

# БІОРЕСУРСИ ТА ЕКОЛОГІЯ ВОДОЙМ

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Ribogospod. nauka Ukr., 2015; 4(34): 5-14

DOI: <http://dx.doi.org/10.15407/fsu2015.04.005>

УДК [574.64 : 639.3/6] : 546.3 (477)

## HEAVY METALS IN ABIOTIC AND BIOTIC COMPONENTS OF AQUACULTURE HYDROECOSYSTEM "ISHKHAN"

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**Purpose.** To determine the heavy metal content in abiotic components (water and bottom sediments of tanks), feeds, organs and tissues of rainbow trout in the conditions of industrial aquaculture.

**Methodology.** The materials for the study were 1+ rainbow trout cultivated in 2011–2012, which were produced from brood rainbow trout reared in the tank aquaculture farm "Ishkhan". Experimental fish were collected from rearing tanks №№ 3–4. Mean fish weight was 466 g with mean fork length of 36 cm. Fish stocking density at the final stage of rearing was 50 kg/m<sup>3</sup> or 100 fish/m<sup>2</sup>. Fish were kept according to standard salmon culture methods. Quantitative determination of heavy metal concentrations in water, bottom sediments and fish were performed by direct suction of solution in propane-butane-air flame with the aid of absorption spectrophotometer S-115-M1.

**Findings.** The results of the performed studies include the determined ecological state of rearing tanks and quality of marketable rainbow trout of the fish farm "Ishkhan" by the above-mentioned characteristics.

Main hydrochemical parameters, which characterized water quality, complied with aquaculture norms. However, a tendency for an increase in heavy metal content was noted in bottom sediments. In particular, an increased content of copper, nickel as well as toxic elements – lead and cadmium was observed.

**Originality.** First study of the ecological state of rearing tanks of the fish farm "Ishkhan".

**Practical value.** The obtained results of the ecological state of rearing tanks of the fish farm "Ishkhan" will allow creating optimum conditions for fish rearing.

**Keywords:** hydrochemistry, heavy metals, bottom sediments, rainbow trout.

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## PROBLEM STATEMENT AND ANALYSIS OF LAST ACHIEVEMENTS AND PUBLICATIONS

To assess the ecological-toxicological situation in water bodies, to determine the quantities of toxic substances, which migrate in aquatic medium, and the degree of their effect and aquatic organisms, it is important to know the levels of their contents and accumulation in abiotic and biotic components of an aquatic ecosystem as well as the processes of the transfer of these substances through the trophic chain. The latter aggravates the ecological risk of water pollution for both restoration of biological

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resources in water bodies and human health when consuming fish. Among toxic substances in the environment, heavy metals pose a special risk. In the majority, metals are an essential component for normal living of aquatic organisms (excluding mercury, lead, and cadmium) but their excessive accumulation in organs and tissues including in fish can be toxic [1–3].

Fish farm "Ishkhan" is located in vil. Banyliv of Chernivtsi region and currently is one of leading fish farm in the field of production of marketable trout. This fact is explained by the use of a wide assortment of trout forms including autumn spawning kamloops, spring spawning rainbow trout and "Adler amber" strain [5]. Water supply of the fish farm is ensured by wells and aquifers, the total debit of which is about 300 dm<sup>3</sup>/sec. For maximum use of the available amounts of water, a semi-closed cycle of water consumption is applied, which is ensured by three airlifts with a power of 300, 200, 300 dm<sup>3</sup>/sec. Average annual temperature is within 12 °C, in summer is can raise to 17 °C, while in winter is within 5 °C. Fish stocking density depends on age group and is 20–50 kg/m<sup>3</sup>. The dissolved oxygen content is incoming water is 85%, which drops to 55% in the outlet. The total water area is 5600 m<sup>2</sup>. The aquaculture facility of the fish farm "Ishkhan" consists of the following tanks: brood stock – 1 (area of 200 m<sup>2</sup>), replacement – 2 (300 m<sup>2</sup>), nursery for fingerlings – 15 (57 m<sup>2</sup>), nursery for yearlings – 7 (1400 m<sup>2</sup>), fattening — 12 (3724 m<sup>2</sup>).

