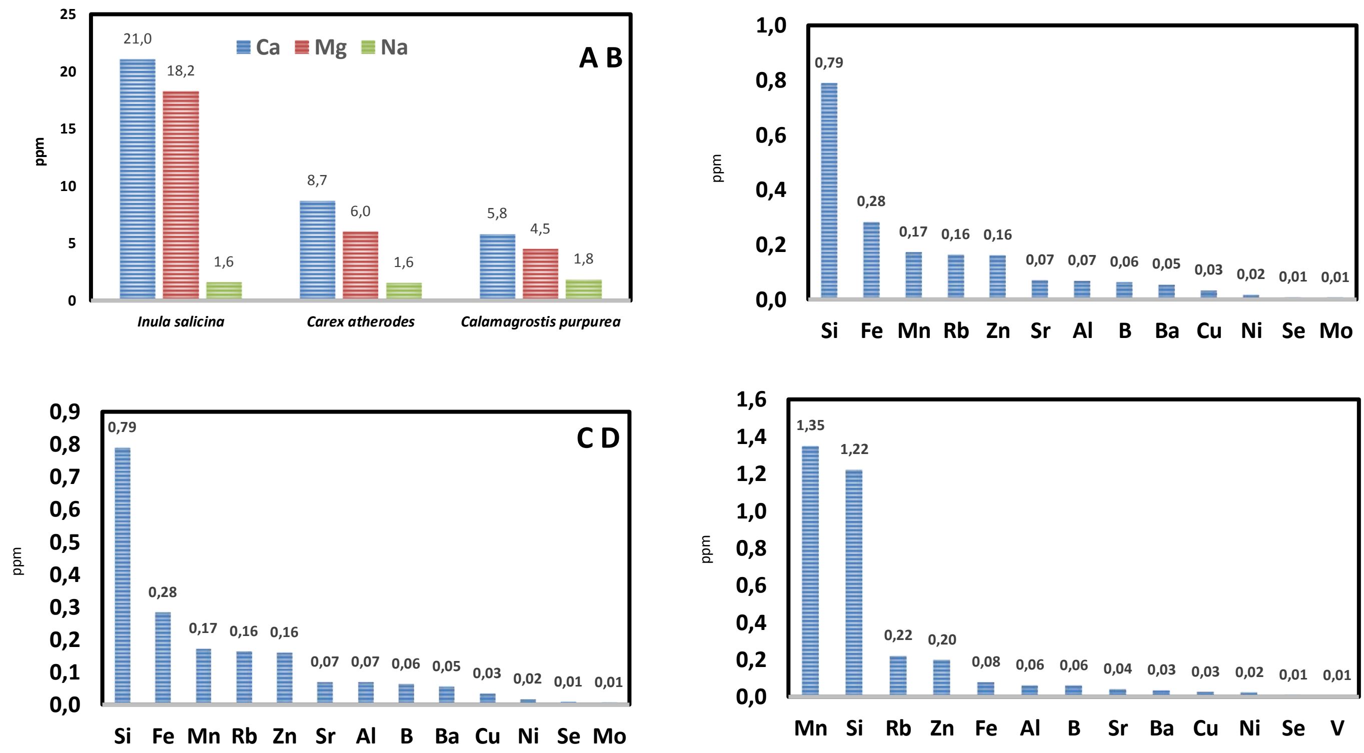

Fig. 2. Amount of enleached major and trase elements, ppm. A – major elements; B – trace elementsin the process of leaching *Inula salicina*; C – trace elements in the process of leaching *Carex atherodes*; D - trace elements in the process of leaching *Calamagrostis purpurea*

