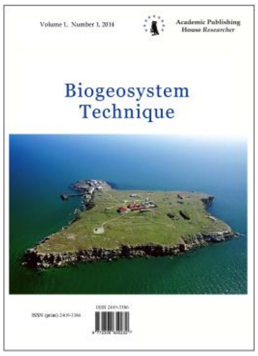
Copyright © 2017 by Academic Publishing House Researcher s.r.o.

Published in the Slovak Republic
Biogeosystem Technique
Has been issued since 2014.
ISSN: 2409-3386
E-ISSN: 2413-7316
2017, 4(2): 189-206

DOI: 10.13187/bgt.2017.2.189
www.ejournal19.com



Composition of the Middle Amur Ice Cores after Catastrophic Flooding in 2013

Galina V. Kharitonova [a, *], Vladimir I. Kim [a], Angelina S. Stenina [b], Vladimir P. Shesterkin [a], Natalya S. Konovalova [c]

[a] Institute of Water and Ecological Problems Far East Branch of RAS, Khabarovsk, Russian Federation
[b] Institute of Biology of Komi Scientific Centre of the Ural Branch of the RAS, Syktyvkar, Russian Federation
[c] Institute of Tectonics and Geophysics Far East Branch of RAS, Khabarovsk, Russian Federation

Abstract

Content and composition of ice inclusions are the important characteristics of the redistribution of substance in river ecosystems, which allows taking into account transport of the inclusions matter during the spring ice drift. The data on the composition of the ice cores from the Middle Amur (Khabarovsk water node) after the extreme flooding in 2013 and its terrigenous, chemogenic (formed through chemical processes) and biogenic (diatoms) components are presented in this paper. The importance of the work lies in the fact that the impact on the river ecosystems of catastrophic floods, such as the 2013 flood on the Amur River, due to their uniqueness, has been extremely poorly studied. The analysis showed that the content of terrigenous material and its variation in ice thickness does not exceed the average multi-annual values. The particle-size distribution of the terrigenous material (on their volume and the number) corresponds to that of the river suspended matter, warps (silt deposits on the flood plain) and bottom sediments in the studied river area. Composition of diagnosed chemical inclusions (neoformations of calcite $CaCO_3$ and pyrite FeS_2), their number and size depends on the chemical composition of water during the freeze-up and redox conditions in the layer. Flooding had the main impact on biogenic inclusions (diatoms). The change of the leading species (from single population *Aulacoseira islandica* to *Stephanodiscus hantzschii* Coscinodiscophyceae class, *Stephanodiscaceae* family, genus *Stephanodiscus*) was fixed. This is one of the main indicators of structural and functional violations orderliness hydrobionts. The change in the composition of the leading species associated with the arrival of eutrophying substances and pollutants from the Sungari River (the largest tributary of Amur River) as a result of outcome flooding agricultural lands and residential territories.

Keywords: ice, ice inclusions, Amur River, floods, Russia.

1. Introduction

Amur River refers to the Far East type of rivers, which are characterized by a predominance of full-blown rainfall runoff (60–80 % of the annual runoff water) over snow and soil nutrition, because of the peculiarities of the climate (Resources, 1966). Climate is formed under the strong influence of oceanic factors. In the second half of the summer and early autumn, warm and moist

* Corresponding author
E-mail addresses: gkharitonova@mail.ru (G.V. Kharitonova)

tropical masses penetrate deep enough into the continent, resulting in abundant (up to catastrophic) rainfall and, as a consequence, to flooding. Floods on the Amur have great repeatability – once in 5 years on the Upper Amur, every 3 years on the Middle Amur, and 1.5 years on the Lower Amur (Boikova, 1963). A large catchment area (1.86 million km^2), locality of precipitation and their large intensity are the reasons for the existence of several hypocenters of flood formation on the Amur. There are four basic hypocenter: Upper Amur, Zeya-Bureya, Sungari and Ussuri parts of the Amur River basin, each of them can cause catastrophic floods. Especially powerful floods are formed if they arise in two or three hypocenters and combined in the Amur River channel.

Flood in 2013 became an extraordinary one: high rain floods consistently formed in the whole Amur River basin (Danilov-Danilyan, 2014; Dugina, 2013). Flood, formed on the Upper Amur was not extreme. However, its peak was supplemented by the floods with other parts of the basin: from the Zeya, Bureya, Sungari, and the Ussuri rivers. In this period, there has been a unique coincidence of flood peaks passing. Below the confluence of the Sungari River the maximum levels exceeded historical highs in the 0.40–2.11 m. Duration of inundation of the floodplain was two to three months and the height of the layer of water on the floodplain reaches was 2–4 m. In the area of the Khabarovsk water node (Khabarovsk) the maximum level of floods and floodplain inundation depth totaled 8.08 m (excess over historically maximum of 1897 – 1.66 m), floodplain inundation level reached 5.08 m. Maximum flow of water in the Amur River (16 km above Khabarovsk) totaled 33400 m^3/s, the total flow of all tributaries (Khabarovsk, below the railway bridge) was 46100 m^3. High intensity and duration of flooding resulted in significant removal of soluble substances. Thus, runoff of major ions in the flood reached 19.6 million t/d, nitrate nitrogen – 64.5 thousand t/d (Shesterkin, 2010, 2016). Discharge of suspended load was accompanied by their accumulation in unloading zones (floodplain). In the first accumulation zone after the Sungari River the thickness of warps 2013 exceeded to the order the long-term average values (Shaldybin et al., 2016).

Such significant changes in hydrological and hydrochemical regimes could not affect the composition of the Amur River ice, work on the study of which began relatively recently (Ivanov et al., 1987; Shesterkin, 1990; Makhinov, 2013, 2017). It was found that the ice cover is characterized by a significant amount of terrigenous material. The main sources of terrigenous material are wind shift, capture soil on the shoals during the fall ice surfacing bottom ice, avalanches block when ice erosion of clayey floodplain, rockfalls from the steep slopes on the ice surface in the mountainous part of the valley and lift of anchor ice. Ice can also contain chemical (formed through chemical processes) and biogenic (mainly diatoms) components (Lebedev et al., 1981; Nemirovskaya, 2015; Nikulina, 2014; Strakhov et al., 1954; Yuryev & Lebedev, 1988).

The aim of this study is to define the composition of the ice in the Middle Amur after the extreme flooding in 2013, its terrigenous, chemical and biogenic components. The importance of the work lies in the fact that the impact on the river ecosystem of catastrophic floods such as flooding of 2013 in the Amur River due to their unique studied sorely lacking.

2. Materials and methods

Study area

The work was carried out on the flat part of the basin of the Middle Amur. In this area of the Amur River the formation of ice cover begins in early November when the temperature substantially decreases and flow speed significant increases. Freeze-up on the Amur River in 2013 near Khabarovsk started in 1 December, which is 7 days later than average multi-annual values. Autumn freeze-up is frozen masses of floating frazil ice, sludge and floes. At the last stage of freeze-up formation in the river hummocks are formed, whose number and height (up to 1.5 m) on mainstream are the maximum. Near the shores the ice surface is usually smooth (Makhinov, 2013, 2017). According to the thickness and stratigraphy the ice in the main channel is divided into the following types: strong, moderate, weak, flat hummocky and flat ice (naled ice in this work is not considered). About half of the ice surface falls on moderately hummocky ice, which area is located on both sides of the zone of strongly hummocky ice (mainstream). At a fraction of the latter account for about 15 %. By the end of winter ice thickness reaches 1.1–1.3 m and in severe winters – 1.6–1.8 m. Ice thickness has a complex structure. The upper part of matt in color is usually solid ice formed during the formation of ice cover and cemented by frazil ice. The lower part of the ice thickness is presented with glassy transparent ice. Its formation is associated with freezing of new layers of ice at its bottom after freeze-up, mainly in the middle and late winter.

Methods of study

The material for the study was ice samples from a well drilled in a zone of moderately hummocky ice – 3 km, Middle Amur, 350 m from the edge of the right bank (48°36.308' N135°02.397' E), depth 4 m, ice thickness 1.33 m (Fig. 1). Sampling was conducted in March, 2014 (when the minimum water level and a maximum thickness of ice). While sampling, a mechanical drill with the 18 cm diameter was used. In core the following layers were identified by color, transparency, ice inclusions: 0–40 cm – transparent mat ice; 40–43 cm – dirty ice; 43–52 cm – transparent mat ice; 52–70 cm – transparent frosted ice with occasional scattered by inclusions; 70–117 cm – transparent frosted ice with occasional scattered particles, layers and lenses of dirty ice; 117–133 cm – glassy ice with dirty layers.

