International Journal of GEOMATE, June, 2017, Vol.12 Issue 34, pp. 89-95
Geotec., Const. Mat. & Env., ISSN:2186-2990, Japan, DOI: http://dx.doi.org/10.21660/2017.34.2710

ECOLOGICAL STATE AND NEW APPROACHES TO THE RESTORATION OF LAKE UVILDY, RUSSIA

Irina V. Mashkova, *Tatyana G. Krupnova, Anastasiya M. Kostryukova and Varvara Yu. Schelkanova

Chemistry Department, South Ural State University, Russia

* Irina V. Mashkova, Received: 10 June 2016, Revised: 09 August 2016, Accepted: 24 Oct. 2016

ABSTRACT: Lake Uvildy is situated in the North of Chelyabinsk region. Lake Uvildy is one of the largest and the most unique of South Ural's lakes. In 1975–1977 the drought occurred and water supplies dried up in South Ural. 234 million cubic meters were moved from the Uvildy lake in Argazi reservoir, which was a source of water supply of the Chelyabinsk city. The lake's water level fell by more than 4 meters. Only in 2008 the water level returned to the previous position, but riparian vegetation was flooded. In July 2014 we carried out an ecological survey of the lake in five sites. We discovered submerged tree and shrub vegetation at 50–70 meters from the bank. Chemical analysis of water revealed the accumulation of organic substances and the transition of nitrogen from nitrate to nitrite and ammonia, of sulfur from sulfate to sulfite and hydrogen sulphide, of carbon to methane. We found blue-green algae (*Microcystis, Anabaen*a, *Oscillatoria*) in all the sites. It indicates the beginning of water eutrophication. We proposed a new method of ecological restoration of the lake. In August 2014 we cleaned the bottom of the lake in two research points with a special innovative bottom-cleaning machine working both as a pump and a crusher. The research in summer 2015 showed that the water quality had significantly improved and the process of eutrophication had stopped in the points where the bottom was cleaned. Works on the lake trophicity will be continued.

Keywords: Ecological restoration, Eutrophication, Lake, Water quality

1. INTRODUCTION

Lakes are complex ecosystems able to restore and clean themselves. Lake ecosystem is developing very slowly from oligotrophic stage to eutrophic or dystrophic [1]. Nowadays the study of lake evolution to forecast the change in lake trophicity in prospect is of much interest [2]–[4].

Natural eutrophication increases if a lake is subject to human made load [5]. Different characteristics are used to assess the previous and current environmental condition of eutrophic lake under human made impact, e.g. phytoplankton data [6], [7].

There are two basic types of restoration methods relative to eutrophication [8]–[11]. The first type is measure which decrease phosphorus availability (increased bottom up control), it is sediment removal, hypolimnetic oxygenation and alum treatment. The second type is measure which increase the zooplankton grazing on phytoplankton (increased top-down control), it is pike stocking and removal zooplankti-benthivorous fish.

The method of lake biomanipulation is now widespread in Europe [8], [12]. The sustainability of the positive effects of biomanipulation has been considered over a decade. But there are cases of failures [13].

The aim of this research was to study the environmental condition of lake Uvildy and to test the device for mechanical cleaning of the lake bottom at the coast.

2. METHODS

2.1 Study Area

Uvildi Lake is located in the north of the Chelyabinsk region in the eastern foothills of the South Urals within the lake-forest landscape. The coordinates of the lake: 55º28,2' – 55º35,9' N 60º25,1' – 60º34,8' E.

Uvildy is often called "a pearl of the South Urals". Lake Uvildy is a typically tectonic lake in a deep piedmont fault. Its catchment area and water surface are 209 and 69 m^2 respectively [2]. Its length is 13.5 km, its maximum width is 9 km. The average depth of the lake is 15.6 m. The maximum depth measured by echometer is 37 m. The coasts are considerably fringed by peninsulas and bays. The coastline of the lake is 117 km. The total volume of water exceeds one billion cubic meters.

Uvildy mirror-like surface stretches on the eastern slope of the Urals range, near the foot of Fominka and Cheremshanka Mounts – in the west, Sobachya Mount – in the south-west, Barsuchya Mount – in the south. The lake's surface is like a pear thickening in the southern part. There are health spa and resorts highly popular both among Ural citizens and guests.

The climate is classified as continental, with warm summers and cold winters. The coldest month of the year is January with an average temperature range of -16 ºC. The warmest month is July with an average monthly temperature of +17 ºC.

