Features of biotesting rice soils for the purpose of their ecotoxicological assessment

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Abstract. Biotesting is a method of integral environmental assessment. In biotesting, toxicological analysis is carried out using approved methods, taking into account the total effect, regardless of the qualitative and quantitative characteristics of the tested environment. Biotesting is applicable for assessing the quality of natural and waste water, soil. Representativeness of the data obtained by biotesting depends on the selected test-objects, their quantity and use of the approved methodology. Problems of toxicological assessment of contaminated soils and selection of biotesting techniques are considered. A set of biotests is proposed, the use of which gives a reliable characteristic of ecotoxicological state of soil.

Keywords: biotesting, phytotesting, toxicity, rice

1 Introduction

The problem of rice cultivation is inseparable from ecology and economy, they are interrelated. Nowadays, rice farming is experiencing certain difficulties, and further increase of its efficiency is possible only through the observance of scientifically grounded, environmentally safe technology of rice cultivation. Therefore, the question arises about the choice of priorities of economic development, which would improve the ecological situation and people's health, and at the same time increase welfare [1].

The necessity of transition of the Krasnodar Region rice industry to the path of sustainable environmentally safe and dynamically developing agricultural production is dictated by the limitations. They have developed to date both in world practice and as a result of more than 50 years of experience of industrial rice cultivation in Kuban: environmental, economic (investment) and social.

Rice cultivation brings significant changes to human ecology as it changes and transforms the environment. One of the important problems is water pollution by pesticides. For example, fish diseases are regularly reported in the Temryuksky, Slavyansky and Krasnodarsky districts due to herbicide water entering ponds.

Rice production in Kuban has been and remains an important strategic area for the development of the Krasnodar Region's agro-industrial complex economy, rice being the most profitable crop of all cereals.

However, the intensive development of rice farming is leading to problems:

1 The use of chemical substances: pesticides and herbicides, and high doses of mineral fertilisers by rice farms negatively affects the entire ecosystem of Kuban.

2. Inefficient use of water resources in rice irrigation systems. Since rice farming prevails in terms of water consumption among other agricultural sectors, taking into account the growing water deficit, this problem is aggravated every year.

3. Currently applied rice cultivation technologies lead to crisis consequences of the ecosystem of the whole region. There is a need to develop measures to reduce the severity of the problems [3].

2 Materials and methods

A significant part of the fields allocated for rice is in the Krasnoarmeysky, Abinsky and Kalininsky districts.

On the basis of FGBOU VO "Admiral F.F. Ushakov State Medical University", a study of chemical contamination of soil was carried out. It was sampled on rice checks in the delta of the Kuban River in Anastasievskaya village.

The study was conducted in September 2022.

Biotesting is the determination of the toxicity of a sample (water, soil, sediments, etc.) of a given culture of organisms in a laboratory experiment. Biotesting is based on such method of scientific knowledge as biological modelling.

The method of assessing abiotic and biotic habitat factors using biological systems is called bioindication [1, 5–8, 20–22].

A good bioindicator is cress, an annual vegetable plant. This plant is highly sensitive to soil contamination.

This bioindicator is characterised by rapid seed germination and almost 100 per cent germination, which decreases markedly in the presence of pollutants. In addition, shoots and roots of this plant under the influence of pollutants undergo noticeable

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morphological changes (stunting and curvature of shoots, reduction of length and weight of roots, as well as number and weight of seeds). In the work, we used the methods of Fedorov A.I., Nikolskaya A.N. [5, 9–12, 23, 24].

Water sampling for the study was conducted from surface water sources on the territory: at certain collection points at a depth of 0.5 m. For chemical and organoleptic analyses, water was sampled once; for irrigation, three times at the same sampling points.

During the experiment, the following criteria were monitored: time of sprouting, germination within 21 days. Statistical processing was carried out.

The lengths of the above-ground parts (length of the plant stem, length of the root) were measured. The results of observations were recorded in tables. The data were statistically processed using formulae. The toxicity index of factors was calculated.

On the basis of the chemical laboratory of FGBOU VO "Admiral F.F. Ushakov State Medical University", organoleptic and chemical studies of water were carried out.

Equipment and materials are containers for water intake, seeds test – plant cress, cloth napkins containers for germination, ruler, magnifying glass, student scales, laboratory 200g, accuracy of 0.01g, with digital indication.

In the process of the study, we obtained quantitative characteristics of the studied factor. We found out whether there were reliable differences between the studied variants. We determined whether there were reliable differences in root length and stem length. We found the mean square deviation [5, 8, 13–15, 26].

The mathematical processing of data on the lengths of seedlings depending on the level of pollution was performed. The mean square deviation (σ) characterises the degree of dispersion of the obtained data and is determined by the following formula (1):

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(M - x_i)^2}{N-1}} = \sqrt{\frac{N\sum_{i=1}^{N}x_i^2 - \left(\sum_{i=1}^{N}x_i\right)^2}{(N-1)N}} \quad (1)$$

The error of arithmetic mean (*m*) shows the accuracy of measurements, data obtained and is determined by formula (2):

$$m = \frac{\sigma}{\sqrt{N}} \quad (2)$$

The credibility coefficient is determined by formula (3):

$$t = \frac{M_1 + M_2}{\sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}}} \quad (3)$$

where:

M_1 and M_2 are arithmetic averages of the lengths in the two samples;

σ_1 and σ_2 are the mean square deviations in the two samples;

N_1 and N_2 are the number of germinated seeds in the two samples.