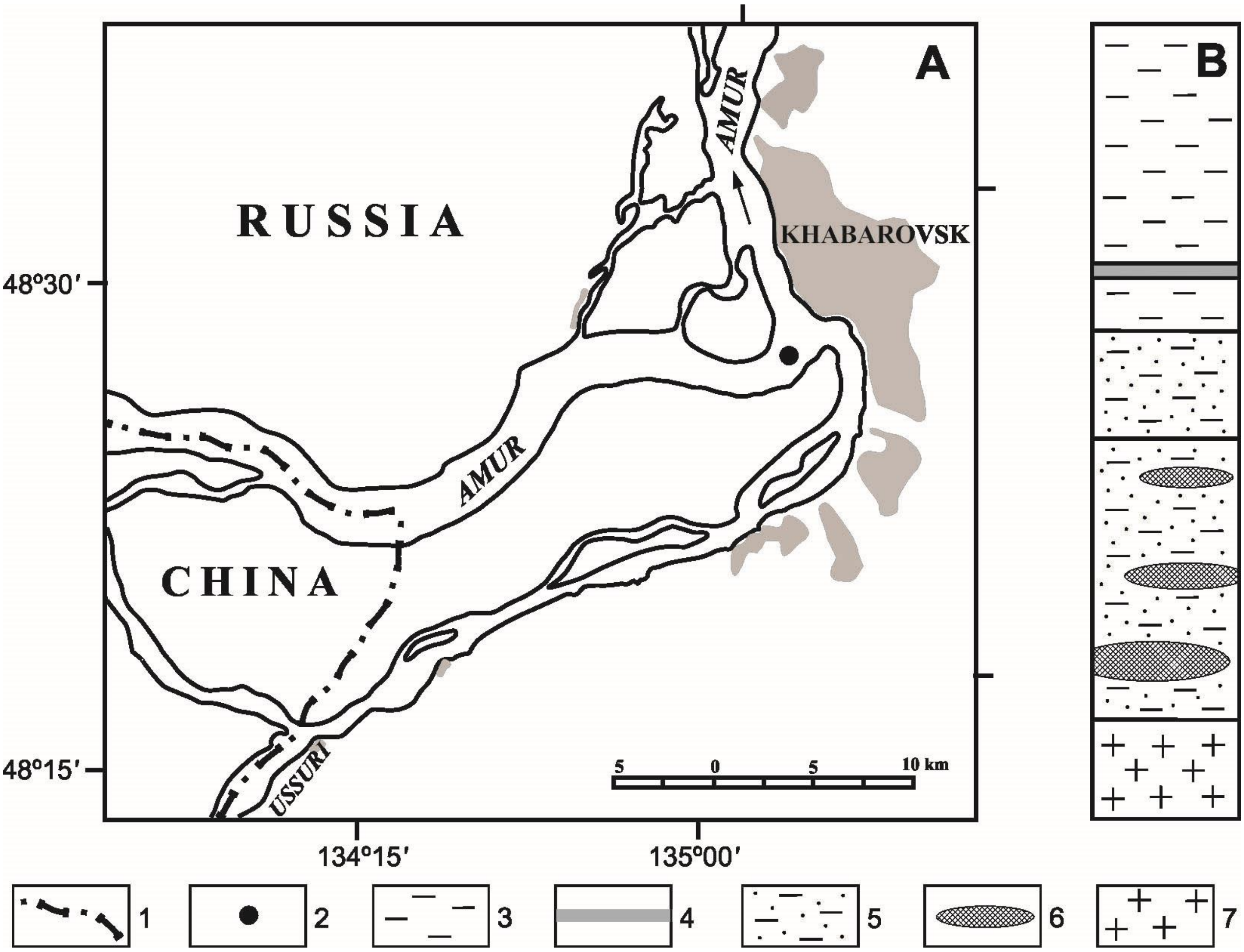


Fig. 1. A. Sketch map of sampling site. **B.** Schematic ice coring. 1 – state border, 2 – place coring, 3 – transparent matte ice, 4 – dirty ice, 5 – ice with occasional scattered by inclusions, 6 – layers and lenses dirty ice, 7 – glassy ice. For other explanations see text.

Core was sawed into layers, than each layer of ice melted in the laboratory and after filtering of suspended matter amount of water was measured. Filter with sediment was dried until constant weight to determine the mass of the substances included in the ice. Analysis of the particle size distribution was conducted on a particle size Analyzer SALD-2300 (SHIMADZU, Japan). Additionally samples were studied on scanning electron microscope VEGA 3 LMH (TESCAN, Czech Republic) in Khabarovsk innovative analytical Centre (ITG FEB RAS). Energy dispersive spectrometer X-max 80 (Oxford Instruments, United Kingdom) was used for the elemental composition analysis of suspended matter. To identify the diatoms the main keys, systematic works and selected publications were used (Diatoms, 1992; Genkal et al., 2002; Medvedeva et al., 2001; Medvedeva, Sirotsky, 2002; Medvedeva, Nikulina, 2014). Modern nomenclature changes were clarified by AlgaeBase (Guiry, Guiry, 2017). Ecological and geographical characteristics of species were done according to the literature (Barinova, 1996, 2006; Van Dam et al., 1994; Krammer, Lange–Bertalot, 1991). Analytical work was carried out by hydrochemical research methods (Guide, 1977).

3. Results and discussion

Particle-size distribution data

Before characterizing the ice inclusions, we introduced data on particle-size distribution, which is a source of important information about the origin of sediments (alluvial and eolian), their transport history and sedimentation conditions (Buurman et al., 2001; Van Genuchten et al., 1999; Eshel et al., 2004; Pachepsky, Rawls, 2004; Rawle, 2017; Segal et al., 2009; Wolform, 2011). According to analysis, variation of suspended particles on the selected layers in core is almost three orders of magnitude (2.26 g/L in the 40–43 cm and 0.003 g/L in the 117–133 cm with an average content of 0.71 g/L). But the particle distribution (distribution by volume) in core was closed (Fig. 2). In all layers, peaks of fractions of medium and coarse dust (5-10 and 10-50 μm), fine and medium sand (50–250 and 250–500 μm) are predominantly detected in the upper part of the core. The exception is the layer of 43–52 cm: its differential curve is characterized by a single peak of high intensity with a maximum of about 500 μm, which indicates a high sorting of particles. The reasons for the latter will be discussed below.

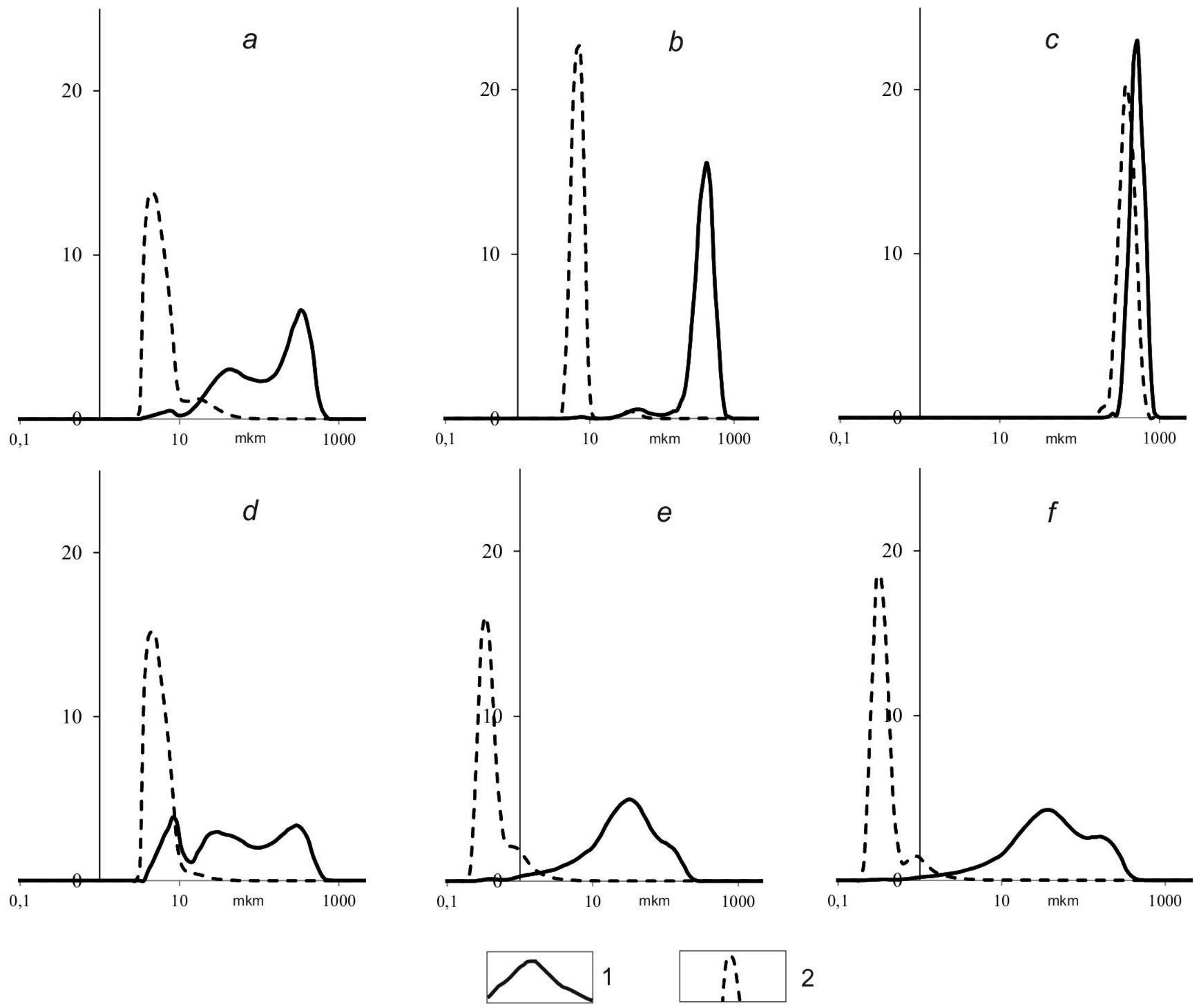


Fig. 2. Differential particle-size distribution in the ice samples: distribution on volume (1) and the number of particles of a certain size, *a* – layer 0–40 cm, *b* – layer 40–43 cm, *c* – layer 43–52 cm, *d* – layer 52–70 cm, *e* – layer 70–117 cm, *f* – layer 117–133 cm. For other explanations see text.

However, layers are drastically different by intensity peaks and, accordingly, the contributions of the individual fractions that related to the predominance of those or other processes in different phases of ice formation. So the particles of medium-sized sand (Fig. 2a, b) dominated at the top of the core (layers 0–40 and 40–43 cm), that corresponds to the formation of layer during freeze-up. Anchor ice participates in the formation of the next layer (43–52 cm), as evidenced by the proximity of differential ice particle distribution curves of inclusions (Fig. 2c) and bottom sediment in this river area (Shaldybin et al., 2016). The inclusions lower layers (layers of core 52–70 and 70–117 cm) are the thinnest in size. Formation irregularly shaped loam accumulations in these layers associated with winter dumping of water from the reservoirs of large hydropower plants in the Sungari, Zeya and Bureya rivers network, which leads to an increase in water velocity and turbidity (Makhinov, Kim 2013, Makhinov et al., 2017). Differential curves (Fig. 2d, e) and dimension prevailing particles ice inclusions coincide with those of the suspended load and warps in this river area. In the layer of glassy ice at extremely low content inclusions their distribution is close (Fig. 2f), as evidenced by the differential distribution curves and calculations on the number of particles of a certain size.

SEM analysis

Analysis of size, morphology and composition of inclusions with electron microscopy methods (Fig. 3) confirms data on particle-size distribution and shows that the upper part of the core is presented mainly as grains of primary minerals – quartz and feldspar (Fig. 3a–c).

