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The impact of drainage reclamation on the components of agricultural landscapes of small rivers

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Abstract. The traditional use of agricultural landscapes of small rivers is agricultural arable land, which requires a number of reclamations and agricultural work. Land drainage has a significant impact on the environment, but these activities were carried out almost without taking into account the requirements of environmental protection. Heavy metals have one of the most significant negative effects on the components of floodplain-channel complexes (floodplain soil, surface water, bottom sediments, macrophytes, hydrobionts). Studies have shown that drainage reclamation leads to a decrease in the content of humus in floodplain soil, collector-drainage runoff, changing the chemical composition of natural water, affects the processes of transit-accumulation of heavy metals from sediments to water. The integrated chemical and ecological assessment of the influence of drainage reclamation on the state of the floodplain soil - water-bottom sediments system showed a critical situation of pollution of agricultural landscapes of water basins with heavy metals. Drainage melioration also negatively affects the state of hydrobionts-aquatic vegetation and fish, heavy metals accumulate in their organisms, which leads to disruption of aquatic flora and fauna life processes.

Key word: agrolandscape of small river, drainage reclamation, collector-drainage water, heavy metals, floodplain soil, surface water, bottom sediments, macrophytes, hydrobionts.

INTRODUCTION

The state of floodplain-channel complexes - agrolandscapes of small rivers located in the Amur river basin in the Far East of Russia is determined by a number of natural factors associated with the instability of the water regime in the monsoon climate, the weak ability of aquatic ecosystems to self-repair, the specific features of the formation of the chemical composition of water within different landscapes, which are influenced by various types of anthropogenesis (Voronov & Makhinov, 2009). The traditional use of agricultural landscapes of small rivers is agricultural arable land, which requires a number of reclamations and agricultural work. Their proper organization is impossible without preliminary research. Land drainage at the initial stage of reclamation construction had a very noticeable impact on the environment, since it was carried out almost without taking into account the requirements of nature conservation. One of the most significant negative effects on the components of the agrolandscapes of small rivers (floodplain soil, surface water, bottom sediments, macrophytes, hydrobionts) is exerted by heavy metals (HM). According to many authors, the group of the most common HM includes iron (Fe), manganese (Mn), copper (Cu), nickel (Ni), zinc (Zn), lead (Pb) and their salts (Nazarov, 2014; Kasiuliene et al., 2016; Dyatel, 2017; Tolkachev et al., 2017; Yashin, 2017; Imeri et al., 2019; Murtic et al., 2019), characterized by long-term storage in water, accumulation in bottom sediments and the aquatic ecosystem as a whole (Israel, 1984; Moore & Ramamurti, 1987; Pais & Jones, 1997; Perevoznikov & Bogdanova, 1999; Kabata-Pendias & Pendias, 2001; Khristoforova, 2007; Tack, 2010; Morais et al., 2012; Chibuike & Obiora, 2014; Lukowski & Wiater, 2016). The danger of HM in the aquatic ecosystem is compounded by the fact that, unlike organic substances, they are not susceptible to decomposition, but are capable of complexation, hydrolysis, and oxidation-reduction processes; they can migrate and accumulate in various components of river ecosystems. Therefore, for an ecological assessment of the agrolandscapes of small rivers under conditions of constant technogenic pressure, along with monitoring the content of HM in ecosystem components, it is necessary to study the features of their accumulation and migration by their components (Dinu, 2010; Mondol et al., 2011, Uddin et al., 2014; Pachura et al., 2016; Fomina et al., 2016; Zubarev & Kogan, 2017; Matveeva et al., 2018). The results of such researches allow us to offer more effective recommendations for the conservation and sustainable use of agrolandscapes of small rivers converted as a result of drainage reclamation.

MATERIALS AND METHODS

The researches were conducted on the territory of the Jewish Autonomous Region, located within the Sredneamurskaya lowland, where, due to the climate, geology, and terrain, in order to create the necessary conditions for agricultural production, large-scale land reclamation was carried out for more than 60 years (Anoshkin & Zubarev, 2018). On the territory of the Jewish Autonomous Region there are 76 drainage and 7 irrigation systems with a total area of 89.1 thousand ha, 36 thousand km of open channels, 2.7 thousand km of closed pottery and polyethylene drainage, 2.4 thousand units of various hydraulic structures were built to remove surface moisture. They are located mainly in the floodplains of small rivers that feed the middle left-bank tributaries of the Amur river and respond most quickly to land reclamation (Fig. 1).