The territory of Uvildi Lake is occupied by mixed forests. In the forests around the lake there are many small boggy brooks, springs, bogs, especially in the North-West of the lake catchment area where two rivers Cheremshanka and Kosaya flow from low-mountain foothills and vanish in the bogs near lake Uvildy. Water catchment area is in the borderline between two natural zones. From spring to autumn you can meet here usual and rare species of plants which are in the Red book: strawberries, blueberries, viburnum, cranberry, wild rose. In the Uvildi Lake from the earliest times live crustaceans, which are a sign of the purity of the lake. The lake has a large number of species of fish. There live roach, perch, pike, lin and whitefish.

2.2 Sample Collection

The sampling was carried out during the vegetation period in July 2014 in 5 sites in the North-West and North-East of lake Uvildy (Fig.1).

Fig.1 Lake Uvildy and sampling sites

The coordinates of the sampling sites: site 1 – 55°32'9.13" N, 60°25'34.05" E, site 2 – 55°31'47.91" N, 60°26'50.46" E, site 3 – 55°31'41.29" N, 60°29'58.96" E, site 4 – 55°31'47.42" N, 60°33'38.89" E, site 5 – 55°32'55.95" N, 60°31'54.10" E.

Lake Uvildy is one of the largest lakes of South Ural. In 1974–1978 South Ural was experiencing a severe drought. To tackle a water shortage problem, there was built a channel, through which more than one third of the lake water volume was carried over to Argazinskoye Reservoir. The water level of the lake fell by 4 meters eventually, and most of the coastal areas became outcropped [14]. The water level started to rise only 20 years later, in 1999, and it resulted in a significant transformation of coast geosystem. Birch forest grown in the drainage zones became flooded together with developing soil. It led to eutrophication in the coastal areas [14]. In 2014 five sites with the highest degree of eutrophication were selected, and their physicochemical and microbiological characteristics were studied. After that in 2015 the lake was cleaned in two sites and the water of these sites was probed.

At each site the samples of a known volume subsurface (5–40 cm) water were taken with a 10 L bucket and then filtered through a plankton net (mesh size: 100 µm). The retained organisms were transferred into glass containers. The collected material was preserved in 5 % formalin.

2.3 Water Quality Analysis

The following instream parameters including pH, dissolved oxygen (DO), and water temperature (WT) were measured in situ by a Portable Meter (Multitest IPL-513, Semico Ltd, Russia, Novosibirsk). Conductivity (COND) and salinity (SALIN) were measured in situ by a Portable Meter (Multitest KSL-111, Semico Ltd, Russia, Novosibirsk) Air temperature was determined with a mercury thermometer. Oxygen saturation (P, %) was calculated.

At each site, water samples were also collected for further laboratory analysis including redox potential (Eh), nitrate–nitrogen (NO_3^-), nitrite–nitrogen (NO_2^-), ammonium–nitrogen (NH_4^+), orthophosphate-phosphorus (PO_4^{3-}), sulfate–sulfur (SO_4^{2-}), hydrogen sulfide–sulfur (H_2S), chlorides (Cl^-), sodium (Na^+), potassium (K^+), total hardness (H), calcium hardness (Ca^{2+}), bicarbonates (HCO_3^-), carbon dioxide (CO_2), permanganate oxidability ([O]), total iron (Fe). All these parameters were measured in the lab of the Department of Chemistry of South Ural State University according to the standard methods (Table 1) [15]. For spectrophotometric analysis the Spectrophotometer KFK-3 was used. Dissolved CO_2 concentrations were determined by calculating from pH and alkalinity, measured by titration with 0.1 N HCl to an end point pH of 3.5.

2.4 Phyto and Zooplankton Analysis

Non-diatom algae were analyzed using a 0.1 mL counting chamberat a magnification of 600× (Altami BIO 2T microscope, Altami Ltd, Russia, St. Petersburg.).