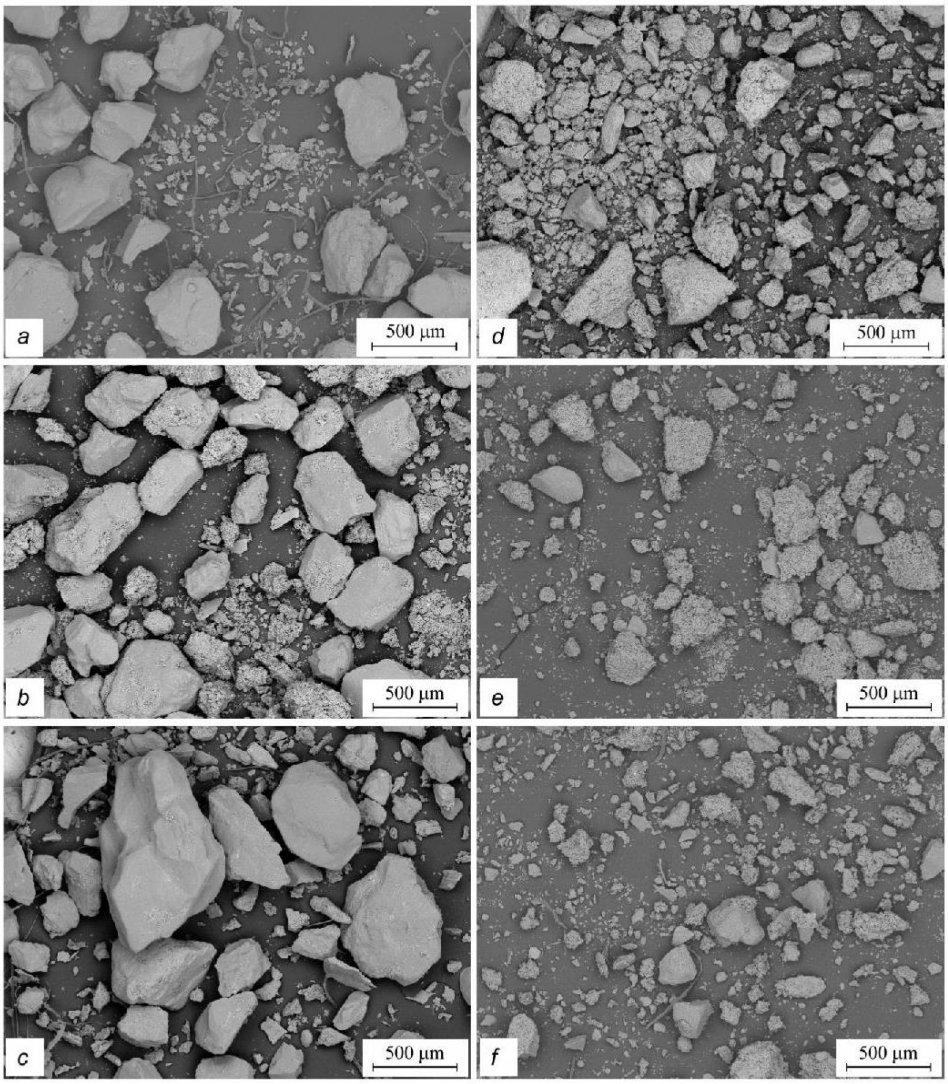


Fig. 3. Micrographs of particles in the ice samples: *a* – layer 0–40 cm, *b* – layer 40–43 cm, *c* – layer 43–52, cm, *d* – layer 52–70 cm, *e* – layer 70–117 cm, *f* – layer 117–133 cm (SEM, BSE-detector).

Also accessory minerals (the content of which <1%) of epidote-hornblende association (zircon $ZrSiO_4$ and ilmenite $FeTiO_3$) were diagnosed by energy dispersive analysis in these layers (Fig. 4a, b). Silty and clayey particles dominated in the lower layers of the core (Fig. 3d–f). Clay minerals are presented mainly as microaggregates, in which participated iron hydroxides (Fig. 4c).

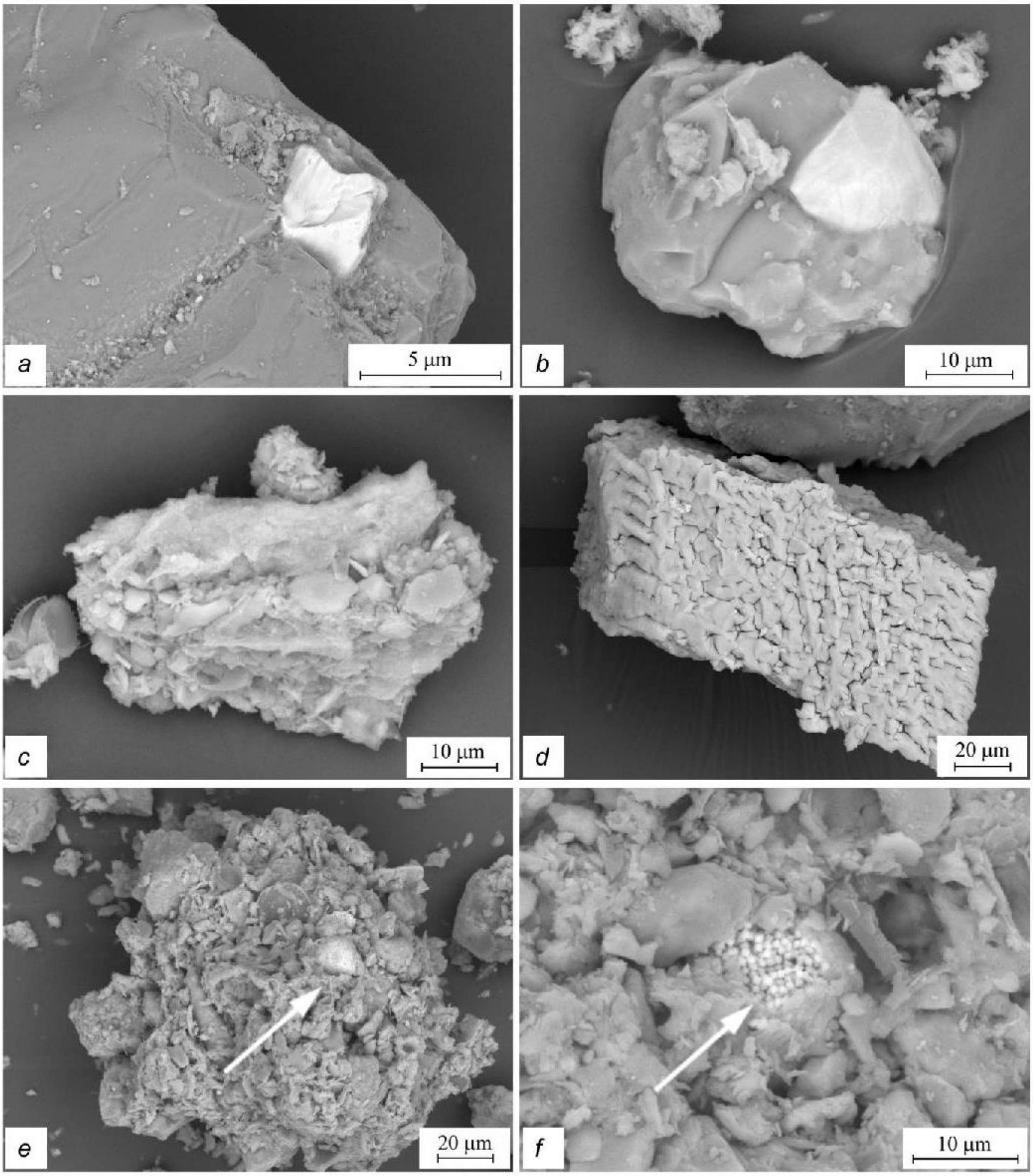


Fig. 4. Micrographs of zircon (*a*) and ilmenite (*b*) grains, clayey microaggregate (c), neoformations of calcite (*d,* layer 43–52 cm) and pyrite in clayey microaggregates (e, f, arrows, layer 70–117 cm) (SEM, BSE-detector)

Of the chemogenic inclusions, calcite $CaCO_3$ and pyrite FeS_2 were diagnosed (Fig. 4d–f). Calcite neoformations were found in a layer 43–52 cm in different forms 100–200 μm in size. Pyrite was discovered below in layers 52–70 and 70–117 cm in the composition of the clayey microaggregates as framboids, consisting of individual octahedral microcrystals. Framboid size does not exceed 2 μm in the layer of 52–70 cm their size reaches 10–15 μm in next layer 70–117 cm. The formation of pyrite testifies to the reducing conditions in the lower layers of the core and the development of sulfate-reducing bacteria in them (Barton, Hamilton, 2009; Berger et al., 1996).

Biogenic ice inclusions – diatom algae – were found throughout the ice (Fig. 5, 6).