### HIGHLIGHT OF THE EARLIER UNRESOLVED PARTS OF THE GENERAL PROBLEM. AIM OF THE STUDY

The aim of this work was to determine heavy metal contents in abiotic components (concentration in water and their content in bottom sediments of tanks), feeds, organs and tissues of rainbow trout of the fish farm "Ishkhan" in the conditions of industrial aquaculture.

### MATERIALS AND METHODS

Sampling was performed in the summer of 2012. The material for the study were 1+ rainbow trout reared in 2011–2012 and obtained from brood rainbow trout kept in the fish farm "Ishkhan". Fish were collected from rearing tanks №№ 3–4. Mean fish weight was 466 g with mean fork length of 36 cm. Fish stocking density was 50 kg/m<sup>3</sup> or 100 fish/m<sup>2</sup>. Fish rearing was performed according to standard trout culture methods [4–6].

Heavy metal contents (iron, zinc, manganese, copper, nickel, cobalt, lead, cadmium) in water, bottom sediments, organs and tissues (muscles, gills, liver, kidneys, heart, spleen, skin) of rainbow trout were measured according to standard methods. The determinations were performed with the aid of atomic-absorption spectrophotometer S-115-M 1 at the laboratory of the Institute of Fisheries NAAS of Ukraine, Kyiv. All hydrochemical parameters were determined based on standard methods at the laboratory of ecological studies.

### STUDY RESULTS AND THEIR DISCUSSION

By chemical composition based on O.A. Al'okhin classification, water in the experimental tanks of the fish farm "Ishkhan" belongs to hydrocarbonate class of calcium group, type I. the content of major anion (hydrocarbonate) was 256.3–268.5 mg/dm<sup>3</sup>, major cation (calcium) — 68.1–70.9 mg/dm<sup>3</sup>. The examined water had



average mineralization, where the total content of ions was 383.7–411.9 mg/dm<sup>3</sup> with pH 7.5. i.e. the medium of rearing tanks was weakly alkaline (Tables 1, 2).

The technological measures performed when rearing rainbow trout have effect on water quality in tanks. Feeding of fish and their metabolites increase biogenic load and result in an increase of nitrogen containing compounds in water, such as ammonium – by 5.6, nitrites – by 4.5, nitrates – by 1.3 times that is observed in the outlets from the tanks (Table 2).

*Table 1. Salt regime in tanks of the fish farm “Ishkhan”, summer 2012*

Sampling site	Major ions, mg/dm <sup>3</sup>						Total hardness, mg-eq/dm <sup>3</sup>	Mineralization, mg/dm <sup>3</sup>
	Cations			Anions				
	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup> + K <sup>+</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>		
Water inlet	70.9	7.3	21.3	256.3	12.0	64.6	4.1	389.6
Water outlet	68.1	6.1	33.5	268.5	13.5	66.7	3.9	411.9
Pump house	68.1	9.7	18.3	256.3	10.7	60.1	4.2	383.7

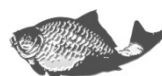
*Table 2. Gas regime, biogenic elements and organic substances in tank water of the fish farm “Ishkhan”, summer 2012*

Sampling site	pH	NH <sub>3</sub> , mg/dm <sup>3</sup>	Oxygen demand, mgO/dm <sup>3</sup>		Biogenic elements				
			Perman-ganate	Bichro-mate	NH <sub>4</sub> <sup>+</sup> , mgN/dm <sup>3</sup>	NO <sub>2</sub> <sup>-</sup> , mgN/dm <sup>3</sup>	NO <sub>3</sub> <sup>-</sup> , mgN/dm <sup>3</sup>	PO <sub>4</sub> <sup>3-</sup> , mgP/dm <sup>3</sup>	Fe <sup>2+,3+</sup> , mgFe/dm <sup>3</sup>
Water inlet	7.5	0.002	2.1	5.2	0.22	0.02	0.49	0.05	0,48
Water outlet	7.4	0.006	1.7	4.4	1.24	0.09	0.62	0.04	0,43
Pump house	7.5	0.002	1.7	4.4	0.21	0.01	0.57	0.02	0,26
Normed values	7.0–7.5	no more than 0.07	10.0	–	1.0	0.05	0.1	–	–
Maximum allowable limits	6.5–8.0	0.1	15.0	–	1.5	0.1	1.0	–	–

Thus, the hydrochemical regime of the investigated tanks by the examined parameters complied essentially with normative values. Water in rearing tanks was loaded with organic substances and biological load did not result in significant consequences of changes in water quality.