Table 1. Watercourses, in the basins of which drainage reclamation works are carried out, on the territory of the Sredneamurskaya lowland

District	Name of watercourse
Birobidzhanskiy	Uldura, Gryaznushka, Ushumun
Leninskiy	Vertoprashikha, Solonechnaya
Octyabrskiy	Osinovka, Kulemnaya

We identified all watercourses in the basins of which drainage works had been carried out (Table 1). After analyzing the cartographic data, the following watercourses were also selected: the Ushumun river (an analogue of the Uldura river) and the Kulemnaya river (an analogue of the Osinovka river), in the basins of which there was no technogenic influence.

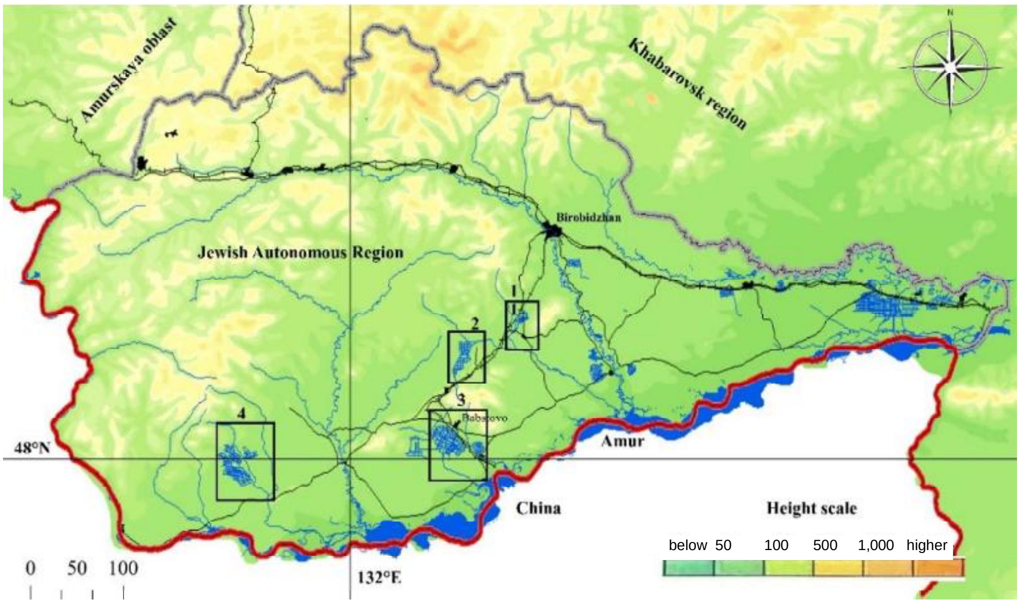

Figure 1. Research areas, southwestern part of the Sredneamurskaya lowland (1–4 - research areas).

These small rivers flow in the southern part of the Jewish Autonomous Region on the territory of the Sredneamurskaya alluvial lowland, they are outside the range of other sources of anthropogenic pollution and are exclusively the receivers of drainage water from drainage reclamation systems. A single method is used to drain floodplains and adjacent territories: land reclamation systems with open trapezoidal collectors and diverting main canals to discharge drainage water into the surface water of selected rivers. The main hydrographic characteristics of the studied small rivers are shown in Table 2.

Table 2. Hydrographic characteristics of small rivers - objects of the research

The name of watercourse	Length, km	Catchment area, km	Width, m	Depth, m
Uldura	15	160	3–5	0.2–0.6
Gryaznushka	32	191	3–5	0.3–0.9
Ushumun	45	260	3–5	1.0–1.5
Vertoprashikha	42	281	3–5	1.0–1.5
Solonechnaya	50	484	3–5	1.0–1.5
Osinovka	50	530	3–5	1.0–1.5
Kulemnaya	40	460	3–5	1.0–1.5

The long-term field researches were carried out to study the impact of drainage reclamation on the components of small river basins. Sampling was carried out at three points: above and below the areas of reclamation activities, as well as directly at the confluence of the drainage channel into the reservoir. Sampling of soil, water, bottom sediments, aquatic vegetation and hydrobionts was carried out in accordance with regulatory documents. 900 samples (350 of water, 225 of soil, 225 of bottom sediments, 50 of aquatic vegetation, and 50 of hydrobionts) were researched.