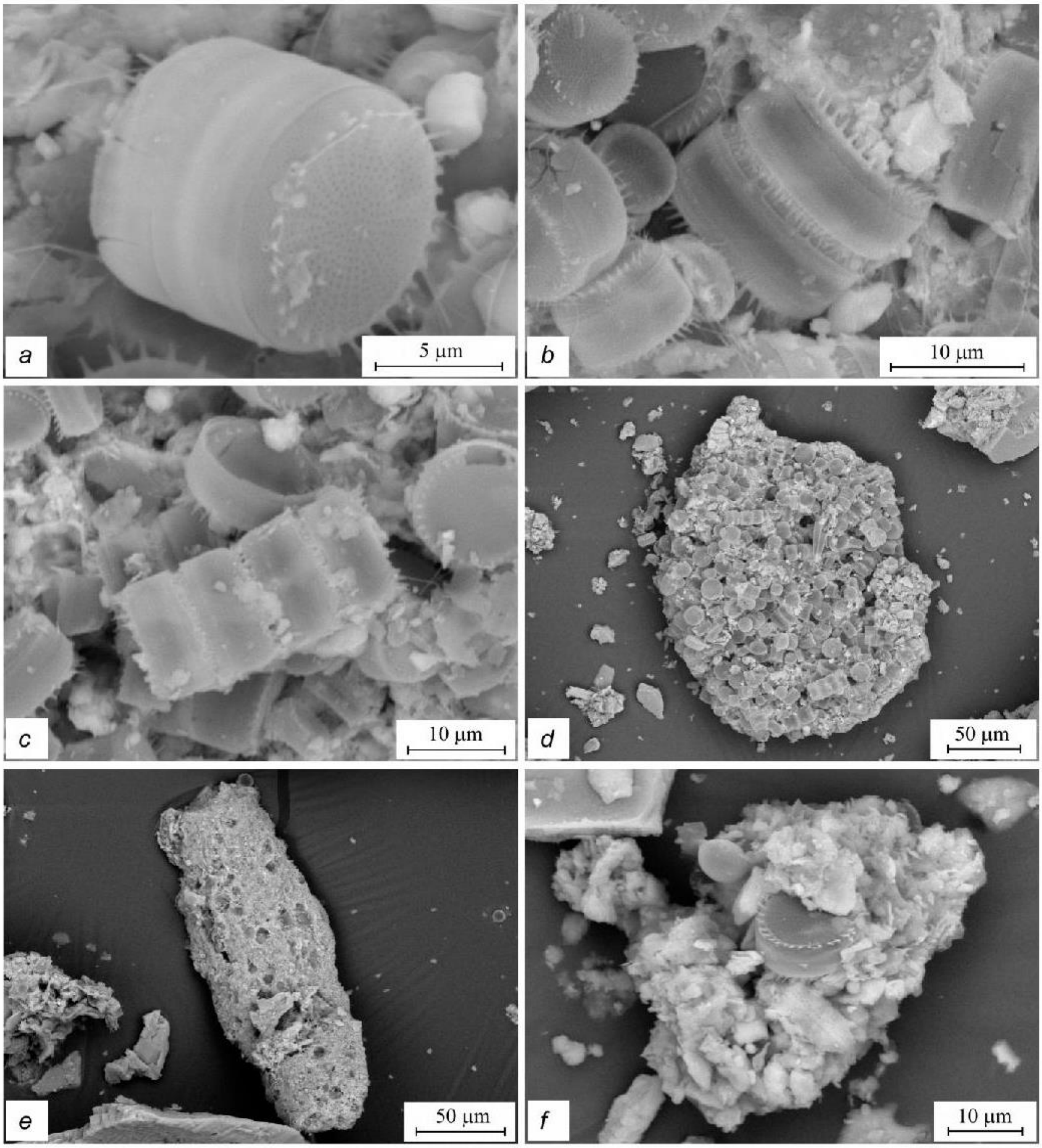


Fig. 5. Centric diatoms of genera *Stephanodiscus* in the ice core: *a-c* – *S. hantzchii* Grunow, *d* – diatom aggregations (layer 40–43 cm) and *e*, *f* – clayey microaggregates with participation of diatoms (SEM, BSE-detector)

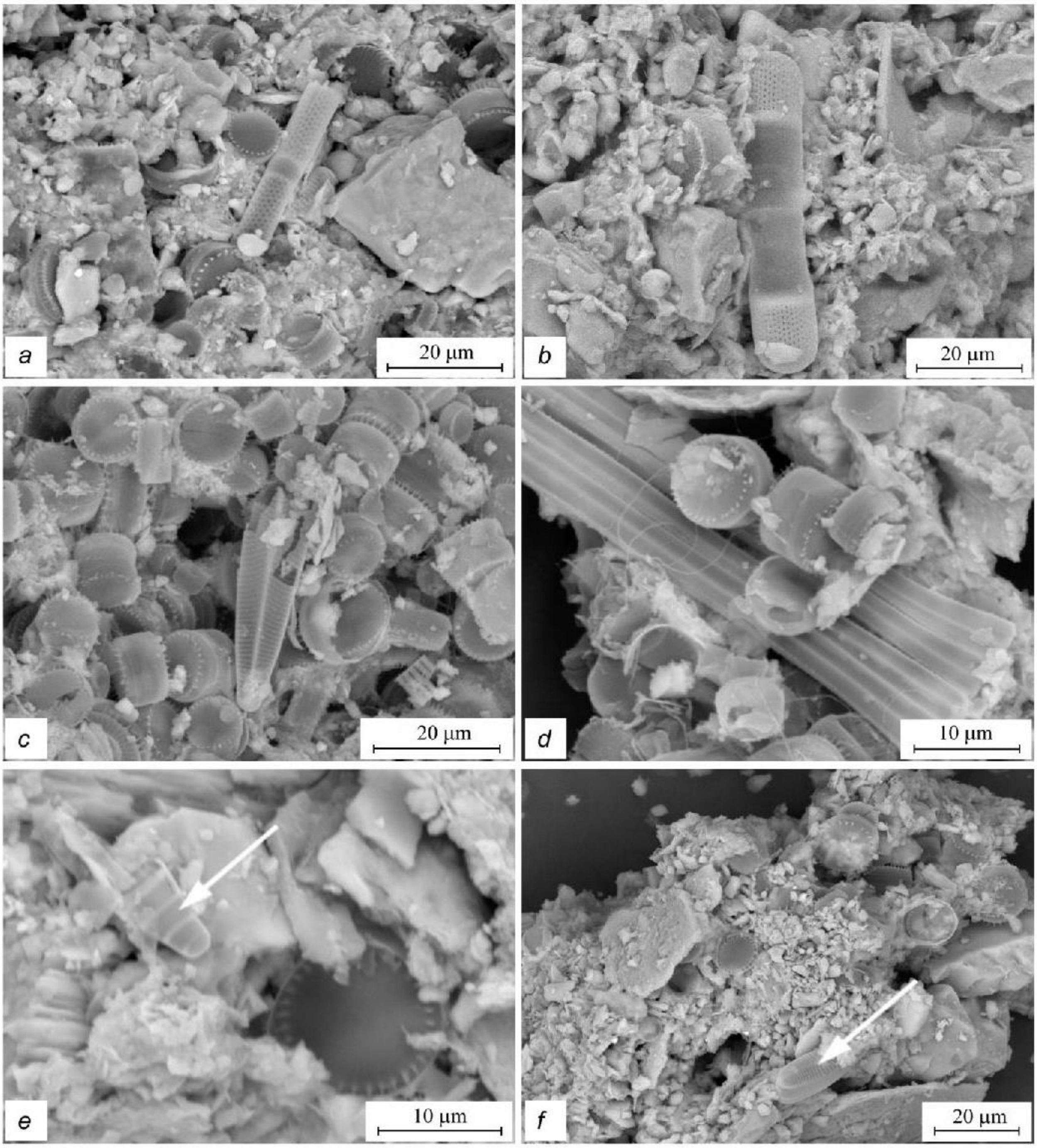


Fig. 6. Centric diatoms of genera *Aulacoseira* (*a–b*) and Pennate species (*c–f*) in the ice core: *a* – *A. islandica* (O. Müller) Simonsen, *b* – germinating spore of *A. islandica, c* – *Navicula* sp., *d* – *Asterionella formosa* sp., *e* – *Meridion circulare* sp. (arrow), *f* – *Gomphonema* sp. (arrow) (SEM, BSE-detector)

Predominantly identified diatoms are planktonic species. The diagnosed species prefer mildly alkaline water, as well as the availability of easy oxidable organic substances (Barinova et al., 2006). Species *Stephanodiscus hantzschii* Grunov (class Coscinodiscophyceae, family *Stephanodiscaceae*, genus *Stephanodiscus*) stands out look among planktonic species on frequency of occurrence and ecology. *S. hantzschii* are single cells, their threads (Fig. 5a–c) and aggregations include some pennate species (Fig. 6c–f). The largest number of them was fixed in a layer with a maximum content of suspended particles (40–43 cm), where they form microaggregates, sizes up to 250 µm (Fig. 5d). In the lower layers of the core, where suspended substance presented mainly clayey particles they form with them microaggregates up 50 to 200–250 µm in size (Fig. 5e, f).

These diatoms use a special strategy for communication with other particles: communication by spines and bonding allocated mucopolysaccharides. With using of both bond mechanisms diatoms became centers of microaggragation and crystallization during freeze-up (Badaut, Risach, 1983; Bowler et al., 2008; Daly, 1994; Fragoulis et al., 2004; Gärdes et al., 2011; Gorsky et al., 1999; Hamm, 2002; Lacelle et al., 2009; Neu, 2000; Shein et al., 2016; Schnell, 1975; Zimmermann–Timm, 2002). Whereby diatoms (live and dead cells) are the substrate for the generation unites of the number and size of the aggregates in aquatic systems.

Such a mass development of this species in krioperiphytone was not previously noted (Yuryev, 1988). Species *Melosira islandica* (*Aulacoseira islandica*) was registered as "an absolute dominant» which gave up to 96% of the biomass (Usolceva et al., 2006). The population of *Aulacoseira islandica* was developed in the lower layer of ice cover and on its bottom surface. Although in individual winter periods centric diatoms from genus *Stephanodiscus* and *Cyclotella* participated in the phytoplankton with up to 44% of biomass. In the ice samples after the flood of 2013 *Aulacoseira islandica* occurs sporadically (Fig. 6a, b).

Change of the leading species is one of the basic indicators of the disturbance of the structural and functional ordering of the hydrobionts. Diatoms like all hydrobionts in watercourses, are organized in such a way as to maximize the utilization of nutrients and energy in certain river areas, on the other hand, adapt to the changes in the river continuum (Bogatov, 2013; Vannote et al., 1980). Floods cause changes not only the hydrological regime of watercourses, but the physico-chemical properties of water. Influence of repeated floods for reofilic systems fairly well researched, formulated the concept of pulsating floods (Junk et al., 1989). However, the impact of catastrophic floods, such as flooding in 2013 on the Amur River, in connection with them infrequently, is unclear. So while it is difficult to call the real cause of mass development of *Stephanodiscus hantzschii* in krioperiphytone. The change in the composition of the leading species may be due to re-colonization from refugiums and with the arrival of eutrophying substances and pollutants from a variety of sources. All the environmental characteristics of *Stephanodiscus hantzschii* (galofil, alkalibiont, alfamezo-polisaprob, inhabitant of eutrophic and hyper-eutrophic waters) allow for consideration of this species as bioindikator of polluted waters.

Analysis of mineralization, content of major ions and nutrients (phosphorus, nitrogen, iron) showed that during the freeze-up period, the sink of nitrate nitrogen was the highest for the entire observation period (Shesterkina, Shesterkin, 2001; Shesterkin, 2010, 2016), the content of Cu and Zn significantly exceeded the MPC. The concentration of nitrates in the sub-ice water in December 2013 was more than 500 mkg N/L, and concentrations of Cu and Zn were extremely high for the Amur River up to 20–30 and 70–90 mkg/L respectively (Fig. 7).

According to de Jonge et al. (2010), Cu and Zn after Si and Fe (Brzezinski et al., 1997; Kröger et al., 2001; Poulsen et al., 2003; Poulsen & Kröger, 2004; Scheffel et al., 2011) are the necessary elements for the development of the diatoms. Pollution of the Amur River is primarily associated with pollutants from its main tributary – the Songhua River. Increased mineralization of the water and the higher concentration of chlorides, sulfates and compounds of nutrients (nitrogen, phosphorus, iron) and trace elements (Cu and Zn) stimulate the development of *Stephanodiscus hantzschii* and confirm his bioindication properties. The mass development of this species and other members of the genus *Stephanodiscus* revealed in other rivers (Irtysh, Ob, Volga, Danube etc.) after antropogenic pollution (Sokolsky, Evseeva, 2011). The data obtained also show high concentrations during freeze-up the bicarbonate ion HCO_3^- (up to 60–80 mg/L, November–December), that explains formation in ice cover chemical inclusions of calcite.

