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ENVIRONMENTAL SAFETY OF WATER BODIES AND COASTAL AREAS USING THE METHOD OF WATER ENVIRONMENT BIOINDICATION BY MEANS OF MACROPHYTES

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Annotation. The purpose of this work is to improve the ecological state of water bodies and coastal area of the "Enerhoharant" LLC company by implementing a series of environmental measures based on research of their ecosystems and environmental-economic assessment that will enable largely to solve the problem of optimal use of natural resources for the recreational purposes.

Key words: ecological safety, water bodies, macrophytes, bioindication, Eichornia crassipes, vegetation

Introduction

Human life is closely connected with water, that is why significant deterioration of water quality in natural reservoirs is an extremely serious problem for the world in general and Ukraine in particular. Human activity results in a large variety of pollutants, which enter water reservoirs with industrial, municipal and agricultural runoff and accumulate there. Today it is not only dangerous to drink water from our lakes or rivers without multi-stage water purification, but also to swim in some of them without risk for health. That is why it is important to objectively assess water quality in reservoirs used for fishery and recreational purposes at the enterprise "Enerhoharant" LLC and offer effective environmental solutions to improve the ecological state of these objects.

Thus, the purpose of this work is to improve the ecological state of water bodies and coastal area of the "Enerhoharant" LLC company by implementing a series of environmental measures based on the research of their ecosystems, and environmental-economic assessment that will enable largely to solve the problem of optimal use of natural resources for the recreational purposes.

To achieve this goal it is necessary to solve the following problems:

– study of the ecosystem of water bodies and coastal areas;

– analysis of biochemical parameters of pond water;

– environmental and economic assessment and development of environmental measures for water bodies and coastal areas;

– implementation of bio-filtration of pond water with macrophytes (water hyacinth, Eichornia crassipes).

Experimental part

Water macrophytes, perform many functions in water for various purposes: meliorative, energy-accumulative, biotechnical, regulatory, resource, indicative. The most important as for the impact of macrophytes on water quality status (enriching it with oxygen, carbon dioxide absorbtion, pH changes, nutrients and heavy metals accumulation, water isotopes of radioactive elements purification), is, of course, a meliorative one.

The use of Eichornia crassipes for biological treatment of wastewater runoffs in Polissya was highly effective [1–3].

Eyhorniya is a typical hydrophyte. For ecological and biological characteristics and habitat conditions, it refers to a group of plants with leaves floating on the water surface. It is a plant, that grows in shallow waters off the coast of the rivers, lakes, ponds, canals, etc, mainly in the waters of tropical and subtropical regions of South America, and it can cover not flowing parts of lakes and ponds by dense thickets [1, 4].

In Vinnitsa region, Eichornia crassipes growing season can last from 4 to 7 months. In autumn, when reaching the average water temperature below 14 °C, water hyacinth, protected from the wind, can endure short-term lowering of the temperature to 6 °C at night and still looks quite viable, with no signs of dying. However, the mass increase of the plant stops.

Monitoring of vital functions of water hyacinth plants showed that this plant has successfully adapted to the conditions of the polluted and clean water environment because biomass of the plants grew quite rapidly, and formed to 8–15 subsidiary plants per month.

The study of the plants that grow in different polluted environments was conducted. The scape diameter ranged from 4.5±1.5 cm. The growth of the root system was the norm - up to 1 cm per week. Cilia on the root system were 0.5±0.2 cm long, black and completely overgrown with dirt, but in a relatively clean pond during one week, the plants considerably differed among themselves for a number of indicators. Their leaves were light green, the seedlings of the leaves were white, with slight greenish tint, the root system grew rapidly (3±1 cm per week), root cilia were 1,0±0,5 cm long, and bright. The diameter of the leaf stalks reached 7±1,5 cm.

Such difference in plant development can be explained by the fact that in the first case these symptoms are associated with lack of organic and mineral substances in water, hence the need to increase the area of the root system through which the plant absorbs contaminants from water (elongated root cilia, a longer root system). In a clean environment, compared to the polluted one an increase in a diameter of leaf stalks is observed (Fig. 1).

In these conditions, the plants were large in size,, sometimes even reached a diameter of 45±5 cm, the leaves were of dark green saturated color. The plants very quickly formed a large number of lateral shoots with subsidiary plants; the increase amounted to 13±3 pieces of seedlings per unit a month, and in some cases reached 15–18 pieces. The number of leaves on one plant was 20±5.