The toxicological state of tanks of the fish farm “Ishkhan” was assessed based on heavy metal content in following components of the aquaculture hydroecosystem – water, bottom sediments, organs and tissues (muscles, gills, liver, kidneys, heart, spleen, skin) of rainbow trout and in the combined feed.

It was found that heavy metal concentration in water (Table 3) of the fish farm was within following limits: iron — 27.3–87.6 µg/dm<sup>3</sup>; zink — 3.0–4.5; manganese — 1.8–6.3; copper — 1.2–1.8; nickel — 4.5–18.6; cobalt — 4.2–4.8; lead — 7.2–9.3; cadmium — 0.18–0.42 µg/dm<sup>3</sup>. An exceeding of fish culture norms was recorded for



the determined concentrations of copper in all examined samples, and an exceeding of nickel was observed in water sample from the pump house.

**Table 3. Heavy metal concentrations in water of the fish farm "Ishkhan", summer 2012**

Sampling site	Heavy metals, $\mu\text{g}/\text{dm}^3$							
	Fe	Zn	Mn	Cu	Ni	Co	Pb	Cd
Water inlet	87.6	4.5	6.3	1.5	4.5	4.8	9.3	0.33
Water outlet	27.3	3.3	3.0	1.2	4.8	4.2	7.2	0.18
Pump house	47.1	3.0	1.8	1.8	18.6	4.5	7.2	0.42
Maximum allowable limits	1000	10	10	1,0	10	10	10	5

In the bottom sediments (remains of fish vital activity and suspended materials from the water supply source, Table 4), an exceeding of normative values was observed for following heavy metals: manganese, copper, nickel, cobalt.

**Table 4. Heavy metal content in bottom sediments of the fish farm "Ishkhan", summer 2012**

Sampling site	Heavy metals, $\mu\text{g}/\text{dm}^3$							
	Fe	Zn	Mn	Cu	Ni	Co	Pb	Cd
Water outlet	1909.2	30.8	2279.9	4.3	27.5	7.5	17.7	1.73
Normative value	–	230.0	1500.0	3.0	4.0	5.0	32.0	5.0

Significant levels of copper, nickel as well as toxic elements: lead and cadmium were detected In the specialized feed manufactured by "Aller Aqua" as a result of the performed study (Table 5).

**Table 5. Heavy metal contents in the combined feed fed to rainbow trout of the fish farm "Ishkhan", summer 2012**

Heavy metals	Fe	Zn	Mn	Cu	Ni	Co	Pb	Cd
Values, mg/kg	268.1	66.5	7.95	16.73	5.70	1.80	3.68	0.51
MAL *	–	50.0	–	10.0	–	–	0.50	0.10

\* Maximum allowable concentrations for cereals and flour

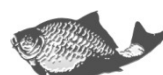
When comparing the obtained results (Table 5) with the maximum allowable content of heavy metals for cereals and flour [13], we detected an insignificant exceeding of zinc and copper values and significant exceeding of lead and cadmium. In our opinion, these combined feeds can be potential pollutants of water and consequently fish in the fish farm "Ishkhan".

Heavy metal content in organs and tissues of rainbow trout of the fish farm "Ishkhan" is shown in the Tables 6, 7.



