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USE OF EICHORNIA CRASSIPES FOR SEWAGE TREATMENT AND PRODUCTION FEED ADDITIVE

The article devotes to the studying of the method of sewage treatment using higher aqueous plant water hyacinth (*Eichornia crassipes*). Studies have shown that the plant can reduce the average COD of polluted water by 90%. Moreover, was shown that the excess of the green mass of water hyacinth can be used in the production of feed additives for farm animals.

Introduction. The idea of use of plants for purification of the polluted waters isn't new as it is possible to call many known plants clearing water in bogs, ponds and lakes, for example, a *Lemna* L., *Wolffia arrhiza* L., *Scirpus sylvaticus* L., *Typha angustifolia* L., *Potamogeton pectinatus* L., *Elodea* Michx., *Butomus* L., *Sagittaria* L., *Mykriokphyllum* L., *Ceratophyllum* L. [1, 2].

One more the higher water plant (HWP) known in quality of a good cleaner of the polluted waters, *Eichornia crassipes* (a water hyacinth) which belongs to *Pontederiaceae* family (*Pontederiyevye*). This perennial water plant which homeland are tropical regions of South America, however now it was settled everywhere in the countries of Asia, Africa, Australia.

At enough heat and light, in water rich with nutrients the plant is capable to expand very quickly. So, for example, in tropics 1 socket for 50 days is capable to give to one thousand new plants.

Eichornia is the semi-shipped plant and is capable to exist both in free-floating on a water surface, and in the attached state.

In a structure of leaves the geterofilliya is observed. Leaves form the socket floating on a water surface, and swellings in which there is a pneumatic fabric, carry out function of the floats giving to a plant stability. Leaves dark green, glossy.

When the eichornia grows a single bush, big swellings thanks to which the plant doesn't overturn on a water surface are formed. If it is surrounded by other sockets, then swellings decrease in sizes, become extended, bottle-shaped. On an adult plant can be to 10 leaves.

At the end of summer, during blossoming, from the center of the socket rises peduncle with a spiky inflorescence on which there are violet-blue flowers, in the center of more brightly painted top petal there is a dark yellow spot.

Under natural conditions by pollination tropical insects at a plant form a fruit – a box with seeds [3]. As under natural conditions the eichornia grows in the countries with tropical and subtropical climate, feature of application of a plant under our conditions is its seasonality.

The eichornia under our conditions only vegetative directly in a reservoir lateral offshoots lateral. On the stollon – lateral horizontal escapes there are young plants with backs.

The root system of an eichornia which is in water represents long, threadlike hairs which provide the main process of cleaning. Eichornia, thanks to the well developed root system, is capable to besiege the weighed substances containing in water and quickly to clear the polluted water therefore now the given plant is considered as one of the best plants filters.

Besides, in the tropical countries ours – whether application to green biomass of a plant: it is used on a forage to fishes, waterfowl and cattle, as green fertilizer, in production of biogas. And also the dried-up parts of plants use by production of paper of low quality, wall plates, ropes, means of personal hygiene, baskets, furniture [4, 5].

Now the eichornia starts winning popularity not only in Russia, but also in our republic. So at Institute of cytology and genetics of the Siberian Branch of the Russian Academy of Science the biological technology of sewage treatment various about different origins by means of an eichornia is developed, and on the lake Yubileyny (Grodno) employees of RUAP “Grodno Vegetable Factory” [6] landed some hundreds of sockets of a plant for its cleaning.

However in work [7] it is specified that the most effective way of use of an eichornia is tertiary treatment of biologically cleared drains having stable structure in comparison with initial drains as excessive emissions of the specific polluting substances lead to partial death of plants.