Table 1 Chemical parameters and their codes sampled at lakes and methods used

Chemical parameters	Codes	Methods
Acidity	pH	Potentiometric method
Redox potential, mV	Eh	Potentiometric method
Conductivity, mS/m	COND	Conductometric method
Salinity (NaCl), mg/l	SALIN	Conductometric method
Ammonium–nitrogen, mg/l	NH_4^+	Spectrophotometric method using Nessler's reagent (at 690 nm; END F* 14.1:2.1-95)
Nitrate–nitrogen, mg/l	NO_3^-	Potentiometric method with ion-selective electrodes (ISE)
Nitrite–nitrogen, mg/l	NO_2^-	Spectrophotometric method using Griss's reagent (at 520 nm; END F* 14.1:2.3-95)
Orthophosphate-phosphorus, mg/l	PO_4^{3-}	Spectrophotometric method using ammonium molybdate (at 690 nm; END F* 4.1:2.112-97)
Chlorides, mg/l	Cl^-	Potentiometric method with ion-selective electrodes (ISE)
Sodium, mg/l	Na^+	Potentiometric method with ion-selective electrodes (ISE)
Potassium, mg/l	K^+	Potentiometric method with ion-selective electrodes (ISE)
Bicarbonates, mg/l	HCO_3^-	Titrimetric Acidity (ISO 9963-1:1994, ISO 9963-2:1994)
Carbon dioxide, mg/l	CO_2	Calculation from pH and alkalinity
Hardness (total), mmol/l	H	EDTA titrimetric method ISO 6059-1984
Hardness (calcium), mmol/l	Ca^{2+}	EDTA titrimetric method ISO 6059-1984
Magnesium, mmol/l	Mg^{2+}	Calculated as the difference between total hardness and calcium hardness.
Permanganate oxidability	[O]	Titrimetric method in an acid environmentaccording to Kubel (END F* 14.1:2:4.154-99)
Iron (total), mg/l	Fe	Spectrophotometric method using sulfosalicylic acid (at 440 nm; END F* 14.1:2:4.50-96)

END F* – Environmental Normative Documents Federated (Russian Federation)

Permanent diatom slides were prepared after oxidizing the organic material (by nitric acid and sulfuric acid) and a minimum of 300 valves were counted for each sample using an Altami BIO 2T microscope at 1000× under oil immersion.

Species were identified using the handbooks by Yarushina et al. [16]. Eco-geographical characteristics of species were made using the handbooks by Barinova [17]. The list of phytoplankton species is presented in Table 2. Number of taxa from sub-division to species level resolution follows a linear trend (Fig.2). Greater numbers of species and individuals were detected at sites 1, 4, 5.

3. RESULTS AND DISCUSSION

Submerged trees and shrubs at 50–70 m from the coast were visually determined (Fig.3). Organic pollutants in water were formed due to the trees and shrubs decay. There was a significant reduction of dissolved oxygen (DO) concentration and higher values of oxidation ([O]). Table 3 shows the results of physicochemical analysis of water in the sampling sites.

The proportion of different forms of Nitrogen showed the transition of nitrate form into ammonium. Dissolving of organic matters in water results in the accumulation of carbon dioxide and transformation of sulfates into hydrogen sulphide. According to different criteria water pollution at these sites varies from polluted to dirty.

The study of phytoplankton of the waterbody in 2005–2006 revealed [18] diatoms (*Bacillariophyta*, 42 %) as a dominant algal group, green algae (*Chlorophyta*, 31 %) as the second in species diversity, and blue-green algae (*Cyanophyta*) accounted only for 10 %. But new species of *Cyanophyta* were identified, and that became an unfavourable sign for interannual dynamics of species diversity.

The study of phytoplankton species diversity of 2014 showed that diatoms had kept their dominant position. They accounted for 42 % of the total number of species. Blue-green algae became second in species diversity, which corresponds to 39 % of the total number of species [19]. It may be explained by the presence of phosphorous and nitrogen compounds in water [20]. The blue-greens were mainly represented by *Anabaena lemmermannii, Microcystis aeruginosa* and *Anabaena flos-aquae*. The most abundant diatoms were the most numerous representatives of *Fragilaria crotonensis* and *Asterionella formosa*. Blue-green algae species (*Microcystis, Anabaena, Oscillatoria*) evolved on the surface of the lake.