*Table 6. The content of iron, zinc, manganese, copper in organs and tissues of rainbow trout of the fish farm “Ishkhan”, summer 2012, mg/kg of wet weight*

№	Metal	Organs and tissues						
		muscles	gills	liver	kidneys	heart	spleen	skin
1	Iron MAL – absent	6.2	28.1	20.4	32.7	59.7	230.8	15,5
2		13.6	31.0	75.0	38.4	59.3	160.3	13,1
3		9.2	33.7	31.7	31.9	68.7	173.7	19,5
4		7.7	43.8	46.8	41.6	100.1	145.5	23,2
5		7.4	38.3	86.6	44.1	120.0	148.9	25,7
M ± m		8.8 ± 1.2	35.0 ± 2.5	52.1 ± 11.5	37.7 ± 2.2	81.6 ± 11.1	171.8 ± 14.2	19.4 ± 2.1
1	Zinc MAL – 40.0	2.0	31.6	14.9	11.3	13.9	11.4	13,9
2		2.2	71.4	17.3	7.6	17.0	23.2	15,8
3		1.7	83.5	17.2	9.8	31.5	29.2	17,9
4		3.2	94.7	20.2	12.8	22.9	11.0	33,2
5		4.0	70.1	25.5	9.6	29.1	33.6	25,3
M ± m		2.6 ± 0.4	70.3 ± 9.7	19.0 ± 1.7	10.2 ± 0.08	22.9 ± 3.1	21.7 ± 4.2	21.2 ± 3.3
1	Manganese MAL – absent	0.12	0.58	0.15	0.17	0.59	0.45	0,62
2		0.13	0.69	0.46	0.12	0.60	0.93	0,69
3		0.18	0.24	0.45	0.15	0.57	0.97	0,43
4		0.12	1.06	0.27	0.19	0.84	0.38	0,35
5		0.10	0.91	0.19	0.12	0.58	0.39	0,31
M ± m		0.13 ± 0.01	0.70 ± 0.13	0.30 ± 0.06	0.15 ± 0.01	0.64 ± 0.05	0.62 ± 0.12	0.48 ± 0.07
1	Copper MAL – 10.0	0.37	0.63	78.85	1.23	2.57	1.34	0,62
2		0.22	0.67	67.39	1.88	2.08	2.56	1,56
3		0.31	0.83	64.46	1.47	3.54	0.77	0,47
4		0.34	0.85	126.08	1.64	3.18	0.94	1,21
5		0.63	0.77	112.13	1.52	2.91	1.31	1,42
M ± m		0.37 ± 0.06	0.75 ± 0.04	89.78 ± 11.33	1.55 ± 0.10	2.86 ± 0.23	1.38 ± 0.29	1.06 ± 0.20



*Table 7. Content of nickel, cobalt, lead, cadmium in organs and tissues of rainbow trout of the fish farm "Ishkhan", summer 2012, mg/kg of wet weight.*

№	Metal	Organs and tissues						
		muscles	gills	liver	kidneys	heart	spleen	skin
1	Nickel MAL – absent	0.71	2.05	0.62	3.16	7.70	3.45	3,77
2		1.00	2.25	0.46	3.57	5.06	4.65	2,97
3		0.49	2.41	1.11	5.82	10.96	2.51	3,74
4		0.45	2.29	0.67	4.11	8.84	3.49	4,67
5		0.73	2.51	0.47	3.94	8.74	3.82	3,34
M ± m		0.68 ± 0.09	2.30 ± 0.07	0.67 ± 0.11	4.12 ± 0.42	8.26 ± 0.88	3.58 ± 0.31	3.70 ± 0.06
1	Cobalt MAL – absent	0.06	0.43	0.12	0.15	0.37	0.11	0,27
2		0.10	0.37	0.08	0.09	0.30	0.23	0,45
3		0.06	0.35	0.11	0.12	0.35	0.19	0,18
4		0.08	0.35	0.18	0.11	0.41	0.37	0,31
5		0.10	0.44	0.09	0.11	0.38	0.38	0,28
M ± m		0.08 ± 0.01	0.39 ± 0.02	0.12 ± 0.02	0.12 ± 0.01	0.36 ± 0.02	0.26 ± 0.05	0.30 ± 0.04
1	Lead MAL – 1.0	0.67	1.17	0.71	0.64	3.67	1.11	0,99
2		0.67	1.17	1.00	0.81	5.04	2.11	1,38
3		0.73	1.45	0.94	0.45	6.01	2.61	0,68
4		0.63	1.50	1.00	0.58	6.01	1.98	1,32
5		0.61	1.43	1.12	0.62	4.23	2.60	1,13
M ± m		0.66 ± 0.02	1.34 ± 0.07	0.95 ± 0.06	0.62 ± 0.05	4.99 ± 0.43	2.08 ± 0.25	1.10 ± 0.11
1	Cadmium MAL – 0.2	0.003	0.078	0.033	0.067	0.037	0.011	0,013
2		0.003	0.046	0.037	0.058	0.030	0.024	0,020
3		0.002	0.044	0.022	0.055	0.035	0.019	0,023
4		0.002	0.059	0.029	0.056	0.035	0.019	0,016
5		0.002	0.068	0.027	0.064	0.038	0.017	0,024
M ± m		0.002 ± 0.000	0.059 ± 0.006	0.030 ± 0.002	0.060 ± 0.002	0.035 ± 0.001	0.018 ± 0.02	0.019 ± 0.002