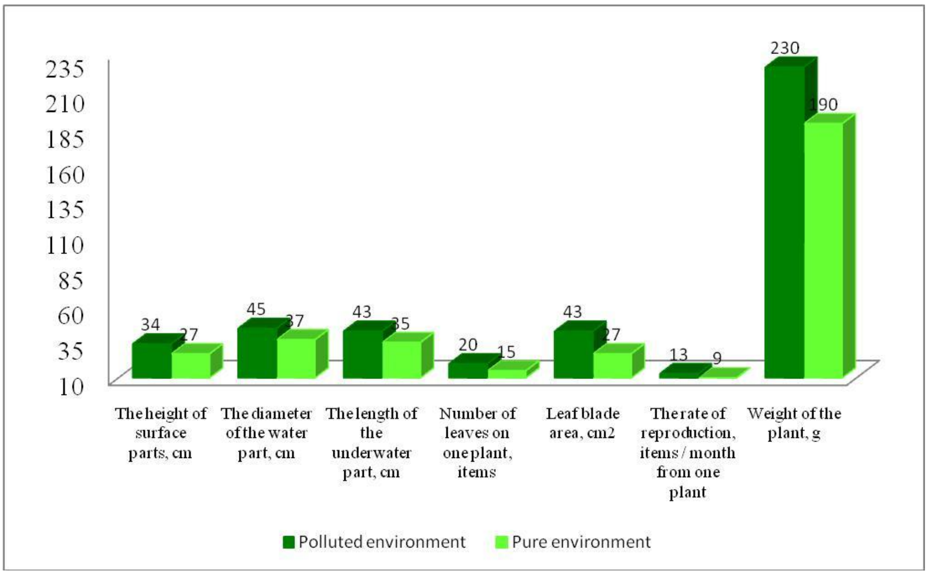

Fig. 1. The growth and development of water hyacinth plants under different growth conditions

The height of the surface part was within 34 ± 5 cm. The length of the root system reached 43 ± 3 cm, and in some instances it reached 50 cm, and the area of leaf plates ranged from 43 ± 7 cm^2. The weight per plant was 230±30 g, the biomass productivity of these plants was in total 1250±40 t/ha. The reason is that the landfills have a lot of substances of organic origin, which water hyacinth digests best. For clean environment the biomass productivity is 900±30 t/ha.

The plants grew quite intensively during the period of study. The average monthly growth of the surface part was 4.8 cm, the highest increase was observed during the first months of life and reached 11–13 cm, and the minimum of 1 cm was during the 5^{th} and the 6^{th} months of life.

The increase in the number of eyhonia plant leaves increases with the increase of the average air temperature (Fig. 2). Correlation-regression analysis showed that there is relationship between the growth rates of leaf mass and temperature conditions with correlation coefficient r = 0,84, which can be described as very high.

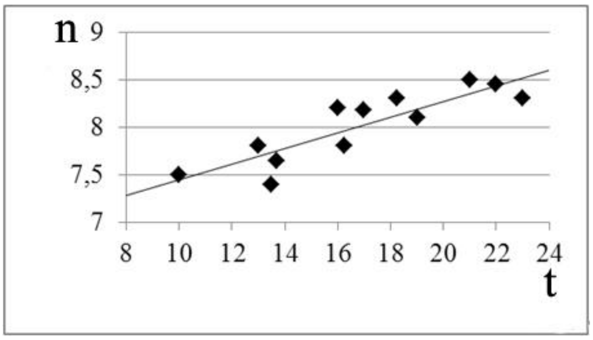

Fig. 2. Growth of assimilation system (n, items) for temperature conditions (t)

The average monthly growth of underwater part was 7.3 cm; the maximum increase was 15 cm during the 2^{nd} and

3rd months of life, the minimum – 1–2 cm – during the 5th and 6th months of life (Fig. 3). Correlation-regression analysis showed that there is relationship between the growth rate of the root system and temperature conditions with correlation coefficient r = 0,79, which can be described as high.