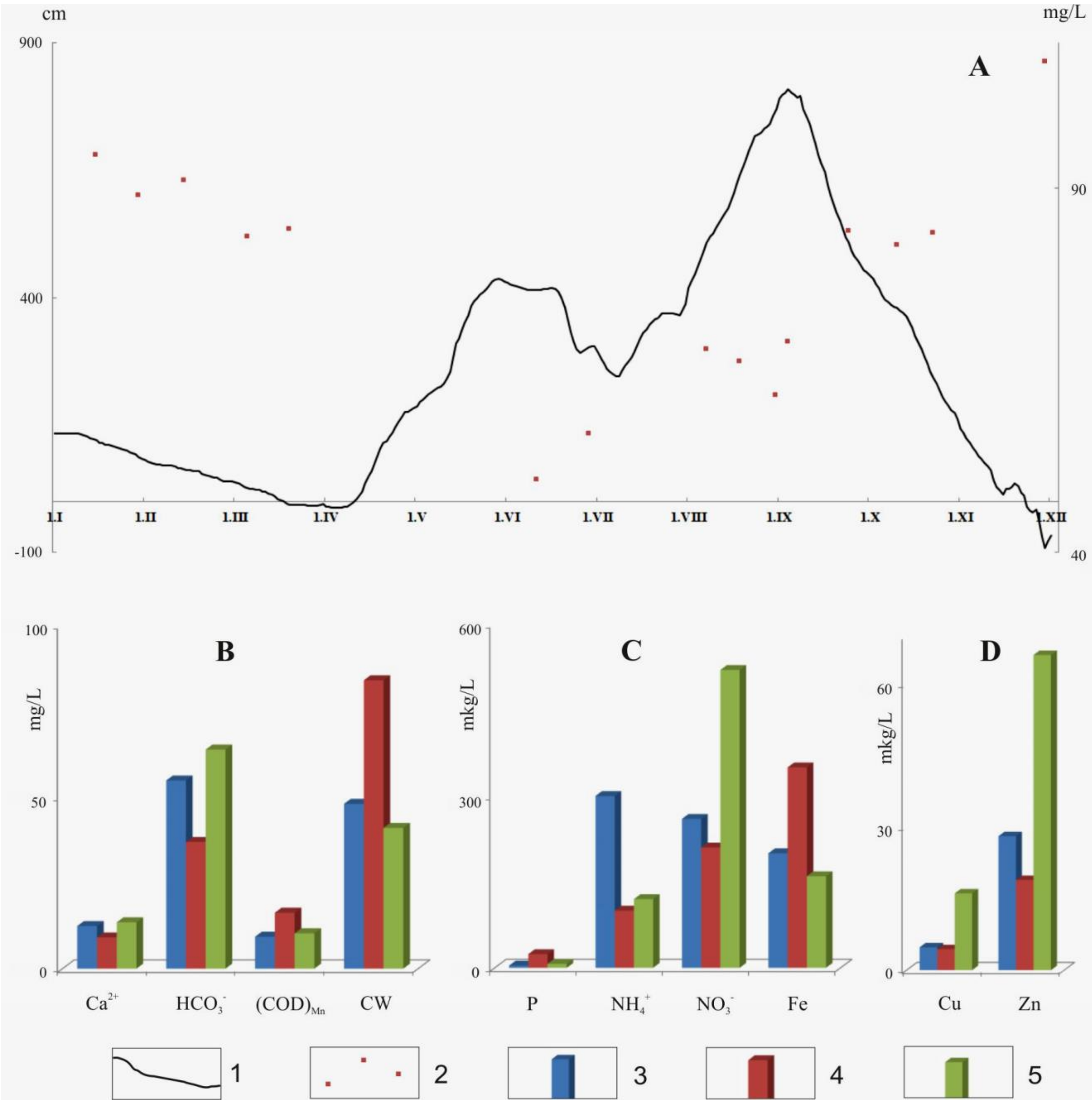


Fig. 7. Levels and average values of water mineralization Amur River (a), content of major ions, $(COD)_{Mn}$ and water colour in degrees (b), content of nutrient content (c) and the trace elements (d), Khabarovsk water node, 2013

4. Conclusion

The paper presents data on the composition of the ice in the Middle Amur (Khabarovsk water node) after the extreme flooding of 2013, its terrigenous, chemicical and biogenic components. The main sources of terrigenous material are wind shift, capture soil on the shoals during the fall ice surfacing bottom ice, avalanches block when ice erosion of clayey floodplain, rockfalls from the steep slopes on the ice surface in the mountainous part of the valley and lift of anchor ice. Chemogenic inclusions are formed due to chemical processes in the ice thickness, biogenic inclusions – due to the development of diatoms.

The analysis showed that the content of terrigenous material and its change in ice thicker does not exceed the average multi-annual values. In general, the distribution of particles in ice thicker on their volume and number (except for layers, formation of anchor ice) is close and corresponds to the composition of the warps (silt deposits on the flood plain) and river suspended matter in the studied river area. In layers, formatted by anchor ice, size of inclusions corresponds to that of the bottom sediments.

Composition of diagnosed chemogenic inclusions (neoformations of calcite $CaCO_3$ and pyrite FeS_2), their number and size depend on the chemical composition of water during the freeze-up and redox conditions in the layer. Calcite $CaCO_3$ neoformations noted at the bottom of the ice thickness, formed at the end of the freeze-up. Formation of pyrite FeS_2 is associated with freezing new layers of ice at its bottom after freeze-up in reducing conditions, mainly in the middle and late winter.

The main impact of flooding had on biogenic inclusions (diatoms), they are found throughout ice thicker. Species *Melosira islandica* (*Aulacoseira islandica*) was previously registered as "an absolute dominant» before flood of 2013, after that meets in ice samples sporadically. The change of the leading species (from single population *Aulacoseira islandica* to *Stephanodiscus hantzschii*, Coscinodiscophyceae class, *Stephanodiscaceae* family, genus *Stephanodiscus*) was fixed. By frequency of occurrence in the entire ice thickness, species *Stephanodiscus hantzschii* stands out. This is one of the main indicators of structural and functional violations orderliness of hydrobionts. The mass development of this species and other members of the genus *Stephanodiscus* were revealed in other rivers (Irtysh, Ob, Volga, Danube, etc.) after antropogenic pollution. The change in the composition of the leading species associated with the arrival of eutrophying substances and pollutants from the Sungari River (the largest tributary of the Amur River) as a result of outcome of flooding of agricultural lands and residential territories.

Литература

Баринова, Медведева, 1996 – *Баринова С.С., Медведева Л.А.* (1996). Атлас водорослей–индикаторов сапробности (российский Дальний Восток). Владивосток: Дальнаука, 364 с.

Баринова и др., 2006 – *Баринова С.С., Медведева Л.А., Анисимова О.В.* (2006). Биоразнообразие водорослей–индикаторов окружающей среды. Tel-Aviv: Pilies Studio. 498.

Богатов, 2013 – *Богатов В.В.* (2013). О закономерностях функционирования речных экосистем в свете базовых научных концепций // *Вестник СВНЦ ДВО РАН* 4: 90–99, doi: 10.7868/S0321059617040101

Бойкова, 1963 – *Бойкова К.Г.* (1963). Наводнения на реках Амурского бассейна. Хабаровск, Хабаровское книжное издательство, 192–259.

Генкал и др., 2002 – *Генкал С.И., Чекрыжева Т.А., Комулайнен С.Ф.* (2002). Диатомовые водоросли водоемов и водотоков Карелии. М.: Научный мир. 202.

Данилов-Данильян, Гельфан, 2014 – *Данилов-Данильян В.И., Гельфан А.Н.* (2014). Экстраординарное наводнение в бассейне реки Амур // *Вестн. РАН* 84(9): 817–825, doi: 10.7868/S0869587314090060

Диатомовые, 1992 – Диатомовые водоросли СССР (ископаемые и современные) / отв. ред. И.В. Макарова (1992). СПб.: Наука, Т. II, вып. 2. 125.

Дугина, 2013 – *Дугина И.О.* (2014). Выдающееся наводнение на Амуре 2013 года и его особенности. Взгляд гидролога // *Наводнение-2013,* Талакан: ОАО РусГидро, с. 41–57.

Иванов и др, 1987 – *Иванов А.В., Юрьев Д.Н., Лебедев Ю.М.* (1987). Криоперифитон в ледяном покрове р. Амур // *Материалы гляциологических исследований* 60: 184–188.

Лебедев и др., 1981 – *Лебедев Ю.М., Юрьев Д.Н., Сиротский С.Е.* (1981). Зимний фотосинтез в р. Амур и развитие водорослей в связи с подледными световыми условиями // *Круговорот вещества и энергии в водоемах*. Вып. 1. Элементы биотического круговорота. Иркутск: СО АН СССР, с. 88–89.

Махинов, Ким, 2013 – *Махинов А.Н., Ким В.И.* (2013). Ледяной покров реки Амур и его влияние на русловые процессы // *Водные ресурсы,* 40(4):356–366, doi: 10.7868/S0321059613040081

Махинов и др., 2017 – *Махинов А.Н., Ким В.И., Шмигирилов С.А.* (2017). Строение льда и ледового покрова реки Амур в нижнем течении на участках разветвленного русла // *Водные Ресурсы* 44(4): 432–441, doi: 10.7868/S0321059617040101

Медведева и др., 2001 – *Медведева Л.А., Сиротский С.Е., Оглы З.П.* (2001). Водоросли бассейна реки Амур (Россия): Литературный обзор // *Биогеохимические и гидроэкологические особенности экосистем бассейна реки Амур,* вып. 11, Владивосток: Дальнаука, с. 151–174.

Медведева, Сиротский, 2002 – *Медведева Л.А., Сиротский С.Е.* (2002). Аннотированный список водорослей реки Амур и водоемов его придаточной системы // *Биогеохимические и геоэкологические исследования наземных и пресноводных экосистем,* вып. 12, Владивосток: Дальнаука, с. 130–218.

Медведева, Никулина, 2014 – *Медведева Л.А., Никулина Т.В.* (2014). Каталог пресноводных водорослей юга Дальнего Востока России. Владивосток: Дальнаука, 271 с.

Немировская и др., 2015 – *Немировская И.А., Кравчишина М.Д., Реджепова З.Ю.* (2015). Органические соединения и взвесь в снежно-ледяном покрове и почвах в районах антарктических станций России, *Лёд и Снег.* 55(4): 114–126, doi: 10.15356/2076-6734-2015-4-114-126

Никулина, 2014 – *Никулина Т.В.* (2014). Видовой состав альгофлоры Нижнего Амура в 2005–2014 гг. и оценка качества воды по данным биологического анализа // *Чтения памяти Владимира Яковлевича Леванидова,* вып. 6, Владивосток: Дальнаука, с. 483–500.