Sampling of floodplain soil was carried out from the upper horizon. The samples were dried and subjected to grinding, an average sample was formed. The following indicators were determined in each prepared soil sample: humus content by Tyurin I.V., based on the oxidation of soil organic matter by chromic acid to carbonic acid formation, actual acidity - by the potentiometric method, HM gross forms by atomic absorption spectrometry on a ‘ThermoElectron SOLAAR 6M’ instrument.

When sampling water, a visual inspection of the river state was carried out, the following parameters were determined: water temperature, pH, and oxygen content by the iodometric method. HMs in water were determined by atomic absorption spectrometry on a ‘ThermoElectron SOLAAR 6M’ instrument. Computer control of the measurement process and information processing was carried out in triplicate with automatic calculation of the confidence interval.

Hydrobionts are a reliable indicators of negative anthropogenic impact, including drainage reclamation, on aquatic ecological systems.For analysis on the content of HM, the highest aquatic plants of the pondweed family - *Potamogeton perfoliatus*, which belong to the group of submerged rooting hydrophytes, were selected and analyzed. To identify the impact of drainage on the aquatic fauna, Lagowski's minnow (*Phoxinus Lagowskii*) was chosen, this species is most often found in small rivers of Sredneamurskaya lowland. Samples of vegetation and fish were dried and subjected to ashing in a muffle furnace. To determine the gross content of HM, all samples were subjected to acid decomposition (HCl) in the ‘Mars-6’ microwave system. In samples of vegetation and fish, the content of HM was determined by atomic absorption spectrometry on the ‘SOLAAR M6’ instrument.

All analyzes were performed in triplicate. Statistical processing of the results was carried out using the Microsoft Excel software package.

RESULTS AND DISCUSSION

Drainage reclamation is meant to improve the water regime in waterlogged land and has a significant effect on humus and soil acidity. The researches have shown that the surface fertile horizons of undrained floodplain soil (0–20 cm) contained more humus than reclaimed ones (Table 3). This phenomenon can be explained by the increased aeration of soil under the influence of periodic treatments, leading to an increase in the biological activity of soil and acceleration of the processes of organic matter mineralization, as well as a change from the stagnant water regime to stagnant-flushing one with frequent changes in anaerobic and aerobic conditions.

The researches of soil acidity have shown that in all floodplain soil the pH_{KCl} varies in the upstream in the range of 4.1–4.8, and belongs to the category of ‘medium acid’ soil. On drainage systems, the pH is classified as ‘slightly acidic’ - pH - 5.0–6.1 (Table 3). These indicators have a significant impact on transit processes - HM accumulation in soil of agrolandscapes of river basins (Wang et al., 2006).