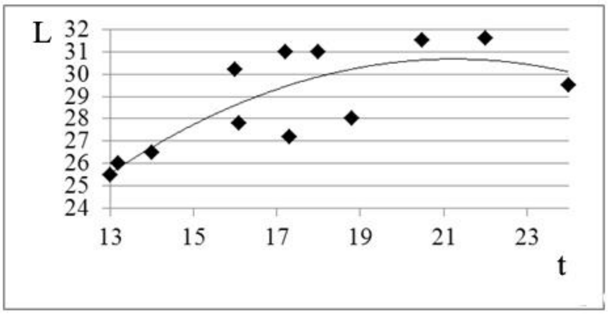

Fig. 3. Growth of the root system (L, cm) with temperature increase (t, ° C)

The average monthly increase in biomass plants of water hyacinth is 39.2 g. The total increase by one plant for 6 months is 186–206 g. The maximum monthly increase was 58 grams in six-month specimens of plants and the minimum was 27 g in one-month plants.

Correlation-regression analysis showed that the increase in biomass of water hyacinth is quite fast both in the length of surface and underwater parts – up to 13–15 cm per month, the average monthly increase is 39.2 g. For all the indicators there are relations with a coefficient of determination R2 = 0.89–94, which can be described as very high.

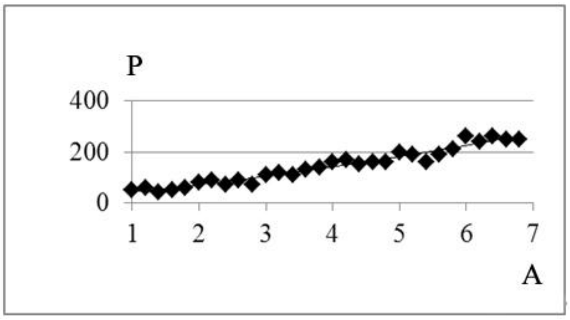

Fig. 4. Growth of biomass (P, g) of water hyacinth over time (A, months)

Further cooling caused the transfer of plants in artificial conditions, and some were left in the landfills and covered with foil (such as floating greenhouse). Water hyacinth representatives remaining in the chamber conditions evolved quite well. At water temperature of 20–30 °C, air temperature of 20–36 °C, with regular top-dressing of plants with silt every two days, Eyhornia vegetation and reproduction were quite successful.

1. Vegetation period of water hyacinth can last from 4 to 7 months in Vinnitsa region.

2. Water hyacinth has successfully adapted to the growing conditions, as biomass plants grew quite rapidly and formed to 8–15 subsidiary plants per month.

3. The most active vegetation of plants occurred in the reservoir, which was constantly affected with pulp of granite processing.

4. The average monthly increase of water part was 4.8 cm, the highest increase was observed in the first months of life and reached 11–13 cm, and the minimum of 1 cm – on the 5th and 6th months of life.

5. The average monthly increase of underwater part was 7.3 cm, the maximum increase was 15 cm in the 2nd – 3rd months of life, the minimum – 1–2 cm – 5th –6th month.

Research results

The average and maximum values of dry and wet water hyacinth biomass were established depending on the growth conditions (depth of water, % of water surface coverage, trophic level of ponds). According to the data the growth curve was constructed, its phases were defined and a model of water hyacinth growth was created.

Increase or decrease in the number of individual populations of plants is the result of physical, chemical and biological changes. In general, these changes are caused by the uncontrolled flow of nutrition elements from urban, agricultural and industrial centers.

Water hyacinth, due to its life cycle and survival strategy has significant advantages over other types of aquatic plants. Its adaptations to many environmental factors make extinction of this species almost impossible.

Westlake qualified water hyacinth as a very productive plant. According to the data obtained in Louisiana (USA) and in the waters of the river Nile (Africa), it was estimated that this kind under optimal conditions could produce up to 110–150 tons of organic matter per hectare per year [5, 6].

A wide range of productivity of this plant is noted in literature. These figures were calculated in different ways (Gopal [7]), Kipling and others [8] estimate that the annual production may be between 269 t/ha. Boyd [8] received the average productivity of 194 kg/ha/day in the enriched nutrient reservoir. This indicates that water hyacinth has a wide range of productivity.

The aim of this work is a description of the initial population of water hyacinth regarding environmental factors, creation of a model of optimum quantity of water hyacinth in water bodies and determination of the amount of biomass needed to remove the object in case of overcrowding.

Biomass was determined as the amount of organic matter in relation to the area or volume. Biomass and water volume in this case are directly proportional as the plant biomass grows in the presence of nutrient resource.

The plants biomass was studied by weighing samples, measuring of the studied area and defining the biomass of the entire population. From one square meter, the samples were collected, drained for 5–7 minutes, and their weight was determined.