High contents of iron in the organs of the examined fish were observed in spleen and heart (171.8 and 81.6 mg, respectively), zinc — in gills (70.3 mg/kg), manganese — in gills, heart, and spleen (62–70 mg/kg), copper — in liver (89.80 mg/kg), nickel — in heart and kidneys (8.26 and 4.12 mg/kg), cobalt — in gills (0.39 mg/kg), lead — in heart and spleen, cadmium — in kidneys (0.06 mg/kg).



Organs and tissue of rainbow trout by the intensity of heavy metal accumulation can be ordered as follows:

iron – spleen > heart > kidneys > liver > gills > skin > muscles;

zinc – gills > heart ≥ spleen ≥ skin ≥ liver > kidneys > muscles;

manganese – gills > heart > spleen > skin > liver > kidneys > muscles;

copper – liver > heart > kidneys > spleen > skin > gills > muscles;

nickel – heart > kidneys > skin > spleen > gills > muscles ≥ liver;

cobalt – gills > heart > skin > spleen > kidneys ≥ liver > muscles;

lead – heart > spleen > gills > skin > liver > kidneys ≥ muscles;

cadmium – kidneys > gills > heart > liver > skin > spleen ≥ muscles.

Heavy metal content in fish increases as follows:

muscles – liver – kidneys – skin – heart – spleen – gills

When comparing the obtained results with the maximum allowable levels for fish as a food product, it can be noted that no exceeding of the mentioned norms for the majority of the investigated metals in rainbow trout muscles was observed. An exceeding of the normative value of nickel was noted in all examined organs and tissues. An exceeding of the maximum allowable level of zinc and lead was observed in gills; copper — in liver, heart, spleen, and kidneys.

## CONCLUSION AND PERSPECTIVES OF FURTHER DEVELOPMENT

The hydrochemical regime of the examined tanks by the investigated parameters complied with normative values. The biological load of rearing tanks did not result in significant changes in water quality.

The study of heavy metal content in water showed an exceeding of aquaculture norms for copper in all samples, while an exceeding of nickel content was observed in the pump house.

An exceeding of following heavy metals was observed in bottom sediments: copper, nickel, cobalt.

In the examined feeds used in the fish farm, an insignificant exceeding of zinc and copper contents and significant lead and cadmium contents was recorded compared to the maximum allowable levels for heavy metals in cereals and flour. Thus, in our opinion, the combined feeds are potential pollutants of water in the fish farm “Ishkhan”.

No exceeding of normative values for the majority of the investigated heavy metals was detected in rainbow trout muscles. However, an exceeding of zinc content was detected in gills, copper — in liver, lead — in gills, spleen, and kidneys.

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### ВАЖКІ МЕТАЛИ У АБІОТИЧНИХ І БІОТИЧНИХ СКЛАДОВИХ РИБОГОСПОДАРСЬКОЇ ГІДРОЕКОСИСТЕМИ «ІШХАН»

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**Мета.** Визначення вмісту важких металів в абіотичних компонентах (вода та донні відклади басейнів), кормах, органах та тканинах райдужної форелі в умовах індустріального вирощування.