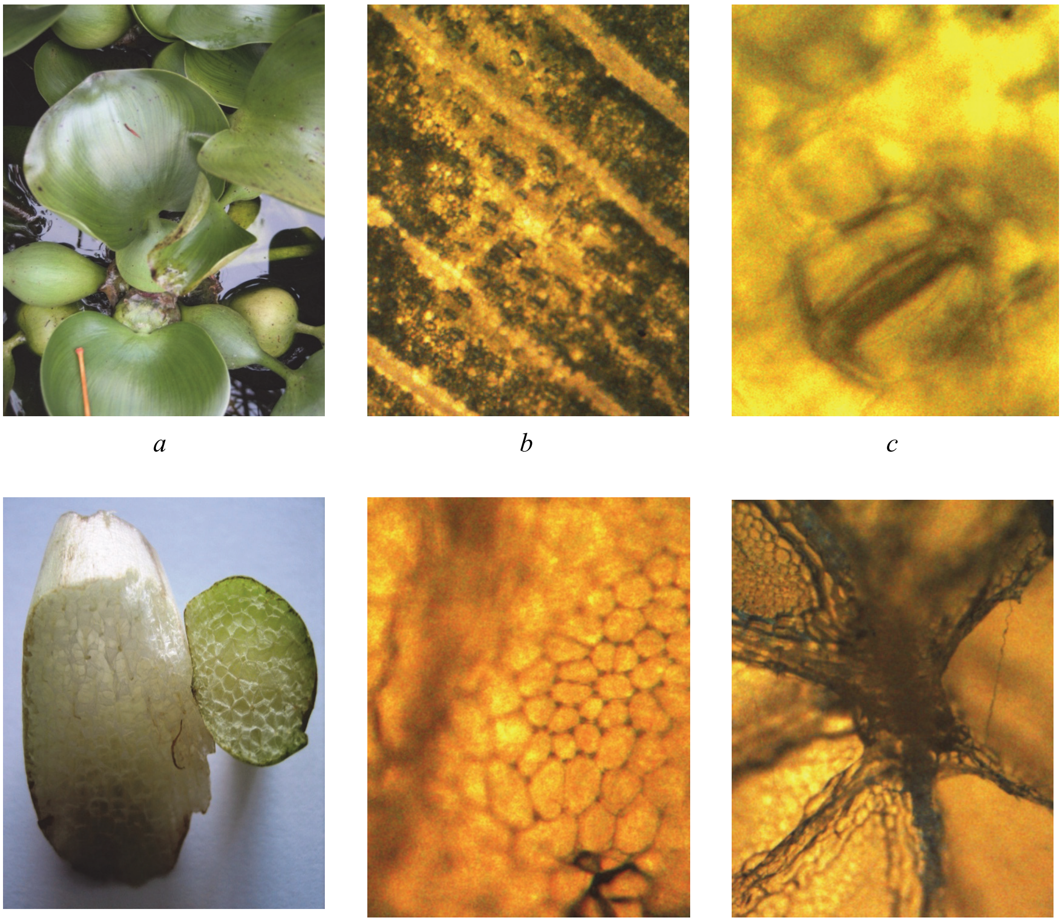
The work purpose – to define efficiency of sewage treatment by the higher water plant *Eichornia crassipes* and possibility of use of biomass of a plant for production of feed additive.

Main part. At the first stage of researches by means of a microscope (MBL2000-Serie Multipurpose microscope, Germany) the structure of leaves and roots of a water hyacinth was studied. Leaves of a water hyacinth (Fig. 1, *a*) are covered with the wax raid which is badly passing moisture. It promotes reduction of loss of water from a surface of leaves and to maintenance of a plant on a surface of reservoirs. From above and from below the leaf is covered with integumentary fabric (Fig. 1, *b*). Among colorless cages of a thin skin from the lower party pair semicircular stomatal cells between which there is an opening – a stomatal slit (Fig. 1, *c*) are located.

The internal part of a leaf is formed by the assimilating fabric providing photosynthesis process. Cells of this fabric contain a large number of chloroplasts which give green color to a leaf. The pulp of a leaf is penetrated by the veins formed by the conducting vessels and sieve tubes, and also the fibers giving durability. The water hyacinth has very unusual, round swollen petioles (Fig. 1, *d*).

The main part of petioles is made by the pneumatic fabric or an aerenchyma constructed of the cages connected among themselves in such a way that between them there are large emptiness filled with air (Fig. 1, *e*). The aerenchyma is constructed of the cages of a star-shaped form connected with each other by the spurs (Fig. 1, *f*). Thanks to an aerenchyma the specific weight of a plant decreases and bodies of a plant stand up straight in water.