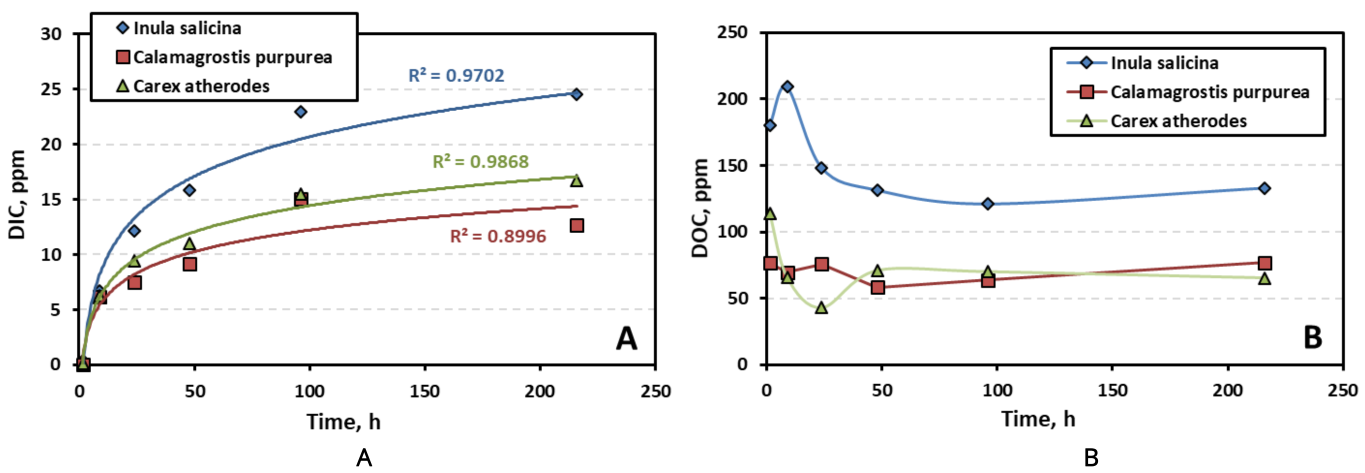

Fig. 3. Dynamics of DIC (A) and DOC (B) content in water during plant enleaching

As can be seen, when the studied plant species were leached, the hydrophilic material fell into the water, as is indicated by the low $SUVA_{254}$ (Sedzwald and Tobiason, 1999; Minor and Stephens, 2008; Matilainen et al., 2011). In the first hours of the experiment, the little amount of aromatics was present in the water, but then it increased sharply; this is especially characteristic of *Inula salicina*. The maximum of aromatic substances was noted in the waters at the fiftieth hour of the experiment, however, during the mineralization of substances, their amount decreases and after 200 hours this parameter is close to the initial values for all plant species (Fig. 4). After 120 hours of leaching *Calamagrostis purpurea* and *Carex atherodes*, the $SUVA_{254}$ falls below 1, indicating that waters were dominated by only aliphatic compounds with low molecular weight (Weishaar et al., 2003; Chowdhury, 2013).

The spectral coefficient ofE_{250}:$E_{365}$is also related to the molecular weight and content of condensed carbon fragments in the structure of the components of DOC (Korshin et al., 1997; Peuravouri, Pihlaja, 1997).It is believed that if the size of the molecules is larger, the E_{250}:E_{365} ratiois smaller due to the stronger absorption of light by high molecular weight DOM on longer waves (Korshin et al, 1997). In our case, the lowest content of condensed carbon fragments was noted in the first hours of the experiment, then, within 50 hours, it grew, and then again decreased as well as the $SUVA_{254}$indicator.

The E_{465}:E_{665}ratio correlates better with the size ratios of the molecules O:C and C:N and the content of carboxyl groups than with aromaticity and can, therefore, be used as a common feature of humification (Adani et al., 2006; Schnitzer et al., 1985; Chen et al., 1977). The values of the E_{465}:E_{665} coefficient in the tested samples ranged from 1.9 to 13.3. The lowest E_{465}:E_{665} values were found for *Inula salicina* and indicate a higher degree of humification of organic matter (Schnitzer et al., 1985; Chen et al., 1977).