The research program included the determination of such HMs as iron, manganese, zinc, lead, copper, nickel in the soil of the studied agrolandscapes. Fluctuations in the iron content in the studied soil are very significant. The Fe concentrations in all samples exceed clarke values for soil - 38,000 mg per kg by about 1.5 times. The lowest concentrations of Fe are determined in the floodplains of the Uldura and Gryaznushka rivers, the highest ones - Solnechnaya and Vertoprashikha. When reclaimed within the drained territory, iron concentrations in soil are reduced. In samples that are not subject to the effect of drainage (upstream and downstream), the approximately 80% of total Fe is in the form of ferrous iron and 20% - in ferric iron. When draining by drainage channels, improved aeration conditions are created that contribute to a decrease in humidity and a change in the acidity of floodplain soil towards a weaker acidic pH medium. This led to an increase in ferric iron up to 40%. The increased amount of Fe^{2+} is associated with glue processes, the development of which depends on various factors, which include moisture conditions of the researched area, granulometric composition of soil, chemical and biological processes, as well as the content and forms of organic matter. The Mn content in the researched soil is in the range of 600–700 mg per kg, that is by 1.5 times lower than the average clarke indicator for Russian soil. In floodplain soil not affected by drainage, zinc concentrations were 70–80 mg per kg. In drained floodplain soil, zinc content decreases by 1.5–2 times. The maximum content of gross zinc was observed on the drainage systems of the floodplain soil of the Solonechnaya and Osinovka rivers during the catastrophic flood of 2013. A direct correlation dependence (*r* = 0.7) between the zinc content and the change in the pH value of the environment for floodplain soil of the Solonechnaya and Osinovka rivers was also established during researches. According to our researches, the concentration of lead in floodplain soil above the drainage area is in the range of 23–25 mg per kg. In soil selected in areas of drainage reclamation, a decrease in lead concentrations in relation to undrained soil. During the flushing type of the water regime (2013–2014), an increase in lead mobility was observed due to the large amount of precipitation. A correlation dependence (*r* = 0.6) was established between the content of gross forms of lead in the arable horizon and the change in the value of the pH medium, as well as with the amount of precipitation for floodplain soil of the Solonechnaya and Osinovka rivers, which were affected by reclamation. The concentration of gross forms of copper on drainage systems is reduced compared to the background. A correlation dependence (*r* = 0.7) was established between the content of gross forms of lead, a change in the pH medium, and the volume of precipitation for the floodplain soil of the Solonechnaya and Osinovka rivers, affected by drainage. A fairly uniform distribution of nickel in floodplain soil was noted throughout the researched area, with an average content of 24.3 mg per kg. Long-term drainage and the use of various fertilizers had a weak effect on the content of gross nickel in the soil (Table 4).

Table 3. Average humus content and acidity in floodplain soil of small rivers *

The name of watercourse	Humus, %	pH$_{KCl}$, un.pH
Floodplain soil - subject to drainage		
Vertoprashikha	5.74 ± 0.3	4.27 ± 0.4
	4.53 ± 0.4	5.13 ± 0.4
Uldura	5.83 ± 0.4	4.42 ± 0.3
	3.70 ± 0.3	5.18 ± 0.5
Gryaznushka	5.68 ± 0.3	4.55 ± 0.3
	3.13 ± 0.2	5.22 ± 0.4
Solonechnaya	5.46 ± 0.4	4.51 ± 0.3
	3.11 ± 0.2	6.21 ± 0.5
Osinovka	5.41 ± 0.3	4.27 ± 0.3
	3.33 ± 0.3	6.02 ± 0.4
Floodplain soil - not affected by drainage		
Kulemnaya	5.47 ± 0.5	4.30 ± 0.3
	5.28 ± 0.4	4.35 ± 0.3
Ushumun	5.64 ± 0.4	4.60 ± 0.4
	5.44 ± 0.4	4.58 ± 0.3

*The note: the numerator is the upper flow, the denominator is the drainage system. For floodplain soil not affected by drainage: the numerator is the upper course, the denominator is the lower course.

Table 4. The average content of gross forms of heavy metals in floodplain soil of small rivers (mg kg^{-1}) *