Table 2 Phytoplankton species observed in Lake Uvildi

Divisions	Species	Divisions	Species
Bacillariophyta	*Asterionella formosa*	*Cyanophyta*	*Anabaena flos-aquae*
	Aulacoseira granulata		*Anabaena hassalii*
	Cymbella cistula		*Anabaena lemmermannii*
	Diatoma vulgare		*Aphanothece clathrata*
	Epithemia argus		*Merismopedia elegans*
	Epithemia turgida		*Microcystis aeruginosa*
	Fragilaria crotonensis		*Microcystis pulverea f. planctonica*
	Gyrosigma spenceri		*Oscillatoria limosa*
	Navicula radiosa		*Woronichinia naegeliana*
	Pinnularia viridis	*Chlorophyta*	*Closterium parvulum*
	Rhopalodia gibba		*Coenococcus planctonicus*
	Surirella linearis		*Cosmarium caelatum*
	Synedra ulna		*Dictyosphaerium pulchellum*
Euglenophyta	*Euglena acus*		*Eudorina elegans*
	Euglena gracilis		*Gloeocystis ampla*
	Euglena proxima		*Oocystis borgei*
	Trachelomonas euchlora		*Scenedesmus quadricauda*
Chrysophyta	*Dinobryon divergens*		*Staurastrum paradoxum*
	Dinobryon sociale americanum		
Dinophyta	*Ceratium hirundinella*		