Ресурсы, 1966 – *Ресурсы поверхностных вод СССР.* Т. 18, Дальний Восток, вып.1, Верхний и Средний Амур (1966). Л.: Гидрометеоиздат, 780 с.

Руководство, 1977 – *Руководство по химическому анализу поверхностных вод суши* (1977). Л.: Гидрометеоиздат, 550 с.

Сокольский, Евсеева 2011 – *Сокольский И.А., А.Ф., Евсеева С.С.* (2011). Фитопланктон Нижней Волги и других рек Европы при антропогенном воздействии. Водные биоресурсы и их рациональное использование // *Вестник Астраханского государственного техн. ун-та* 2: 49–52.

Страхов и др., 1954 – *Страхов Н.М., Бродская Н.Г., Князева Л.М., Разжигина А.Н., Ратеев М.А., Сапожников Д.Г., Шишова Е.Е.* (1954). Образование осадков в современных водоемах, Москва: АН СССР, 791с.

Усольцева и др., 2006 – *Усольцева М.В., Никулина Т.В., Юрьев Д.Н., Лихошвай Е.В.* (2006). К изучению развития и морфологических особенностей *Aulacoseira islandica* (O. Müller) Simonsen (Bacillariophyta) // *Альгология* 16(2):145–155.

Шалдыбин и др., 2016 – *Шалдыбин М.В., Харитонова Г.В., Ким В.И., Лопушняк Ю.М., Уткина Е.В., Дембовецкий А.В., Коновалова Н.С., Юдина А.В., Шмигирилов С.А.* (2016). Минералогия и состав отложений реки Амур в зоне влияния реки Сунгари // *Тихоокеанская геология* 35(1):92–108.

Шестеркин, 1990 – *Шестеркин В.П.* (1990). Особенности химического состава льда р. Амур // *Гидрохимические материалы* 108:3–112.

Шестеркина, Шестеркин, 2001 – *Шестеркина Н.М., Шестеркин В.П.* (2001). Зимний сток растворенных веществ Среднего Амура // *География и природные ресурсы* 4: 144–147.

Шестеркин, 2010 – *Шестеркин В.П.* (2010). Изменение химического состава речных вод в Хабаровском водном узле за столетие // *Тихоокеанская геология* 29(2): 112–118.

Шестеркин, 2016 – *Шестеркин В.П.* (2016). Изменение химического состава вод Амура в период исторического наводнения в 2013 году // *Водные ресурсы* 43(3): 287–296, doi: 10.7868/S0321059616030159

Юрьев, Лебедев, 1988 – *Юрьев Д.Н., Лебедев Ю.М.* (1988). Развитие ледового перифитона р. Амур в связи со световым фактором // *Ботан. журн.* 73(11):1546–1551.

Badaut & Risach, 1983 – *Badaut D., Risach F.*(1983). Authigenie smectite on diatom frustules in Bolivian saline lakes // *Geochimica et Cosmochimica Acta* 47:363-375, doi: 10.1016/0016-7037(83)90259-4

Barton & Hamilton, 2009 – *Barton L., Hamilton A.* (2009). Sulphate-reducing bacteria: environmental and engineering systems. Cambridge University Press: New York, 533 p.

Berger et al., 1996 – *Berger B., Hoch B., Kavka G., Herndl G.J.* (1996). Bacterial colonization of suspended solids in the River Danube // *Quatic Microbial Ecology* 10:37–44.

Bowler et al., 2008 – *Bowler C., Allen A.E., Badger J.H., Grimwood J., Jabbari K., Kuo A., Maheswari U., Martens C., Maumus F., Otillar R.P., Rayko E., Salamov A., Vandepoele K., Beszteri B., Gruber A., Heijde M., Katinka M., Mock T., Valentin K., Verret F., Berges J.A., Brownlee C., Cadoret J.-P., Chiovitti A., Choi C.J., Coese S., De Martino A., Detter J.C., Durkin C., Falciatore A., Fournet J., Haruta M., Huysman M.J.J., Jenkins B.D., Jiroutova K., Jorgensen R.E., Joubert Y., Kaplan A., Kröger N., Kroth P.G., La Roche J., Lindquist E., Lommer M., Martin–Jézéquel V., Lopez P.J., Lucas S., Mangogna M., McGinnis K., Medlin L.K., Montsant A., *Oudot–Le Secq M.-P., Napoli C., Obornik M., Parker M.S., Petit J.-L., Porce B.M., Poulsen N., Robison M., Rychlewski L., Rynearson T.A., Schmutz J., Shapiro H., Siaut M., Stanley M., Sussman M.R., Taylor A.R., Vardi A., von Dassow P., Vyverman W., Willis A., Wyrwicz L.S., Rokhsar D.S., Weissenbach J., Armbrust E.V., Green B.R., Van de Peer Y., Grigoriev I.V.* (2008) The Phaeodactylum genome reveals the evolutionary history of diatom genomes // *Nature* 456:239–244, doi:10.1038/nature07410

Brzezinski et al., 1997 – *Brzezinski M.A., Alldredge A.L., O'Bryan L.M.* (1997). Silica cycling within marine snow // *Limnology and Oceanography* 42(8):1706–1713, doi: 10.4319/lo.1997.42.8.1706

Buurman et al., 2001 – *Buurman P., Pape T., Reijneveld J.A., de Jong F. and van Gelder E.* (2001). Laser-diffraction and pipette method grain sizing of Dutch sediments: correlations for fine fractions of marine, fluvial and loess samples // *Netherlands Journal of Geosciences* 80(2): 49–57.

Daly, 1994 – *Daly S.F.* (1994). Report on frazil ice. Engineering Research & Development Center, Cold Regions Research and Engineering Laboratory, CRREL Special Report 94-23. Hanover, NH. 43 p.

Dam van et al., 1994 –*Dam H. van, Mertens A., Sinkeldam J.* (1994). A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands // *Neth. J. Aquat. Ecol.* 1(28):117–133.

Eshel et al., 2004 – *Eshel G., Levy G.J., Migelgrin U. and Singer M.J.* (2004). Critical evaluation of the use of laser diffraction for particle-size distribution analysis // *Soil Science Society of America Journal* 68:736–743.

Fragoulis et al., 2004 – *Fragoulis D., Stamatakis M.G., Chaniotakis E., Columbus G.* (2004). Characterization of lightweight aggregates produced with clayey diatomite rocks originating from Greece // *Materials Characterization* 53:307–316, doi:10.1016/j.matchar.2004.05.004

Gärdes et al., 2011 – *Gärdes A., Iversen M.H., Grossart H.-P., Passow U., Ullrich M. S.* (2011). Diatom-associated bacteria are required for aggregation of *Thalassiosira weissflogii* // *ISME Journal* 5(3): 436–445, doi: 10.1038/ismej.2010.145

Genuchten van et al., 1999 – *Genuchten M.T. van, Leij F.J. and Wu L.* (1999). Characterization and measurement of the hydraulic properties of unsaturated porous media. In van Genuchten, M.T. et al. (eds.) Proceedings of the International Workshop on Characterization and Measurement of the Hydraulic Properties of Unsaturated Porous Media: University of California, California, pp. 1–12.

Gorsky et al., 1999 – *Gorsky G., Chrétiennot-Dinet M.J., Blanchot J., Palazzoli I.* (1999). Picoplankton and nanoplankton aggregation by appendicularians: fecal pellet contents of *Megalocercus huxleyi* in the equatorial Pacific // *Journal of Geophysical Research* 104 (C2): 3381–3390, doi:10.1029/98JC01850

Guiry & Guiry, 2017 – *Guiry M.D., Guiry G.M.* (2017). AlgaeBase. World-wide electronic publication, National University of Ireland. Galway. 2017. http://www.algaebase.org; searched on 15 May 2017.

Hamm, 2002 – *Hamm C.* (2002). Interactive aggregation and sedimentation of diatoms and clay-sized lithogenic material // *Limnology and Oceanography* 47(6): 1790–1795, hdl:10013/epic.15046.d001

Jonge de et al., 2010 – *Jonge M.D. de, Holzner C., Baines S.B., Twining B.S., Ignatyev K., Diaz J., Howard D.L., Legnini D., Miceli A., McNulty I., Jacobsen C.J., Vogt S.* (2010). Quantitative 3D elemental microtomography of *Cyclotella meneghiniana* at 400-nm resolution // *Proc Natl Acad Sci USA* 107(36):15676–80, doi: 10.1073/pnas.1001469107

Junk et al., 1989 – *Junk W.J., Bayley P.B., Sparks R.E.* (1989). The flood-pulse concept in river-floodplain systems: Proceedings of the International Large River Symposium (ed. Dodge D.P.) // *Can. J. of Fish. Aquat. Sci. Spec. Publ.* 106:110-127

Krammer & Lange–Bertalot, 1991 – *Krammer K., Lange–Bertalot H.* (1991). Bacillariophyceae. Teil 3. Centrales, Fragilariaceae, Eunotiaceae. In: Süsswasserflora von Mitteleuropa Stuttgart & Jena: Gustav Fischer Verlag. Bd. 2/3. 576 s.

Kröger et al., 2001 – *Kröger N., Deutzmann R., Sumper M.* (2001). Silica-precipitating Peptides from Diatoms (The chemical structure of silaffin-1a from *Cylindrotheca fusiformis*) // *The Journal of Biological Chemistry* 276(28):26066–26070, doi: 10.1074/jbc.M102093200

Lacelle et al., 2009 – *Lacelle D., Lauriol B., Clark I.D.* (2009). Formation of seasonal ice bodies and associated cryogenic carbonates in Caverne de l'Ours, Quebec, Canada: kinetic isotope effects and pseudo-biogenic crystal structures // *Journal of Cave and Karst Studies* 71(1):48–62.

Neu, 2000 – *Neu T.R.* (2000). In situ cell and glycoconjugate distribution in river snow studied by confocal laser scanning microscopy // *Aquatic Microbial Ecology* 21:85–95.

Pachepsky & Rawls, 2004 – *Pachepsky Ya., Rawls W.Y.* (2004). Development of Pedotransfer Functions in Soil Hydrology. Elsevier: Amsterdam, 542 p.