The name of watercourse	Heavy metals, mg kg^{-1}					
	Fe, 10^3 mg kg^{-1}	Mn, 10^3 mg kg^{-1}	Zn	Pb	Cu	Ni
Floodplain soil - subject to drainage						
Vertoprashikha	51.7 ± 3.0	65.3 ± 3.3	74.3 ± 3.4	25.1 ± 2.0	20.6 ± 2.0	21.6 ± 2.0
	48.9 ± 2.3	55.1 ± 2.8	68.3 ± 3.0	19.2 ± 1.7	19.3 ± 1.7	19.6 ± 1.3
Uldura	47.7 ± 2.6	65.0 ± 3.1	80.1 ± 3.1	24.7 ± 2.2	19.5 ± 2.1	21.6 ± 2.0
	45.0 ± 2.3	57.8 ± 2.0	62.3 ± 3.0	19.9 ± 2.0	17.7 ± 1.6	20.2 ± 1.1
Gryaznushka	47.6 ± 2.5	67.1 ± 3.7	74.0 ± 3.2	24.7 ± 2.9	19.4 ± 1.9	23.1 ± 2.2
	45.0 ± 2.3	53.4 ± 2.9	55.8 ± 2.7	21.6 ± 1.9	17.7 ± 1.7	21.9 ± 1.9
Solonechnaya	53.7 ± 2.6	64.5 ± 3.4	70.8 ± 3.5	24.8 ± 2.1	22.8 ± 2.0	21.0 ± 2.4
	49.1 ± 2.8	46.9 ± 2.3	52.1 ± 2.4	19.1 ± 1.3	17.9 ± 1.8	19.7 ± 1.3
Osinovka	48.0 ± 2.7	65.9 ± 3.1	81.6 ± 3.7	23.9 ± 1.9	19.7 ± 2.5	23.1 ± 2.6
	44.9 ± 2.3	47.1 ± 2.3	51.8 ± 2.7	20.5 ± 1.5	17.4 ± 1.3	21.4 ± 1.7
Floodplain soil - not affected by drainage						
Kulemnaya	48.3 ± 2.4	65.2 ± 3.6	71.1 ± 3.2	23.4 ± 2.1	19.2 ± 1.2	23.1 ± 2.0
	48.3 ± 2.3	64.1 ± 3.3	76.1 ± 2.7	23.4 ± 2.0	19.0 ± 1.8	23.2 ± 2.3
Ushumun	47.0 ± 2.3	62.5 ± 3.4	76.7 ± 3.4	23.4 ± 2.4	19.4 ± 1.7	22.1 ± 2.2
	47.2 ± 2.3	63.3 ± 3.7	77.4 ± 3.5	23.4 ± 2.1	19.9 ± 1.4	23.2 ± 1.8

*The note: the numerator is the upper flow, the denominator is the drainage system. For floodplain soil not affected by drainage: the numerator is the upper course, the denominator is the lower course.

During research, we were studying such important parameters for the migration of heavy metals as temperature, pH, and oxygen content in the water of objects flowing in the territories of drained landscapes (Table 5).

Analysis of the temperature distribution along the longitudinal profile has shown that drainage channels were characterized by higher temperatures of water that can affect the increase in the migratory capacity of HM. The pH value determines the state and mobility of many elements in the aquatic ecosystem, changes the degree of toxicity of pollutants. According to researches the reaction of water changed from slightly acidic to slightly alkaline. In the water of the drainage channel, a decrease in the oxygen content was observed, that led to a change of oxidizing conditions to recovery ones and increased the mobility of HM.

Table 5. Physical and chemical indicators of small rivers in areas of land reclamation *

Indicator	Sampling location		
	Upstream	Drainage channel	Downstream
t, °C	16.1–18.4	20.0–23.1	17.3–21.9
	17.5 ± 1.2	22 ± 1.5	20 ± 1.8
O_2. mgO_2 dm^{-3}	8.4–11.8	5.5–8.1	7.6–9.2
	9.8 ± 1.7	6.7 ± 1.2	8.1 ± 1.4
pH. units	6.1–6.7	7.4–8.5	6.1–8.0
	6.3 ± 0.3	7.8 ± 0.4	6.5 ± 0.3

* The note: in the numerator the minimum and maximum values, in the denominator - the average value of the indicator.

Analysis of the results of the determination of HM in water has shown the following: in surface water taken above the drainage area, the Fe content varies from 1.5 to 2.5 mg dm^{-3}, its amount significantly increases in reclamation channels. The concentration of Fe in the Ushumun and Kulemnaya rivers, not subject to drainage, is almost the same in the upstream and downstream. The high iron content was observed in the water of the drainage channels. According to the results of our researches, the minimum Mn content in the upstream of all watercourses is in the range from 0.1 to 0.6 mg dm^{-3}. The highest concentrations are observed for the water of drainage channels - 1.5–2.5 mg dm^{-3}. In the water of small rivers, above the area of drainage reclamation, low zinc concentrations were revealed, that is explained by its sorption by suspended solids. Under the influence of drainage, there is a change in the pH of water towards a slightly alkaline reaction of the medium, which causes the formation of sparingly soluble zinc hydroxides. In surface water not affected by drainage, the main form of Pb migration is the free form. When the pH of the water changes from 7 to 8, under the influence of drainage reclamation, readily soluble lead hydroxide is formed. The copper content in surface water, above the drainage area, was in the range of 0.0–0.09 mg dm^{-3}. Copper has high complexing ability. In surface water not affected by drainage, the main form of Cu migration is the free form. When the pH of water changes to alkaline values, under the influence of drainage reclamation, the ratio of hydrated forms of copper changes: 30% - Cu^{2+} and 70% - $(Cu\ (OH))^{+}$. In all small rivers, at all sampling points, low nickel concentrations are traced as a result of its sorption, the formation of insoluble compounds, as well as absorption by various organisms. The main form of Ni migration in water is the free form. In areas of drainage reclamation, there is a decrease in lead concentrations at all points relative to the background.