The water hyacinth possesses very developed root system. A root (Fig. 2, *a*) on length it is possible to divide into some sites, having a different structure and carrying out certain functions. These sites are called root zones. Root hairs (Fig. 2, *b*) are the strongly extended outgrowths of the external cages covering a root. Their length reaches 10 mm. The root continuously grows, forming all new sites of root hairs. The root site where root hairs died off, some time is capable to soak up water, but then becomes covered by a stopper and loses this ability.



a *b* *c*

d *e* *f*

Fig. 1. *Eichornia crassipes*:
a – a plant in the pond; *b* – the lower surface of the sheet at ×40 magnification; c – while increasing stoma ×400;
d – the cut stem water hyacinth; *e* – aerenchyma with increasing ×100;
f – connect with increasing cell aerenchyma ×40

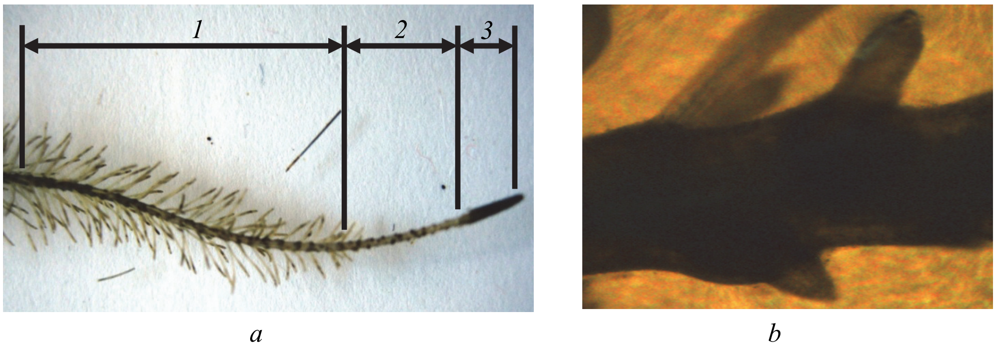


Fig. 2. Eichornia root:
a – a root (*1* – an absorption zone; *2* – stretching zone; *3* – division zone);
b – a place of growth of root hairs at increase in ×40

The hair cover very thin that facilitates absorption of nutrients. Occupies almost all cell of a hair vacuoles, surrounded with a thin layer of cytoplasm. Absorption is promoted by allocation by root hairs of acids (coal, apple, lemon) which dissolve mineral salts. Ability of an eichornia to cleaning of the polluted drains and removal of a huge range of pollution has also a talk with a large number of root hairs existences of the developed root system.

In literature there are data that by means of an eichornia it is possible to draw the majority of nutrients from drains, such as nitrogen, phosphorus, potassium, calcium, magnesium, manganese, sulfur, and also to delete phenols, sulfates, oil products, synthetic surface-active substances, phosphates. Thus indicators of COD and BOD decrease [8–10].

For studying of efficiency of sewage treatment by means of an eichornia model sewage and water from the Minsk Treatment Plant (MTP) were used. In capacity from 5 dm^3 of sewage placed on one socket of an eichornia. Used six monthly plants. Experiment was made in triple frequency at the room temperature (22 ± 2)°C.

The composition of model sewage is developed according to literary data on admissible values of concentration of the polluting substances in the sewage cleared by means of an eichornia (Table 1) [11].

Table 1

Composition of model sewage

Chemical substance	Quantity, mg/dm^3
Sodium hydrophosphate twelve-water	67.80
Ammonium nitrate	282.35
Sodium sulfide nine-water	157.50
Gland chloride six-water	106.27
Synthetic surface-active substance	14.00
Petroleum products	25.00
Phenols	340.00

In the course of cleaning measurements of the main indicators of the cleared waters were taken, results are presented in Tables 2 and 3.

Table 2

Indicators of purification of model sewage

Indicators	Model sewage	
	control*	sample**
BOD, mg O_2/dm^3		
0 days	306.1 ± 15.3	
8 days	253.1 ± 12.7	169.2 ± 8.5
19 days	200.4 ± 10.0	69.1 ± 3.5
COD, mg O_2/dm^3		
0 days	591.8 ± 29.6	
6 days	552.3 ± 27.6	441.6 ± 22.1
15 days	507.4 ± 25.4	158.2 ± 7.9
27 days	481.7 ± 24.1	73.6 ± 3.7
Nitrate ions, mg/dm^3		
0 days	205.8 ± 10.4	
27 days	201.4 ± 10.7	8.7 ± 0.4
Ions of ammonium, mg/dm^3		
0 days	58.6 ± 3.1	
28 days	55.4 ± 2.8	5.3 ± 0.3
Phosphate ions, mg/dm^3		
0 days	18.2 ± 0.9	
29 days	17.4 ± 0.9	1.2 ± 0.1
Phenols		
0 days	345.3 ± 17.0	
29 days	308.1 ± 10.3	No
Fats and oils, mg/dm^3		
0 days	25.3 ± 1.3	
30 days	20.7 ± 1.1	No

COD and BOD determined by the techniques stated in [12], other indicators determined by techniques [13].