**Методика.** Матеріалом для досліджень були дволітки райдужної форелі, котрих культивували в 2011–2012 рр., одержані від плідників райдужної форелі вирощуваних в басейновому господарстві «Ішхан». Дослідні екземпляри риб були відібрані з вирощувальних басейнів №№ 3–4. Середня маса риб становила 466 г, за середньої довжини за Смітом 36 см. Щільність посадки риб на завершальному етапі вирощування складала 50 кг/м<sup>3</sup>, або 100 екз./м<sup>2</sup>. Утримання риб проводили згідно загально вживаних у форелівництві методик. Кількісне визначення концентрацій важких металів у воді, донних відкладах та рибі здійснювали прямим всмоктуванням розчину у пропан-бутан-повітряне полум'я за допомогою абсорбційного спектрофотометра С-115-М1.

**Результати.** В результаті проведених досліджень визначені екологічний стан вирощувальних басейнів та якість товарної продукції райдужної форелі господарства «Ішхан» за вищевказаними показниками.

Основні гідрохімічні показники, які характеризували якість води, відповідали рибницьким нормативам. Однак, у донних відкладах була визначена тенденція до зростання вмісту важких металів. Зокрема, відмітили підвищений вміст рівнів купруму, ніколу, а також токсичних елементів — плумбуму та кадмію.

**Наукова новизна.** Вперше досліджений екологічний стан вирощувальних басейнів господарства «Ішхан».

**Практична значимість.** Отримані результати стосовно екологічного стану вирощувальних басейнів господарства «Ішхан» дозволять створити оптимальні умови для вирощування риби.

**Ключові слова:** гідрохімічний режим, важкі метали, донні відклади, райдужна форель.



## ТЯЖЕЛЫЕ МЕТАЛЛЫ В АБИОТИЧЕСКИХ И БИОТИЧЕСКИХ СОСТАВЛЯЮЩИХ РЫБОХОЗЯЙСТВЕННОЙ ГИДРОЭКОСИСТЕМЫ «ИШХАН»

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**Цель.** Определение содержания тяжелых металлов в абиотических компонентах (вода и донные отложения бассейнов), кормах, органах и тканях радужной форели в условиях индустриального выращивания.

**Методика.** Материалом для исследований были двухлетки радужной форели, которых культивировали в 2011–2012 гг., полученные от производителей радужной форели, выращиваемых в бассейновом хозяйстве «Ишхан». Опытные экземпляры рыб были отобраны из выростных бассейнов №№ 3–4. Средняя масса рыб составляла 466 г, при средней длине по Смитту 36 см. Плотность посадки рыб на завершающем этапе выращивания составляла 50 кг/м<sup>3</sup>, или 100 экз./м<sup>2</sup>. Содержание рыб проводили согласно общепринятым в форелеводстве методикам. Количественное определение концентраций тяжелых металлов в воде, донных отложениях и рыбе осуществляли прямым всасыванием раствора в пропан-бутан-воздушное пламя с помощью абсорбционного спектрофотометра С-115-М1.

**Результаты.** В результате проведенных исследований определено экологическое состояние выростных бассейнов и качество товарной продукции радужной форели хозяйства «Ишхан» по вышеуказанным показателям.

Основные гидрохимические показатели, характеризующие качество воды, отвечали рыбоводным нормативам. Однако, в донных отложениях была определена тенденция к росту содержания тяжелых металлов. В частности, отметили повышенное содержание уровней меди, никеля, а также токсичных элементов — свинца и кадмия.

**Научная новизна.** Впервые исследовано экологическое состояние выростных бассейнов хозяйства «Ишхан».

**Практическая значимость.** Полученные результаты касательно экологического состояния выростных бассейнов хозяйства «Ишхан» позволят создать оптимальные условия для выращивания рыбы.

**Ключевые слова:** гидрохимический режим, тяжелые металлы, донные отложения, радужная форель.