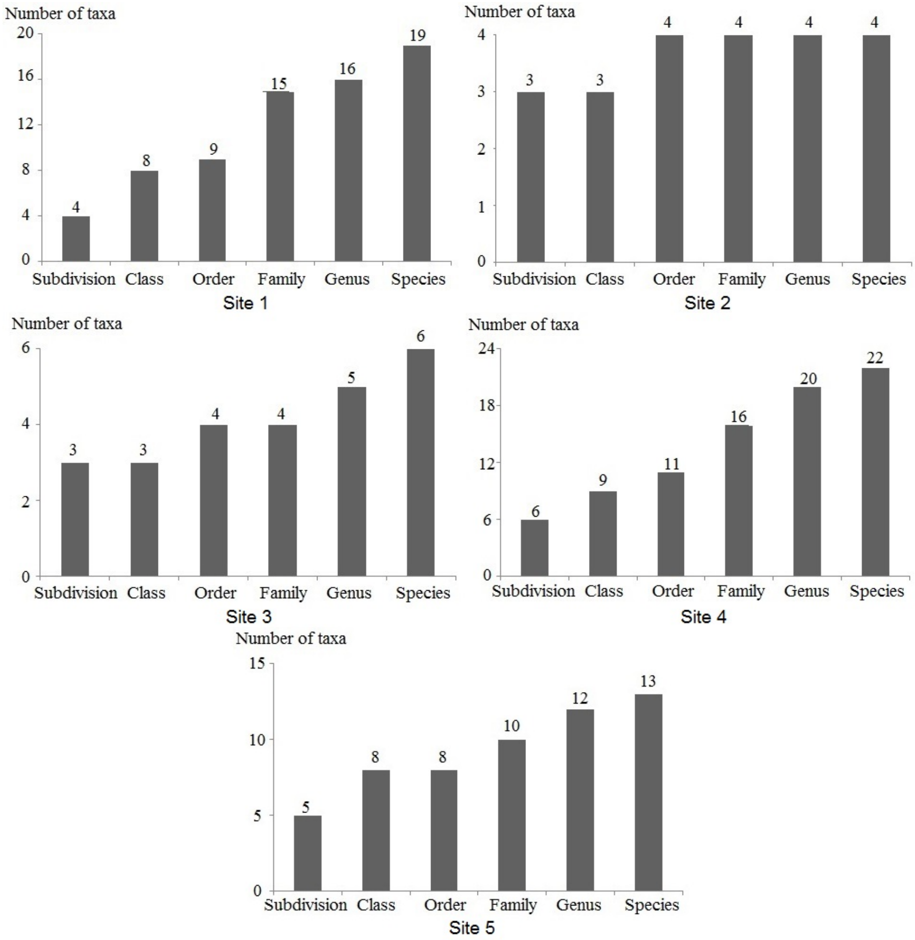

Fig.2 Number of taxa for each taxonomic resolution

Table 3 Physico-chemical parameters

Chemical parameters	Site 1	Site 2	Site 3	Site 4	Site 5
TW, °C	20	18.4	19	20	20
DO, mgO/l	3.12	4.55	3.9	3.4	2.95
P, %	34.6	48.8	42.3	37.7	32.7
pH	8.712	8.751	8.860	8.896	8.950
Eh, mV	259.1	251.1	257.5	256.0	238.2
COND, mS/m	36.1	36.59	34.86	35.94	35.71
SALIN, mg/l	192.3	194.9	185.5	191.4	190.1
NH_4^+, mg/l	0.54	0.70	0.96	0.95	0.75
NO_3^-, mg/l	0.24	0.28	0.51	0.51	0.34
NO_2^-, mg/l	0.005	0.006	0.008	0.006	0.005
SO_4^{2-}, mg/l	32.8	25.6	25.2	28.4	33.1
H_2S, mg/l	0.05	0.05	0.08	0.06	0.09
PO_4^{3-}, mg/l	0.002	0.002	0.04	0.10	0.300
CO_2, mg/l	3.5	3.8	4.2	4.2	4.5
Cl^-, mg/l	32	32	37	32	32
Na^+, mg/l	13.87	12.08	12.08	12.08	13.9
K^+, mg/l	0.80	0.70	0.80	0.695	0.80
HCO_3^-, mmol/l	3.6	3.4	3.6	3.3	3.3
H, mmol/l	4.8	4.8	5	5	4.9
Ca^{2+}, mmol/l	1.9	1.8	1.8	1.9	1.8
Mg^{2+}, mmol/l	2.9	3	3.2	3.1	3.1
Fe, mg/l	0.02	0.05	0.06	0.03	0.07
[O]	8	8.0	15	10.5	11.0

The waterbody trophic state was characterized as mesotrophic.

Fig.3 Submerged trees and shrubs

The decay of lots of submerged organic matter and the following die-away of water plants rapidly growing on that soil during the first years of flooding led to bogging of the lake coast (Fig.4). At these sites trophic status develops into eutrophic.

Fig.4 Boggy site

In August 2014 at sites 1 and 2 the bottom was mechanically cleaned from the sediments containing thick roots of trees and shrubs remains. A special device was used in cleaning [21].

In July 2015 physico-chemical parameters of water at these sites were analyzed (Table 4).

Table 4 Physico-chemical parameters

Codes of chemical parameters	Site 1	Site 2
TW, °C	20	20
DO, mgO/l	7.36	7.52
P, %	81.6	83.4
pH	8.031	8.074
Eh, mV	259.1	251.1
COND, mS/m	36.1	36.59
SALIN, mg/l	192.3	194.9
NH_4^+, mg/l	0.15	0.17
NO_3^-, mg/l	0.78	2.15
NO_2^-, mg/l	0.006	0.006
SO_4^{2-}, mg/l	5.26	5.87
H_2S, mg/l	0	0
PO_4^{3-}, mg/l	0.002	0.002
CO_2, mg/l	2.2	1.9
Cl^-, mg/l	32	32
Na^+, mg/l	13.87	12.08
K^+, mg/l	0.80	0.70
HCO_3^- mmol/l	3.1	3.0
H, mmol/l	4.8	4.9
Ca^{2+}, mmol/l	1.9	1.9
Mg^{2+}, mmol/l	2.9	3.0
Fe, mg/l	0.013	0.024
[O]	6	6.8

The analysis results prove water pollution decrease after the use of the device. The oxidation of the lake self-purification is getting more intense, as the analysis showed. Organic pollutants and biogenic elements concentration has substantially declined. Dissolved oxygen concentration has increased. According to different criteria water condition at these sites varies from clean to moderately polluted.

4. CONCLUSION

Water eco-system abuse as a result of human-made impact and inefficient water management is one of the most crucial problems today.

The paper considers aggravation of Lake Uvildy trophic status after one third of the lake water volume was carried over, and water level increased later and flooded birch forest that had grown in the drainage zone.

The use of the device for mechanical cleaning of coasts from trees and shrubs remains gave positive results. We suggest using the device for further cleaning of the lake**.**

ACKNOWLEDGEMENTS

The authors thank Genadiy Sidorov for his assistance in the field. This work was supported by the Law 211 of the Russian Federation Government contract № 02.A03.21.0011.

REFERENCES

[1] Björk S, The Evolution of Lakes and Wetlands, Restoration of lakes, streams, floodplains, and bogs in Europe. Principles and case studies, Part 2, Eiseltova, Ed. London New York: Springer, 2010. pp. 25–35.

[2] Izmest'eva LR, Moore MV, Hampton SE, Ferwerda CJ, Gray DK, Woo KH, Pislegina HV, Krashchuk LS, Shimaraeva SV, Silow EA, “Lake-wide physical and biological trends associated with warming in Lake Baikal”, Journal of Great Lakes Research, Vol. 48, 2016, pp. 6–17.

[3] Mitraki C, Crisman TL, Zalidis G, “Lake Koronia, Greece: Shift from autotrophy to heterotrophy with cultural eutrophication and progressive water-level reduction”, Limnologica – Ecology and Management of Inland Waters, Vol. 34, 2004, pp. 110–116.