During researches it was established that less than for 30 days efficiency of purification of model sewage made more than 80%. Indicators of purification of sewage with MTP are slightly worse, but all received results confirm possibility of use of an eichornia for sewage treatment.

Table 3

Indicators of purification of sewage with MTP

Indicators	Sewage with MTP	
	control*	sample**
1	2	3
BOD, mg O_2/dm^3		
0 days	243.0 ± 12.2	
12 days	189.1 ± 9.5	84.1 ± 4.2
1	2	3
COD, mg O_2/dm^3		
0 days	572.9 ± 28.5	
12 days	385.3 ± 19.3	172.6 ± 8.6
21 days	303.3 ± 15.2	58.2 ± 2.9
Nitrate ions, mg/dm^3		
0 days	0.29 ± 0.01	
20 days	0.51 ± 0.03	–
Nitrate ions, mg/dm^3		
0 days	0.11 ± 0.01	
20 days	0.12 ± 0.01	0.10 ± 0.01
Ions of ammonium, mg/dm^3		
0 days	39.5 ± 1.9	
21 days	31.6 ± 1.6	10.8 ± 0.5
Sulfate ions, mg/dm^3		
0 days	45.4 ± 2.3	
21 days	52.8 ± 2.6	23.4 ± 1.2
Phosphate ions, mg/dm^3		
0 days	4.7 ± 0.2	
23 days	4.3 ± 0.2	0.15 ± 0.03
Fats and oils, mg/dm^3		
0 days	3.5 ± 0.2	
24 days	3.2 ± 0.2	No

* Control – an initial sample of sewage;

** A sample – a sewage sample with the eichornia placed in it.

On the following stage of researches before us there was a task to define the main indicators of plant material as by production of feed additive the great value is given to indicators of a chemical composition of plants on the basis of which judge possibility of its use.

From the data presented in Table 4 it is visible that the plant is rich with carotene, crude cellulose, a protein and, besides, doesn't accumulate in the composition of radionuclides that corresponds to literary data [5, 11].

Table 4

Chemical composition of vegetable weight eichornia (in terms of solid)

Indicator		Value of an indicator
Humidity, %		25.00 ± 1.05
Crude ashes, %		16.66 ± 0.82
Crude cellulose, %		11.21 ± 0.56
Carotene, mg/kg		69.68 ± 3.48
Crude fat, %		1.60 ± 0.08
Crude protein, %		10.83 ± 0.54
Specific activity, Bq/kg	Caesium-137	10.50 ± 1.00
	Potassium-40	437.40 ± 87.50
Soluble carbohydrates, %		19.00 ± 0.95

For studying of change of chemical composition of biomass of a plant before sewage treatment researches with use of the scanning electronic microscope of JSM 5610LV with system of the electron probe power dispersive analysis (JEOL Ltd were conducted., Japan). By results of the power dispersive analysis it was established that before sewage treatment, the composition of biomass of a plant remains invariable.

Proceeding from a sugar ratio to a crude protein 1.7: 1.0 it is possible to draw a conclusion that an eichornia it will be good to be exposed to siloing [11].

All green biomass of an eichornia after sewage treatment with MTP was dried up at the room temperature. It is known that these raw materials can be used as feed additive for farm animals. However biomass of a plant can be used for receiving a silo. In Fig. 3 the scheme of experiment on studying of process of siloing with plant biomass use is submitted.