Poulsen et al., 2003 – *Poulsen N., Sumper M., Kröger N.* (2003). Biosilica formation in diatoms: characterization of native silaffin-2 and its role in silica morphogenesis // *Proc Natl Acad Sci USA* 100(21):12075–12080, doi: 10.1073/pnas.2035131100

Poulsen & Kröger, 2004 – *Poulsen N., Kröger N.* (2004). Silica morphogentsis by alternative processing of silaffins in the diatom *Thalassiosira pseudonana // The Journal of Biological Chemistry* 279:42993–42999, doi:10.1074/jbc.M4077344200

Rawle, 2017 – *Rawle A.* Basic principles of particle size analysis. Malvern Instruments Technical Paper MRK034. www.malvern.co.uk

Scheffel et al., 2011 – *Scheffel A., Poulsen N., Shian S., Kröger N.* (2011). Nanopatterned protein microrings from a diatom that direct silica morphogenesis // *Proc Natl Acad Sci USA* 108(8):3175–3180, doi: 10.1073/pnas.1012842108

Schnell, 1975 – *Schnell R.C.* (1975). Ice nuclei produced by laboratory cultured marine phytoplankton // *Geophysical Research Letter* 2(11): 500–502, doi: 10.1029/GL002i011p00500

Segal et al., 2009 – *Segal E., Shouse P.J., Bradford S.A., Skagss T.Y. and Corwin D.L.* (2009). Measuring particle size distribution using laser diffraction: Implications for predicting soil hydraulic properties // *Soil Science* 174(12):639–645.

Shein et al., 2016 – *Shein E.V., Kharitonova G.V., Milanovsky E.Yu.* (2016). Aggregation of natural disperse formations: value of organic matter, soluble salts and diatoms, *Biogeosystem Technique* 7(1):77–86, doi: 10.13187/bgt.2016.7.77

Vannote et al., 1980 – *Vannote R.L., Minshall G.W., Cummins K.W., Sedell J.R., Gushing C.E.* (1980). The river continuum concept // *Can. J. Fish. Aquat. Sci.* 37: 130–137.

Wolform, 2011 – *Wolform R.L.* (2011). The language of particle size // *J. GXP Compliance* 15(2): 10–20.

Zimmermann–Timm, 2002 – *Zimmermann–Timm H.* (2002). Characteristics, dynamics and importance of aggregates in rivers (An Invited Review) // *Internat. Rev. Hydrobiol.* 87(2–3):197–240.

References

Barinova, Medvedeva, 1996 – *Barinova S.S., Medvedeva L.A.* (1996). Atlas of the algal indicators of saprobity (Russian Far East). Vladivostok: Dal'nauka, 364 p.

Barinova et al., 2006 – *Barinova S.S., Medvedev L.A., Anisimova O.V.* (2006). Biodiversity of algae-environmental indicators. Tel-Aviv: Pilies Studio. 498 p.

Bogatov, 2013 – *Bogatov V.V.* (2013). About the patterns of functioning of river ecosystems in light of basic scientific concepts, *Bulletin of the SVNC FEB RAS* 4: 90–99, doi: 10.7868/S0321059617040101

Boikova, 1963 – *BoIkova K.G.* (1963). Floods on the rivers of Amur basin, *Issues of the geography of the far East* 5: 192–259, Khabarovsk, Khabarovsk Book Publishing.

Genkal et al., 2002 – *Genkal S.I., Chekruzheva T.A., Komulainen S.F.* (2002). Diatom ponds and watercourses of Karelia. Moscow: The scientific world. 202 p.

Danilov-Danilyan, Gelfand, 2014 – *Danilov-Danilyan V.I., Gelfand A.N.* (2014). Extraordinary flooding in the basin of the Amur River, *Bulletin of the RAS* 84(9): 817–825, doi: 10.7868/S0869587314090060

Diatoms, 1992 – Diatoms of the USSR (fossil and modern), ed. I.V. Makarov (1992). St. Petersburg: Nauka, 2(2), 125 p.

Dugina, 2013 – *Dugina I.O.* (2014). Outstanding on the Amur floods of the year 2013 and its features. View a hydrology expert, *Flood -2013,* Talakan: OAO Rushydro, 41–57.

Ivanov et al., 1987 – *Ivanov A.V., Yuryev D.N., Lebedev Yu.M.* (1987). Ice periphyton in the Amur River ice cover, *Glaciological studies* 60:184–188.

Lebedev et al., 1981 – *Lebedev Yu.M., Yuryev D.N., Sirotsky S.E.* (1981). Winter photosynthesis in the Amur River and the development of algae in connection with podlednymi light conditions, *Cycles of matter and energy in reservoirs: Biotic elements cycle* 1. Irkutsk: Academy of Sciences USSR, pp. 88–89.

Makhinov, Kim, 2013 – *Makhinov A.N., Kim V.I.* (2013). Ice Cover of the Amur River and Its Impact on Channel Processes процессы, *Water Resources* 40(4):391–398, doi: 10.1134/S0097807813040088

Makhinov et al., 2017 – *Makhinov A.N., Kim V.I., Shmigirilov S.A.* (2017). The Structure of Ice and Ice Cover in Lower Amur Reaches with Branched Channel, *Water Resources* 44(4):559–578, doi: 10.1134/S0097807817040108

Medvedeva et al., 2001 – *Medvedeva L.A., Sirotsky S.E., Oglu Z.P.* (2001). Algae Amur River basin (Russia): Review, *Biogeochemical and hydrological features of ecosystems of the basin of the Amur River* 11:151–174.

Medvedeva, Sirotsky, 2002 – *Medvedeva L.A., Sirotsky S.E.* (2002). An annotated list of algae of the Amur River and reservoirs it system, *Biogeochemical and geoecological studies of terrestrial and freshwater ecosystems* 12:130–218.

Medvedeva, Nikulina, 2014 – *Medvedeva L.A., Nikulina T.V.* (2014). Catalogue of freshwater algae in the South of the Russian Far East. Vladivostok: Dal'nauka, 271 p.

Nemirovskaya et al., 2015 – *Nemirovskaya I.A., Kravchishina M.D., Rejepov Z. Yu.* (2015). Organic compounds and suspended in the snow-ice cover and soils in the vicinities of the Russian Antarctic stations, *Ice and Snow* 55(4):114–126, doi: 10.15356/2076-6734-2015-4-114-126

Nikulina, 2014 – *Nikulina T.V.* (2014). The species composition of the algae flora of Lower Amur in 2005-2014 years and assessment of water quality according to the biological analysis, *Readings in memory of Vladimir Yakovlevich Levanidova* 6, Vladivostok: Dal'nauka, pp. 483–500.

Resources, 1966 – Surface water resources of the USSR. V. 18. Far East. Вып.1. Upper and Middle Amur (1966). Leningrad: Hydrometeoizdat, 780 p.

Guide, 1977 – Guide to chemical analysis of the surface land waters (1977). Leningrad: Hydrometeoizdat, 550 p.

Sokolsky, Evseeva, 2011 – *Sokolsky A.F., Evseeva S.S.* (2011). Phytoplankton of the lower Volga and other rivers of Europe when anthropogenic impact. Water bio-resources and their rational use, *Bulletin of Astrakhan State technical University* 2:49–52

Strakhov et al., 1954 – *Strakhov N.M., Brodskaya N.G., Knyazev L.M., Razzhigina A.N., Rateev M.A., Shoemakers D.G., Shishov E.E.* (1954). The formation of sediments in modern reservoirs, Moscow: AN USSR, 791 p.

Usolceva et al., 2006 – *Usolceva M.V., Nikulin T.V., Yuryev D.N., Lihoshvaj E.V.* (2006). To study the development and morphological characteristics of *Aulacoseira islandica* (o. Müller) At (Bacillariophyta), *Phycology* 16(2):145–155.

Shaldybin et al., 2016 – *Shaldybin M.V., Kharitonova G.V., Kim V.I., Lopushnyak Yu.M., Utkina E.V., Dembovetsky A.V., Konovalova N.S., Yudina A.V., Shmigirilov S.A.* (1990). Mineralogy and composition of the Amur River bottom sediments in the Sungari River zone of influence, *Pacific geology* 35(1):92–108.

Shesterkin, 1990 – *Shesterkin V.P.* (1990). Features of chemical composition of ice Amur River, *Hydrochemical materials* 108:3–12.

Shesterkina, Shesterkin, 2001 – *Shesterkina N.M., Shesterkin V.P.* (2001). Winter flow of dissolved substances on the Middle Amur, *Geography and natural resources* 4:144–147.

Shesterkin, 2010 – *Shesterkin V.P.* (2001). Centennial variation in the chemical composition of the river water in the Khabarovsk water node, *Russian Journal of Pacific Geology* 4(2):187–199.

Shesterkin, 2016 – *Shesterkin V.P.* (2016). Variations of Amur Water Chemistry during the Historical 2013 Flood, *Water Resources* 43(3):495–503, doi: 10.1134/S0097807816030155

Yuryev & Lebedev, 1988 – *Yuryev D.N., Y. Lebedev Yu.M.* (1988). Development of ice periphyton Amur River in connection with the light factor, *Botanical journal* 73(11):1546–1551.

Badaut & Risach, 1983 – *Badaut D., Risach F.*(1983). Authigenie smectite on diatom frustules in Bolivian saline lakes, *Geochimica et Cosmochimica Acta* 47:363-375, doi: 10.1016/0016-7037(83)90259-4

Barton & Hamilton, 2009 – *Barton L., Hamilton A.* (2009). Sulphate-reducing bacteria: environmental and engineering systems. Cambridge University Press: New York, 533 p.

Berger et al., 1996 – *Berger B., Hoch B., Kavka G., Herndl G.J.* (1996). Bacterial colonization of suspended solids in the River Danube, *Quatic Microbial Ecology* 10:37–44.

Bowler et al., 2008 – *Bowler C., Allen A.E., Badger J.H., Grimwood J., Jabbari K., Kuo A., Maheswari U., Martens C., Maumus F., Otillar R.P., Rayko E., Salamov A., Vandepoele K., Beszteri B., Gruber A., Heijde M., Katinka M., Mock T., Valentin K., Verret F., Berges J.A., Brownlee C., Cadoret J.-P., Chiovitti A., Choi C.J., Coese S., De Martino A., Detter J.C., Durkin C., Falciatore A., Fournet J., Haruta M., Huysman M.J.J., Jenkins B.D., Jiroutova K., Jorgensen R.E., Joubert Y., Kaplan A., Kröger N., Kroth P.G., La Roche J., Lindquist E., Lommer M., Martin–Jézéquel V., Lopez P.J., Lucas S., Mangogna M., McGinnis K., Medlin L.K., Montsant A., Oudot–Le Secq M.-P., Napoli C., Obornik M., Parker M.S., Petit J.-L., Porce B.M., Poulsen N., Robison M., Rychlewski L., Rynearson T.A., Schmutz J., Shapiro H., Siaut M., Stanley M., Sussman M.R., Taylor A.R., Vardi A., von Dassow P., Vyverman W., Willis A., Wyrwicz L.S., Rokhsar D.S., Weissenbach J., Armbrust E.V., Green B.R., Van de Peer Y., Grigoriev I.V.* (2008) The Phaeodactylum genome reveals the evolutionary history of diatom genomes, *Nature* 456:239–244, doi:10.1038/nature07410

Brzezinski et al., 1997 – *Brzezinski M.A., Alldredge A.L., O'Bryan L.M.* (1997). Silica cycling within marine snow, *Limnology and Oceanography* 42(8):1706–1713, doi: 10.4319/lo.1997.42.8.1706

Buurman et al., 2001 – *Buurman P., Pape T., Reijneveld J.A., de Jong F. and van Gelder E.* (2001). Laser-diffraction and pipette method grain sizing of Dutch sediments: correlations for fine fractions of marine, fluvial and loess samples, *Netherlands Journal of Geosciences* 80(2):49–57.