Germination energy and germination performance of cress seeds. The germination energy ($\mathcal{B}$) is determined according to formula 4:

$$\mathcal{B} = \alpha/\beta \times 100 \quad (4)$$

where α is the number of germinated seeds;

β is a total number of seeds taken for the experiment.

Germination is the number of normally germinated seeds expressed as a percentage of the total number taken for analysis [12,14,25].

Calculation of the water toxicity index. In order to obtain comparable test results, the ITF toxicity index of the evaluated factor (germination energy, germination, length of shoots and roots, weight of seedlings) is calculated for each test-crop according to formula 5:

$$ITF = TF_0/TF_к \quad (5)$$

where TFo is the average value of the indicator in the experiment;

TFc is an average value of the same registered indicator in the control.

3 Results and discussion

A toxicity scale (Table 1) is used to determine the toxicity class of the test water.

Table 1. Water toxicity scale

ITF value	Toxicity class
>1.10	VI(stimulation)
0.91–1.10	V – norm
0.71–0.90	IV – low toxicity
0.50–0.70	III – moderate toxicity
<0.50	II – high toxicity
The environment is an uninhabitable test-object	I – ultra-high toxicity, causing death of the test subject

The results of each water sample were compared pairwise with the control result. As can be seen from this table (Table 2), all measurement results are reliable, since for our experiments, the differences between the objects are reliable with a reliability coefficient of ≥ 3.

Also in this table, we can see that the length of roots and stems of test plants is longer than that in the control variant, that is, there is no suppression of growth and development of experimental plants. According to this methodology [5], the result of test plants can be higher, which indicates that the experimental water samples contain a lot of mineral nutrients for plants [10, 11, 16–18, 27, 28].

Table 2. Comparison of the length of roots and aboveground shoots, the weight of test-crop seedlings in the experimental samples and in the control sample.

	Root length	Stem length

Options	Length, mm	Reliability of results	% of control	Length, mm	Reliability of results	% of control
Tap water (control)	34.4±3.7		100	50.6±0.7		100
1 point	56.6±2.0	6,2	124	64,2±1	16.6	166
2 point	56.1±2.4	5.2	126	66.6±1.4	12.4	164
3 point	54.4±2.6	5.6	122	64.2±1.6	8	186

To obtain comparable test results, the toxicity index of the evaluated factor (germination energy, germination, shoot and root length, and seedling weight) (ITF) was calculated for each water source tested (Table 3).

Table 3. Toxicity index of assessed factors

Factor	ITF					
	Objects of research					
	1 point		2 point		3 point	
	ITF	Class toxicities	ITF	Class toxicities	ITF	Class toxicities
Energy germinations	0.80	Low toxicity	1.16	stimulation	1.00	norm
Germination	1.26	stimulation	1.16	stimulation	1.16	stimulation
Stem length	1.28	stimulation	1.26	stimulation	1.24	stimulation
Root length	1.68	stimulation	1.66	stimulation	1.68	stimulation
Weight seedlings	1.66	stimulation	2.26	stimulation	1.8	stimulation

As can be seen from this table, water quality influenced germination energy when using water from 1 point, low toxicity was detected; water from 3 points – ITF – normal. All other factors were affected by water from the studied sources as a growth stimulant. Apparently, water contains substances that favourably affect the growth and development of plants at certain stages of development.

In the process, a number of organoleptic and chemical studies of natural spring water were carried out.

The amount of chloride was investigated (Table 4).

Table 4. Chloride concentrations in water of the investigated sources

Water body	Value, mg/l
1 point	18.0
2 point	24.2
3 point	26.2
Tap water(control)	16

As can be seen from this table, chloride content in water samples from different water sources ranges from 26.2 to 16 mg/l in tap water. Chloride concentration in water bodies is allowed up to 350 mg/l. So, the water samples do not have exceeded MPC for this indicator.

4 Conclusion

As a result of the study, we determined that germination energy in all tested samples was low; germination ranged from 66.6 to 50.6%.

The length of roots and stems of test plants is longer than in the control variant, i.e. there is no suppression of growth and development of experimental plants. This indicates that the experimental water samples contain a lot of mineral nutrients for plants. The differences are reliable. Low toxicity of water, ITF – norm, was revealed in the effect on germination energy. All other factors were affected by water from the studied sources as a growth stimulant.

We conducted a number of organoleptic and chemical studies of water from natural sources. All indices of the investigated water according to the obtained indicators meet the requirements of SanPin [1, 2, 8, 19, 26, 28]. Biotesting is a method of integral environmental assessment. This study confirms the need to use biotesting, but together with methods of physical and chemical analysis.

The solution of modern water use and water resources management problems is possible only under the conditions of forming a single balanced water management complex on the territory.

High-tech organic rice production with efficient water consumption creates an opportunity to preserve the entire ecosystem of the region, will have a positive impact on the reproduction of natural soil fertility and will contribute to the increase of natural biodiversity [3, 19, 28].

Therefore, further development of the rice growing sector should be based on the improvement of cultivation technology by means of balanced application of macro-fertilisers, applying agro-techniques contributing to the improvement of soil fertility and ameliorative state, improvement of crop rotation.

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