7 ponds areas were selected to measure the growth and 1 kg of plants samples were researched (healthy, intact, with 3–5 leaves, of the same weight – from 30 to 45 g each and placed at each site.)

The growth of the plants was determined by weighing the increase in water hyacinth mass per unit of area and for a unit of time i.e. its productivity. Quantitative rate of the growth is essential to control the number of water hyacinth. The rate of this index depends on the following factors: plant age, climate, space and density of plants.

The studies described three parameters (biomass, density and growth rates). The main characteristics of the objects are shown in Table 2. Reservoirs were classified as mesotrophic if phosphorus concentrations were between 10 and 35 mg/m^3 or eutrophic if the concentration of phosphorus ranged from 35 to 100 mg/m^3

The highest average values of biomass were 49.6 (2.79) 42.6 (2.39) and 45.7 (2.57) kg/m^2 and the maximum values of 76 (4.27) 57 (3.20) and 67 (3.76) kg/m^2, were in reservoirs areas 2, 3 and 7. These were the smallest studied reservoirs and they had the highest density. Generally, these values are similar to those obtained in other parts of the world [1; 9–11]. The maximum surface coverage was generally observed when the area coverage was minimal, and therefore the volume was the smallest.

It should also be noted that the growth of water hyacinth plants is the highest in waters with little depth, and the lowest recorded productivity was observed in the deepest waters.

Table 2

Parameters of water object

Water body	Parameters of water reservoir					
	temperature, °C	precipitations, mm	surface area, m^2	volume, th.m^3	depth, m	trophical level
1	17,2	1096	38,79	89,22	2,30	mezotrophic
2	22,0	900	10,00	4,00	0,40	eutrophic
3	24,4	814	5,70	21,60	0,90	mezotrophic
4	25,3	734	24,00	79,83	14,00	eutrophic
5	15,4	553	17,30	27,00	5,00	eutrophic
6	17.0	609	8,43	126,45	15,00	eutrophic
7	21,1	1237	5,40	33,56	1,94	mezotrophic

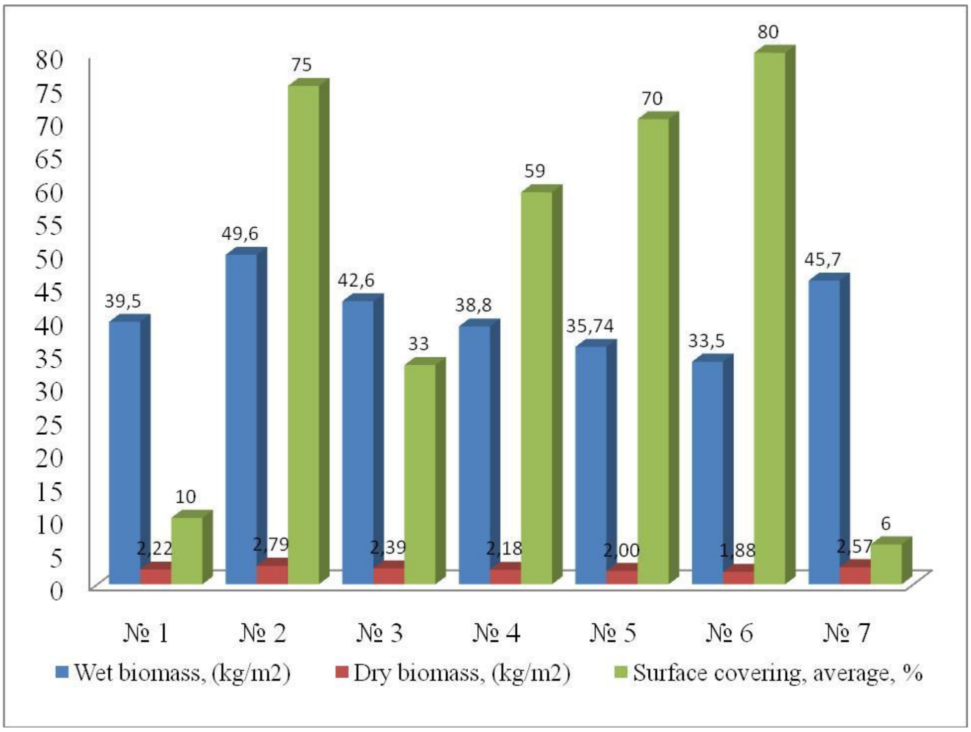

Fig. 5. The total biomass of plants Eichhornia crassipes (Mart.) Solms in vivo environment of water