To identify the impact of drainage on hydrobionts, Lagowski's minnow (*Phoxinus Lagowskii*) was chosen, this species is most common in small rivers of the Sredneamurskaya lowland. The results of the researches showed that the accumulation of HM in fish tissues occurs in the downstream of small rivers in the studied area that is associated with the use of land reclamation, accumulation in the soil and further washing out of heavy metals and their compounds contained in fertilizers into rivers. In the gills of Lagowski’s minnows, which live in the downstream of the Gryaznushka, Vertoprashikha, and Solonichnaya rivers, iron, manganese, and lead concentrations were found that significantly exceeded the standards for commercial fish. The concentrations of zinc and copper in the gills of minnows from the lower reaches of Gryaznushka, Vertoprashikha and Solonichnaya rivers also exceed the concentrations of these metals in the upstream of the rivers that indicates the accumulation of heavy metals in the lower reaches during land reclamation. Both in the upper and lower reaches of the Ushumun river, the basin of which is the least reclaimed, the concentration of heavy metals (iron, manganese, zinc, copper, lead) in the gills of Lagowski’s minnow did not exceed the standard values (Table 6).

The results of the researches showed an intensive accumulation of HM by higher aquatic vegetation (indicator species - *Potamogeton perfoliatus*), selected at different points of small rivers of reclaimed landscapes. According the studied HM, the plants contain Fe to the greatest extent and Ni to the least. According to the content in *Potamogeton perfoliatus,* the elements formed the following decreasing row: Fe > Mn > Pb > Zn > Cu > Ni. The largest accumulations of all HMs in plants were found at the sampling points of the direct inflow of the main canal into the river, this is especially noticeable for the Osinovka and Solonechnaya rivers (Table 7).

Table 6. The concentration of heavy metals in the gills of the Lagowski's minnow (Phoxinus Lagowskii), mg kg^{-1} *

The name of watercourse	Heavy metals					
	Fe	Zn	Mn	Ni	Cu	Pb
Watercourses - subject to drainage						
Gryaznushka	25.0 ± 1.4 48.0 ± 2.3	7.0 ± 0.9 14.5 ± 1.3	12.0 ± 1.3 24.0 ± 0.9	0 1.0 ± 0.09	0.05 ± 0.002 2.5 ± 0.09	0 2.8 ± 0.08
Vertoprashikha	24.0 ± 1.2 45 ± 2.6	6.7 ± 0.8 10.5 ± 1.1	11.5 ± 1.1 18.0 ± 1.7	0 0.3 ± 0.02	0 1.5 ± 0.07	0 0.7 ± 0.04
Solonechnaya	21.5 ± 1.3 62.4 ± 3.1	6.0 ± 0.4 28.6 ± 1.7	10.3 ± 1.2 31.2 ± 2.1	0 2.3 ± 0.09	0 4.25 ± 0.2	0 3.3 ± 0.4
Watercourse - not subject to drainage						
Ushumun	24.0 ± 1.2 28.0 ± 1.7	6.3 ± 0.4 6.5 ± 0.7	8.0 ± 1.4 10.0 ± 0.9	0 0	0 0	0 0
ПД2К*	30	40	10	20	10	1

*The note: the numerator is the upper course, the denominator is the lower course.

MPC – maximum permissible concentrations of HM for commercial fish (Sanitary rules and regulations 2.3.2.1078-01).