Daly, 1994 – *Daly S.F.* (1994). Report on frazil ice. Engineering Research & Development Center, Cold Regions Research and Engineering Laboratory, CRREL Special Report 94-23. Hanover, NH. 43 p.

Dam van et al., 1994 –*Dam H. van, Mertens A., Sinkeldam J.* (1994). A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands, *Neth. J. Aquat. Ecol.* 1(28):117–133.

Eshel et al., 2004 – *Eshel G., Levy G.J., Migelgrin U. and Singer M.J.* (2004). Critical evaluation of the use of laser diffraction for particle-size distribution analysis, *Soil Science Society of America Journal* 68:736–743.

Fragoulis et al., 2004 – *Fragoulis D., Stamatakis M.G., Chaniotakis E., Columbus G.* (2004). Characterization of lightweight aggregates produced with clayey diatomite rocks originating from Greece, *Materials Characterization* 53:307–316, doi:10.1016/j.matchar.2004.05.004

Gärdes et al., 2011 – *Gärdes A., Iversen M.H., Grossart H.-P., Passow U., Ullrich M. S.* (2011). Diatom-associated bacteria are required for aggregation of *Thalassiosira weissflogii*, *ISME Journal* 5(3):436–445, doi: 10.1038/ismej.2010.145

Genuchten van et al., 1999 – *Genuchten M.T. van, Leij F.J. and Wu L.* (1999). Characterization and measurement of the hydraulic properties of unsaturated porous media. In van Genuchten, M.T. et al. (eds.) Proceedings of the International Workshop on Characterization and Measurement of the Hydraulic Properties of Unsaturated Porous Media: University of California, California, pp. 1–12.

Gorsky et al., 1999 – *Gorsky G., Chrétiennot-Dinet M.J., Blanchot J., Palazzoli I.* (1999). Picoplankton and nanoplankton aggregation by appendicularians: fecal pellet contents of *Megalocercus huxleyi* in the equatorial Pacific, *Journal of Geophysical Research* 104 (C2):3381–3390, doi:10.1029/98JC01850

Guiry & Guiry, 2017 – *Guiry M.D., Guiry G.M.* (2017). AlgaeBase. World-wide electronic publication, National University of Ireland. Galway. 2017. http://www.algaebase.org; searched on 15 May 2017.

Hamm, 2002 – *Hamm C.* (2002). Interactive aggregation and sedimentation of diatoms and clay-sized lithogenic material, *Limnology and Oceanography* 47(6):1790–1795, hdl:10013/epic.15046.d001

Jonge de et al., 2010 –*Jonge M.D. de, Holzner C., Baines S.B., Twining B.S., Ignatyev K., Diaz J., Howard D.L., Legnini D., Miceli A., McNulty I., Jacobsen C.J., Vogt S.* (2010).

Quantitative 3D elemental microtomography of *Cyclotella meneghiniana* at 400-nm resolution, *Proc Natl Acad Sci USA* 107(36):15676–80, doi: 10.1073/pnas.1001469107

Junk et al., 1989 – *Junk W.J., Bayley P.B., Sparks R.E.* (1989). The flood-pulse concept in river-floodplain systems: Proceedings of the International Large River Symposium (ed. Dodge D.P.), *Can. J. of Fish. Aquat. Sci. Spec. Publ.* 106:110-127

Krammer, Lange–Bertalot, 1991 – *Krammer K., Lange–Bertalot H.* (1991). Bacillariophyceae. Teil 3. Centrales, Fragilariaceae, Eunotiaceae. In: Süsswasserflora von Mitteleuropa Stuttgart & Jena: Gustav Fischer Verlag. Bd. 2/3. 576 s.

Kröger et al., 2001 – *Kröger N., Deutzmann R., Sumper M.* (2001). Silica-precipitating Peptides from Diatoms (The chemical structure of silaffin-1a from *Cylindrotheca fusiformis*), *The Journal of Biological Chemistry* 276(28):26066–26070, doi: 10.1074/jbc.M102093200

Lacelle et al., 2009 – *Lacelle D., Lauriol B., Clark I.D.* (2009). Formation of seasonal ice bodies and associated cryogenic carbonates in Caverne de l'Ours, Quèbec, Canada: kinetic isotope effects and pseudo-biogenic crystal structures, *Journal of Cave and Karst Studies* 71(1):48–62.

Neu, 2000 – *Neu T.R.* (2000). In situ cell and glycoconjugate distribution in river snow studied by confocal laser scanning microscopy, *Aquatic Microbial Ecology* 21:85–95.

Pachepsky, Rawls, 2004 – *Pachepsky Ya., Rawls W.Y.* (2004). Development of Pedotransfer Functions in Soil Hydrology. Elsevier: Amsterdam, 542 p.

Poulsen et al., 2003 – *Poulsen N., Sumper M., Kröger N.* (2003). Biosilica formation in diatoms: characterization of native silaffin-2 and its role in silica morphogenesis, *Proc Natl Acad Sci USA* 100(21):12075–12080, doi: 10.1073/pnas.2035131100

Poulsen & Kröger, 2004 – *Poulsen N., Kröger N.* (2004). Silica morphogentsis by alternative processing of silaffins in the diatom *Thalassiosira pseudonana*, *The Journal of Biological Chemistry* 279:42993–42999, doi:10.1074/jbc.M4077344200

Rawle, 2017 – *Rawle A.* Basic principles of particle size analysis. Malvern Instruments Technical Paper MRK034. www.malvern.co.uk

Scheffel et al., 2011 – *Scheffel A., Poulsen N., Shian S., Kröger N.* (2011). Nanopatterned protein microrings from a diatom that direct silica morphogenesis, *Proc Natl Acad Sci USA* 108(8):3175–3180, doi: 10.1073/pnas.1012842108

Schnell, 1975 – *Schnell R.C.* (1975). Ice nuclei produced by laboratory cultured marine phytoplankton, *Geophysical Research Letter* 2(11):500–502, doi: 10.1029/GL002i011p00500

Segal et al., 2009 – *Segal E., Shouse P.J., Bradford S.A., Skagss T.Y. and Corwin D.L.* (2009). Measuring particle size distribution using laser diffraction: Implications for predicting soil hydraulic properties, *Soil Science* 174(12):639–645.

Shein et al., 2016 – *Shein E.V., Kharitonova G.V., Milanovsky E.Yu.* (2016). Aggregation of natural disperse formations: value of organic matter, soluble salts and diatoms, *Biogeosystem Technique* 7(1):77–86, doi: 10.13187/bgt.2016.7.77

Vannote et al., 1980 – *Vannote R.L., Minshall G.W., Cummins K.W., Sedell J.R., Gushing C.E.* (1980). The river continuum concept, *Can. J. Fish. Aquat. Sci.* 37: 130–137.

Wolform, 2011 – *Wolform R.L.* (2011). The language of particle size, *J. GXP Compliance* 15(2): 10–20.

Zimmermann–Timm, 2002 – *Zimmermann–Timm H.* (2002). Characteristics, dynamics and importance of aggregates in rivers (An Invited Review), *Internat. Rev. Hydrobiol.* 87(2–3):197–240.

Состав кернов льда Среднего Амура после катастрофического наводнения 2013 года

Галина Владимировна Харитонова [a,*] , Владимир Ильич Ким [a],
Ангелина Степановна Стенина [b], Владимир Павлович Шестеркин [a],
Наталья Сергеевна Коновалова [c]

[a] Институт Водных и Экологических Проблем, Дальневосточное отделение РАН, Хабаровск, Российская Федерация
[b] Институт биологии, Коми Научный Центр Уральского отделения РАН, Сыктывкар, Российская Федерация
[c] Институт Тектоники и Геофизики им. Ю.А. Косыгина, Дальневосточное отделение РАН, Хабаровск, Российская Федерация

Аннотация. Содержание и состав ледовых включений – важная характеристика перераспределения вещества в речных экосистемах, которая позволяет учитывать транспорт взвешенного материала во время весеннего ледохода. В работе представлены данные по составу льда Среднего Амура (Хабаровский водный узел) после экстремального наводнения 2013 г., его терригенных, хемогенных (образуемых за счет химических процессов) и биогенных (диатомовые водоросли) составляющих. Важность работы заключается в том, что влияние на речные экосистемы катастрофических наводнений, таких как паводок 2013 г. на р. Амур, в связи с их уникальностью изучено крайне недостаточно. Анализ показал, что содержание терригенного материала и его варьирование в ледовой толще не превышает среднемноголетних значений. Характер распределения частиц в ледовой толще по их объему и числу соответствует таковому для речных взвесей, наилков и донных отложений рассматриваемого участка реки. Состав диагностированных хемогенных включений (новообразования кальцита $CaCO_3$ и пирита FeS_2) и их проявление в том или ином слое зависит от химического состава воды в период ледостава и от окислительно-восстановительных условий в слое. Наибольшее влияние паводок оказал на биогенные включения (диатомовые водоросли). Была зафиксирована смена ведущих видов – один из основных показателей нарушения структурно-функциональной упорядоченности гидробионтов. Изменение состава ведущих видов (одновидовой популяции *Aulacoseira islandica* на *Stephanodiscus hantzschii*, класс Coscinodiscophyceae, семейство *Stephanodiscaceae*, род *Stephanodiscus*) связано с поступлением эвтрофирующих веществ и поллютантов из самого крупного притока Амура р. Сунгари в результате затопления сельскохозяйственных земель и селитебных территорий.

Ключевые слова: лед, ледовые включения терригенные, хемогенные и биогенные, река Амур, катастрофические паводки, Россия.

* Корреспондирующий автор
Адреса электронной почты: gkharitonova@mail.ru (Г.В. Харитонова)