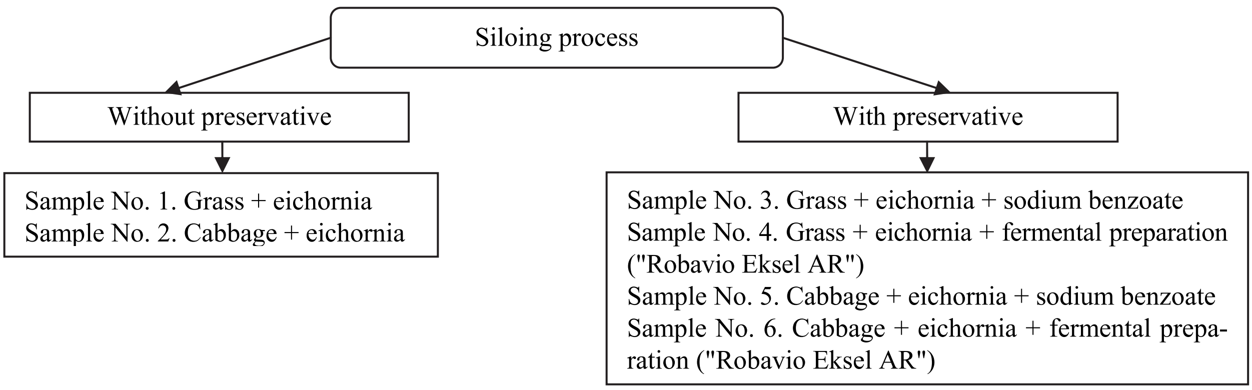


Fig. 3. Scheme of experiment

Bulk feed additive of an eichornia was mixed with various components specified Fig. 3 in such proportion that the general humidity of mix made 60%. Weight was stamped carefully and densely closed in glass capacities with the ground-in covers to prevent contact with air. Capacities left without access of light at the room temperature. The assessment of quality of a ready silo was made not earlier than in 30 d after a laying of raw materials.

The most important for siloing process indicators of the initial raw materials placed on siloing are given in Table 5.

Table 5

Indicators of silosuyemy raw materials *

Indicator	Carotene, mg/kg	Crude protein, %	Crude cellulose, %
Sample No. 1	20.30 ± 1.02	11.59 ± 0.64	6.98 ± 0.33
Sample No. 2	21.78 ± 1.09	8.58 ± 0.43	7.53 ± 0.32
Sample No 3	19.90 ± 1.65	11.73 ± 0.65	6.79 ± 0.33
Sample No. 4	20.10 ± 1.01	11.49 ± 0.57	7.06 ± 0.35
Sample No. 5	21.63 ± 1.08	8.72 ± 0.44	7.36 ± 0.37
Sample No. 6	21.29 ± 1.08	8.39 ± 0.42	7.81 ± 0.38

* Results represent average arithmetic value of three parallel measurements of one experiment.

On the end of siloing carried out determination of quality of a ready silo by the techniques stated in [15–17]. The received results are given inTable 6.

Samples No. 3, 4, 5 and 6 had the pleasant, slightly sourish smell. In them the structure of plants remained, slices of leaves easily differed, they are elastic and easily separated from each other. It characterizes a silo as good-quality. The example of such silo is given in Fig. 4.

Fig. 4. Silo of appropriate quality

Samples No. 1 and 2 were characterized by existence of a mold and a putrefactive smell. Such silo can't be used for feeding by an animal.

Also definition of a contamination of the received silo samples was carried out. When seeding tests of samples No. 3, 4, 5, 6 on nutrient mediums (Capek's circle, a mash an agar, a nutritious agar) a foreign microbiota (filamentous fungi, yeasts) it isn't revealed.

When seeding tests of samples No. 1 and 2 on nutrient mediums mass development of yeast and the filamentous fungi that is inadmissible for a good-quality silo was observed.

As a result of a complex assessment of the received silo it is possible to draw a conclusion that samples No. 3, 4, 5, 6 are suitable for feeding of farm animals and on the quality belong to the first class [14, 15].

Table 6

Indicators of a ready silo

Indicator	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Sample No. 6
Content of dry substance, %	36.52 ± 1.83	59.30 ± 2.97	55.04 ± 2.75	48.69 ± 2.40	53.32 ± 2.67	47.22 ± 2.36
pH	7.50 ± 0.30	6.90 ± 0.30	4.20 ± 0.20	4.00 ± 0.20	3.90 ± 0.20	4.10 ± 0.20
Crude protein, %	14.54 ± 0.73	14.86 ± 0.74	12.80 ± 0.64	13.74 ± 0.68	11.61 ± 0.63	17.75 ± 0.95
Carotene, mg/kg	13.89 ± 0.69	9.49 ± 0.47	10.05 ± 0.05	20.19 ± 1.01	16.19 ± 0.81	4.85 ± 0.24
Crude ashes, %	15.22 ± 0.76	13.61 ± 0.68	14.23 ± 0.71	13.12 ± 0.66	13.99 ± 0.69	13.96 ± 0.69
Crude cellulose, %	4.34 ± 0.30	3.91 ± 0.20	6.92 ± 0.35	7.01 ± 0.35	7.64 ± 0.38	7.56 ± 0.38
Oleic acid, %	yes	yes	no	no	no	no
Fodder units	–	–	0.79	0.80	0.79	0.82
Exchange energy, MDZh	–	–	9.57	9.65	9.46	9.89

Conclusion. The carried-out literary and experimental researches confirmed that by means of an eichornia it is possible to create low-cost water-purifying systems. The plant biomass which is formed at sewage treatment can be used for receiving a high-quality silo.

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