Table 7. The concentration of heavy metals in aquatic plants *Potamogeton perfoliatus*, mg kg^{-1} *

The name of watercourse	Sampling points	Fe· 10^3 mg kg^{-1}	Mn· 10^3 mg kg^{-1}	Zn· 10^3 mg kg^{-1}	Pb mg kg^{-1}	Cu mg kg^{-1}	Ni· 10^{-1} mg kg^{-1}
Watercourses - subject to drainage reclamation							
Solonechnaya	u.c.	7.94 ± 0.6	0.281 ± 0.02	0.117 ± 0.01	3.5 ± 0.2	2.56 ± 0.2	0.3 ± 0.01
	d.c.	17.010 ± 2.6	1.149 ± 0.1	0.624 ± 0.08	11.03 ± 0.6	6.74 ± 0.7	1.6 ± 0.09
	l.c.	10.730 ± 0.1	0.904	0.429 ± 0.02	9.43	3.93 ± 0.4	0.9 ± 0.06
Osinovka	u.c.	7.250 ± 0.6	0.203 ± 0.02	0.178 ± 0.02	2.28 ± 0.2	2.56 ± 0.2	0.3 ± 0.01
	d.c.	18.640 ± 3.4	1.160 ± 0.09	0.663 ± 0.05	10.49 ± 0.7	6.18 ± 0.5	1.4 ± 0.05
	l.c..	16.700 ± 3.0	1.070 ± 0.01	0.351 ± 0.04	8.91 ± 0.6	3.37 ± 0.4	0.8 ± 0.04
Watercourse - not subject to drainage reclamation							
Ushumun	u.c.	5.590 ± 0.4	0.281 ± 0.02	0.117 ± 0.02	3.34 ± 0.4	2.56 ± 0.2	0.3 ± 0.01
	l.c.	5.490 ± 0.4	0.270 ± 0.02	0.186 ± 0.02	3.44 ± 0.1	2.53 ± 0.4	0.3 ± 0.01

*The note: u.c. – upper course; l.c. – lower course; d.c. – drainage channel.

The least impact of drainage is manifested in the downstream of the rivers.

CONCLUSIONS

During drainage reclamation in floodplain soil, conditions are created for improved soil aeration, which leads to a decrease in the humus content and a change in pH from acidic to neutral reaction of the medium. This process contributes to a certain decrease in the concentration of HM in the soil. Conducting drainage reclamation works leads to a decrease in the water quality of all the watercourses considered, as a result of an increase in the concentration of HM in water and bottom sediments. The transformation of landscapes leads to the accumulation of HM in macrophytes and fish, which is potentially dangerous for both the aquatic ecosystem and human health.

REFERENCES

Anoshkin, A.V. & Zubarev, V.A. 2018. Land reclamation and transformation of floodplain-channel complexes at the Sredneamurskaya lowland. *Regional issues* **3–1**, 70–74.

Chibuike, G.U. & Obiora, S.C. 2014. Heavy Metal Polluted Soil: Effect on plants and bioremediation methods. *Appl. Environ. Soil. Sci*. 752708, 12 pp.

Dyatel, A.A. 2017. Ecological and reclamation component of drained lands in the area of impact of the «Khotislavsky» quarry. *Reclamation* **1**(79), 31–38 (in Russian).

Fomina, A.A., Tikhomirova, E.I. & Korableva, A.I. 2016. Analysis of the content of heavy metals in the higher aquatic vegetation of the Volgograd reservoir in the area of the agglomeration of Saratov - Engels. *Bulletin of the Samara Scientific Center of the Russian Academy of Sciences* **2**(3) 822–826. (in Russian).

Dinu, M. 2010. Comparison of Complexing Ability of Fulvic and Humic Acids in the Aquatic Environment with Iron and Zinc Ions. *Water Resources* **37**(1), 65–69.

Israel, Yu.A. 1984. *Ecology and environmental control*. Gidrometeoizdat, Moscow, 560 pp. (in Russian).

Imeri, R., Kullaj, E, Duhani, E. & Millaku, L. 2019. Impact of rootstock on heavy metal bioaccumulation in apple plant grown near an industrial source in Obiliq, Kosovo. *Agronomy Research* **17**(1), 100–110.

Kabata-Pendias, A. & Pendias, H. 2001. *Trace elements in soil and plants (3rd edition*). CRC Press, Boca Raton, 313 pp.