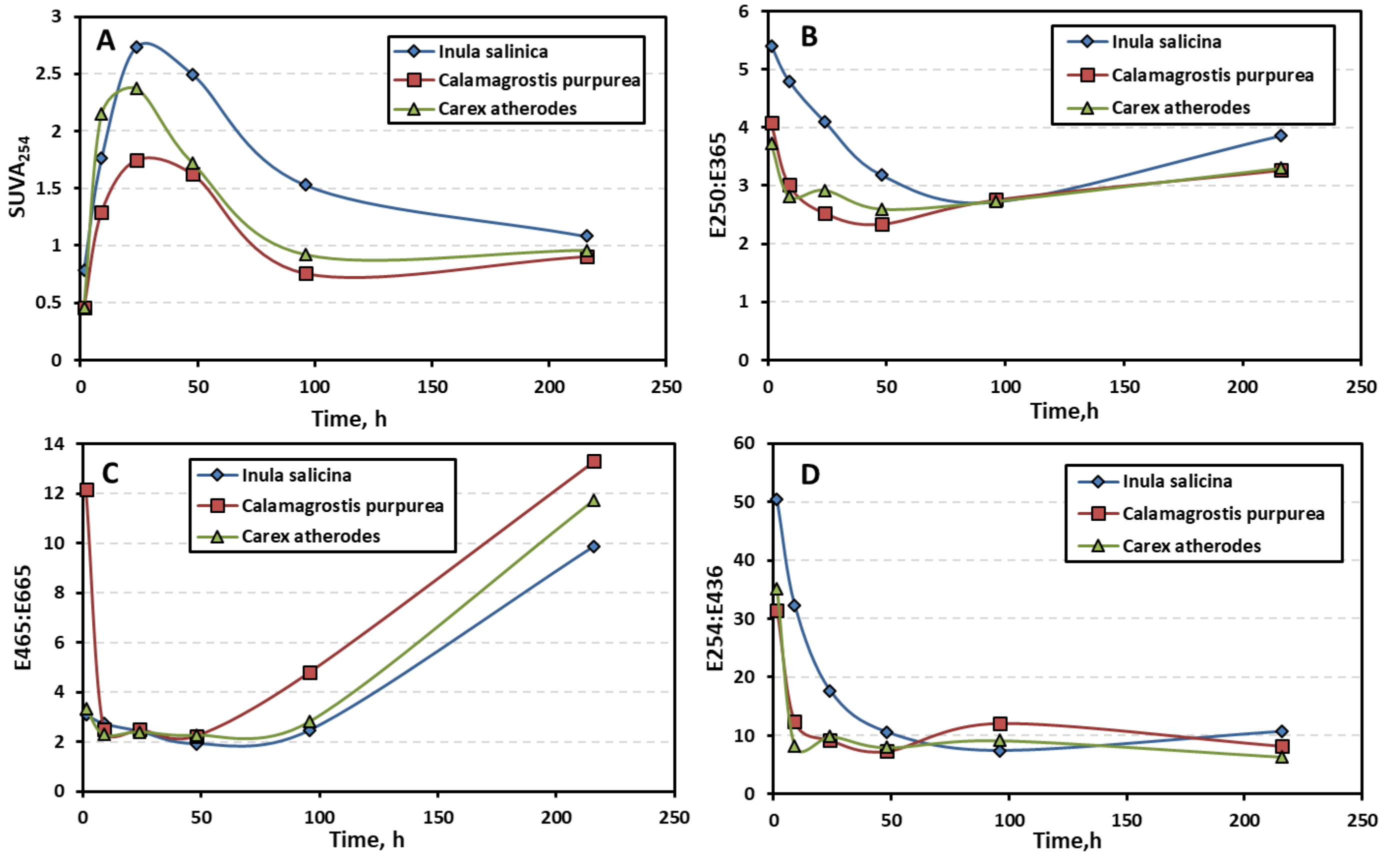

Fig. 4. Changing the structure of organic matter during enleaching of floodplain plants. A – $SUVA_{254}$, B – E_{250}:E_{365}, C – E_{465}:E_{665}, D – E_{254}:E_{436}

The values of the E_{254}:E_{436} coefficient ranged from 7.37 to 50.4, with the maximum values being noted during the leaching of *Inula salicina* (Fig. 4d). In the first hours of the experiment, an autochthonous organic substance formed as a result of the life of microorganisms prevailed, then the spectral coefficient of E_{254}:E_{436} decreased sharply and remained at a close level for all leached plants until the experiment completion. This suggests the inclusion in DOC of allochthonous substances originating from products of incomplete degradation of plant and animal residues (Ilina et al., 2014; Wang et al., 2001).

Conclusion

Therefore, species specificity was revealed in the leaching processes of major and trace elements and organic matter from plants. It has been established that samples of motley grass are primarily affected by the destruction process. The growth of dissolved organic carbon, aromatic substances and condensed carbon fragments in the structure of the DOC components in the investigated waters was observed in the first fifty hours of the experiment; then the corresponding values were reduced, probably due to the mineralization of organic substances. When the studied plant species were leached, hydrophilic material (aliphatic compounds with low molecular weight) fell into the water.

Acknowledgments

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