[4] Chen X, Yang X, Dong X, Liu E, “Environmental changes in Chaohu Lake (southeast, China) since the mid 20th century: The interactive impacts of nutrients, hydrology and climate”, Limnologica – Ecology and Management of Inland Waters, Vol. 43, 2013, pp. 10–17.

[5] Suda H, Tanaka M, Oyagi M, Nobori M, Yagi A, “Water quality and compositions of the phytoplankton and zooplankton before and after building construction in lake Fukami-ike, Japan”, International Journal of GEOMATE, Vol. 10, 2016, pp. 1983–1988.

[6] Suda H, Tanaka M, Nobori M, Yagi A, “Zooplankton and phytoplankton in all anoxic layers of lake Fukami-ike”, International Journal of GEOMATE, Vol. 11, 2016, pp. 2177–2181.

[7] Allinger LE, Reavie ED, “The ecological history of Lake Erie as recorded by the phytoplankton community”, Journal of Great Lakes Research, Vol. 39, 2013, pp. 365–382.

[8] Søndergaard M, Jeppesen E, Lauridsen TL, Skov C, Van Nes EH, Roijackers R, Lammens E, Portielje RE, “Lake restoration: Successes, failures and long-term effects”, Journal of Applied Ecology, Vol. 44, 2007, pp. 1095–1105.

[9] “Intergrated aquatic ecosystem restoration”, Restoration of aquatic ecosystems: Science, technology, and public policy, National Research, Ed. Washington D.C.: National Academy Press, 1992, pp. 341–348.

[10] Cooke GD, Welch EB, Peterson SA, Newroth PR, “Restoration and management of lakes and reservoirs”, Boca Raton, FL: CRC Press, Taylor & Francis Group, 1993.

[11] Drenner RW, Hambright KD, “Biomanipulation of fish assemblages as a lake restoration technique”, Archiv für Hydrobiologie, Vol. 146, 1999, pp. 129–165.

[12] Bergman E, Hansson LA, Andersson G, “Biomanipulation in a theoretical and historical perspective”, Hydrobiologia, Vol. 404, 1999, pp. 53–58.

[13] Hansson LA, Annadotter H, Bergman E, Hamrin SF, Jeppesen E, Kairesalo T, Luokkanen E, Nilsson PA, Søndergaard M, Strand J, “Biomanipulation as an application of food-chain theory: constraints, synthesis, and recommendations for temperate lakes”, Ecosystems, Vol. 1, 1998, pp. 558–574.

[14] Deryagin VV, Belov SA, “Geoecological features differentiating the coastal landscape and recreational areas of Lake Uvildy”, Bulletin of the Tomsk State University, Vol. 333, 2010, pp. 172–176.

[15] Mashkova IV, Krupnova TG, Kostryukova AM, “Water quality and aquatic macrophytes interrelationships for selected reserved lakes of South Ural”, in Proc. 15th Int. GeoConf. SGEM 2015, 2015, Book 3, Vol. 1, pp. 763-770.

[16] Yarushina MI, Tanaeva GV, Eremkina TV, Algae flora of water bodies of the Chelyabinsk region. Ekaterinburg: INSS Ural branch of

Russian Academy of Sciences, 2004, pp. 50–290.

[17] Barinova SS, Medvedeva LA, Anisimova OV, Biodiversity of algae-indicators of the environment. Tel Aviv, Pilies Studio, 2006.

[18] Snitko LV, Snitko VP, “Water EPNT: A Comparison of the state of phytoplankton Uvildy and Turgoyak lakes at the end of the modern high-water hydrological cycle in the South Urals”, Bulletin of the Chelyabinsk State University, Vol. 5, 2011, pp. 105–109.

[19] Kostryukova AM, Krupnova TG, Mashkova IV, “Phytoplankton taxonomic structure as indicator of the trophic status and ecological state of Uvildi lake”, in Proc. 15th Int. GeoConf. SGEM 2015, 2015, Book 3, Vol. 1, pp. 501-508.

[20] Kane DD, Conroy JD, Richards RP, Baker DB, Culver DA, “Re-eutrophication of Lake Erie: Correlations between tributary nutrient loads and phytoplankton biomass”, Journal of Great Lakes Research, Vol. 40, 2014, pp. 496–501.

[21] Sidorov GF, Valeev RK, “Apparatus for cleaning the bottom of the reservoir”, Patent, 135331, issued date December 10, 2013.