Kasiuliene, A., Paulauskas, V. & Kumpiene, J. 2016. Influence of nitrogen fertilizer on Cd and Zn accumulation in rapeseed (*Brassica napus* L.) biomass. *Agronomy Research* **14**(2), 418–427.

Khristoforova, N.K. 2007. *Fundamentals of Ecology*. Far Eastern University Press, Vladivostok, 454 pp. (in Russian).

Lukowski, A. & Wiater, J. 2016. The content and solubility of lead in arable soil of the Podlasie Province (eastern Poland). *Soil Science Annual* **67**(4), 190–196.

Matveeva, A.Yu., Kutlin, N.G., Kardapoltseva, D.G. & Mullagalieva, A.T. 2018. The effect of anthropogenic stress on the accumulation of heavy metals in the organs and tissues of commercial fish. *Environmental Engineering* **2**, 132–136 (in Russian).

Mondol, M.N., Chamon, A.S., Faiz, B. & Elahi, S.F. 2011. Seasonal Variation of Heavy Metal Concentrations in Water and Plant Samples Around Tejgaon Industrial Area of Bangladesh. *J. Bangladesh Acad. Sci.* **35**(1), 19–41.

Moore, J.V. & Ramamurthy, S. 1987. *Heavy Metals in natural Water: monitoring and evaluation of impact*. Mir, Moscow, 286 pp. (in Russian).

Morais, S., Costa, F.G. & Pereira, M.L. 2012. Heavy metals and human health. In: Oosthuizen J. (ed): Environmental health – emerging issues and practice, pp. 227–246.

Murtic, S., Jurkovic, J., Basic, E. & Hekic, E. 2019. Assessment of wild plants for phytoremediation of heavy metals in soil surrounding the thermal power station. *Agronomy Research* **17**(1), 234–244.

Nazarov, N.N. 2014. Hydrological consequences of drainage reclamation and channel processes. *Geographical Bulletin* **1**(28), 4–10 (in Russian).

Pachura, P., Ociepa-Kubicka, A. & Skowron-Grabowska, B. 2016. Assessment of the availability of heavy metals to plants based on the translocation index and the bioaccumulation factor. *Desalin. Water Treat.* **57**(3), 1469–1477.

Pais, I. & Jones, J.B. 1997. *The Handbook of Trace Elements*. Lucie Press, Boca Raton, 223 pp.

Perevoznikov, M.A. & Bogdanova, E.A.1999. *Heavy metals in freshwater ecosystems*. SRILRF, St. Petersburg, 228 pp. (in Russian).

Tack, F.M.G. 2010. Trace Elements: General Soil Chelistry Principles and Processes. In: Hooda PS (ed): *Trace Elements in Soil*, pp. 9–38.

Tolkachev, G.Yu. 2017. Migration and transformation of forms of heavy metals in the catchment area and in the bottom sediments of the Ivankovo reservoir. *Land reclamation and water management* **6**, 35–40 (in Russian).

Uddin, M.N., Alam, M.S., Mobin, M.N. & Miah, M.A. 2014. An Assessment of the River Water Quality Parameters: A case of Jamuna River. *Journal of Environmental Sciences and Natural Resources* **7**(1), 249–256.

Voronov, B.A. & Makhinov, A.N. 2009. *Current state of water resources in the Far East and their anthropogenic transformation*. The 100th anniversary of the Kamchatka expedition of the Russian Geographical Society of 1908–1910: materials of All-Russian scientific conf. Institute of Volcanology and Seismology, Petropavlovsk-Kamchatsky, Russia, pp. 40–48 (in Russian).

Wang, A.S., Angle, J.S., Chaney, R.L., Delorme, T.A. & Reeves, R.D. 2006. Soil pH effects on uptake of Cd and Zn by Thlaspi caerulescens. *Plant and Soil* **281**(1–2), 325–337.

Yashin, V.M. 2017. The formation of the quality of drainage flow on the Yakhroma floodplain. *Land reclamation and water management* **6**, 21–25 (in Russian).

Zubarev, V.A. & Kogan, R.M. 2017. Ecological Conditions of Watercourses in the Middle Amur Lowland in the Areas of Drainage Reclamation. *Water Resources* **44**(7), 940–951.