The studies have also shown the highest rates of biomass observed in reservoirs 2 (49.6 kg / m^2 of wet and 2,79 kg/m^2 of dry biomass), 3 (42.6 kg/m^2 of wet and 2.39 kg/m^2 of dry biomass) and 7 (45.7 kg/m^2 of wet and 2.57 kg/m^2 of dry biomass). Obviously, this is due to the optimum growth of temperature conditions (21,1–24,4 ° C). Minimum rates of biomass were observed in reservoirs 1 (39.5 kg/m^2 of wet and 2.22 kg/m^2 of dry biomass), 4 (38.8 kg/m^2 of wet and 2.18 kg/m^2 of dry biomass), 5 (35, 74 kg/m^2 of wet and 2,0 kg/m^2 of dry biomass) and 6 (33.5 kg/m^2 of wet and 1.88 kg/m^2 of dry biomass).

The percentage of the water surface coverage is associated with trophic level of the reservoir. The nutrients that cause eutrophication, primarily include nitrogen, phosphorus and silicon in a variety of compounds. The most important are phosphorus and nitrogen, which are binding elements of any living organism's tissues.

The concentration of nutrients and their mode depends on the intensity of biological and biochemical processes in the reservoir and the amount of nutrients entering the pond with sewage and surface runoff in the catchment area. The concentrations of nitrogen and phosphorus characterize "trophicality" ("nutrition") of the reservoir.

Excessive water eutrophication begins at nitrogen concentration of 0.2–0.3 mg/l and phosphorus – 0.01–0.02 mg/l.

In the transition from oligotrophic ponds to mesotrophic and eutrophic ones, the content of ammonia nitrogen significantly increases in its total amount.

Thus, areas of water bodies that had a significant level of eutrophication, were characterized by high percentage of water surface coverage (59–80 %), and mesotrophic (with medium eutrophication) had low surface coverage (6–33 %).

In assessing the growth processes of the plants cultivated in version 5, the characteristics of the growth of water hyacinth are defined.

According to the obtained data, one can see that the growth curve is characterized by three phases:

1) phase of delay, represented by exponential growth;
2) phase of linear growth,
3) a slow phase of exponential growth.

Maximum productivity was achieved during the period when maximum biomass of 51 kg/m^2 was obtained in the period from July to February, 51 kg/m^2 from December to March and 55 kg/m^2 from April to June. So maximum biomass was determined, that was about 2,300 g/m^2 in dry weight, with the range of values within 2,101–3.916 g/m^2. The research in all the periods showed a clear linear relationship of biomass growth during the time with determination coefficients of R^2 = = 0.96–0,87, which can be described as very reliable.

Concerning the growth rate, the average rate of 52 g/m^2/day was observed in June and July, with a maximum value of 64 g/m^2/day. In option 5 the rates 59.1 and 60.4 g/m^2/day were defined from July to February and from April to June. The growth rate in both periods was calculated according to the inclination of the growth curve.

If we consider the average growth rate of 0.551 t/ha/day during the increase season (from April to November, 244 days), we can consider, that annual growth can be about 134.4 tons/ha.

As seen in Fig. 6, the seasonal dynamics of water hyacinth growth is distributed as follows: the highest relative growth rate is typical for spring (9.34 %) and summer (8.20 %) periods. During the autumn cold spells, relative growth rate falls (2.03 %). The time of biomass doubling in spring and summer is the highest – 7.42 and 8.45 days, respectively, in the autumn period the time of biomass doubling is much longer, reaching 34.60 days. According to these data, the rate of exponential growth is calculated. It is determined, that in spring and summer this figure is 0.072 and 0.049 g/day, and in autumn it falls to 0.016 g/day.

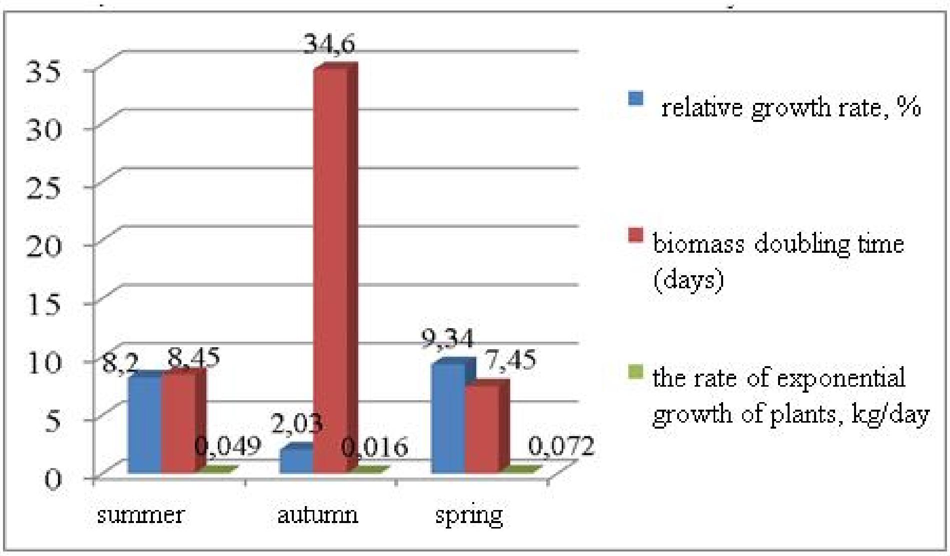

Fig. 6. Relative growth rate, doubling time, the density of the plants and the growth rate of the water hyacinth

Conclusions

The main problem for the studied water objects is the excess of maximum permissible levels of nutrients.

To solve this problem it was proposed to use such environmental measures as bio-filtration of water by means of macrophytes (higher aquatic plants), namely water hyacinth.

The results of the studies of the plants growth and development under conditions of eutrophycation waters are presented.

References

[1] Pazich V. M. Rist i rozvitok ejhorniї prekrasnoї v zabrudnenomu vodnomu seredovishchi // Nauk. zap. Ternop. nac. ped. un-tu. Ser. Biol., 2010, No. 2 (43). – S. 383–386.

[2] Biofil'tr dlya ochistki stichnih vod riznogo pohodzhennya z vikoristannyam vishchoї vodnoї roslinnosti vidu Eichornia crassipes / G. I. Vasenkov, T. P. Vasil'ok, V. M. Dema, V. M. Pazich// Nauk. visnik ZHNAEU: zb.nauk.-tekhn.prac'. ZHitomir, 2009. Vip. 1. – S. 283–289.

[3] Ochistka stokiv sil's'kogospodars'kogo pohodzhennya na biofil'tri z vishchoyu vodyanoyu roslinnistyu vidu Eichornia crassipes / G. I. Vasenkov, T. P. Vasil'ok, V. M. Pazich // Nauka. Molod'. Ekologiya – 2009: mat. V nauk.-prakt. konf. studentiv, aspirantiv ta molodih vchenih. ZHitomir, 27–29 travnya, 2009. Zhitomir, 2009. S. 91–92.

[4] ZHizn' rastenij: v 6-ti t. / gl. red. A. L. Tahtadzhyan. – M.: Prosveshchenie, 1982. T. 6. Cvetkovye rasteniya / pod red. A. L. Tahtadzhyana. 543 s.

[5] Pazich V. M. Model' regulyuvannya biomasi i produktivnosti vodnogo giacinta // Visnik ZHNAEU, No. 2012, No. 1. S. 363–369.

[6] Westlake D. F. Comparisons of plant productivity / D. F. Westlake // Biological Reviews. 1963. P. 38, 385–425.

[7] Gopal B. Water hyacinth. Aquatic Plant, Studies 1 / B.Gopal // Elsevier Science, Amsterdam, 1987. – 471 p.

[8] Strategies for waterhyacinth (Eichhornia crassipes) control in Mexico / Gutierrez, L. E., Huerto, R. D., Saldana, F. P. and Arreguin, F. // Hidrobiologia. 1996. P. 118–185, 340.

[9] Metodika ekologichnoї ocinki yakosti poverhnevih vod za vidpovidnimi kategoriyami. V. D. Romanenko, V. M. ZHukins'kij, O. P. Oksiyuk, ta in. K.: SIMVOL-T, 1998. 28 s.

[10] Braginskij L. P. Nekotorye principy klassifikacii presnovodnyh ehkosistem po urovnyam toksicheskoj zagryaznennosti //Gidrobiol.zhurn. 1985. 21, No. 6. S. 65–74.

[11] GOST 17.1.5.02.80. Ohrana prirody. Gidrosfera. Gigienicheskie trebovaniya k zonam rekreacii vodnyh ob"ektov. M.: Gosstandart SSSR. 6 s.