HUMUS LEVEL IN SOILS OF SOUTHERN KAZAKHSTAN IRRIGATED MASSIFS AND THEIR STATISTICAL CHARACTERISTICS

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Abstract: The development of large-scale irrigation agriculture in the arid region of southern Kazakhstan, which was initiated in the 1960s under the former Soviet Union has resulted not only in salinization of the soil, but also in the process of soil dehumification. Dehumification process is registered at all arable lands, but in southern Kazakhstan, where the agricultural sector is one of the key elements of the country's economy, it is especially important. In order to establish an appropriate countermeasure against soil dehumification the humus level in soils of southern Kazakhstan irrigated massifs, i.e. Akdalinsky massif (Am) and Shieliisky massif (Sm) was investigated and analytical data were statistically elaborated. The soils of both massifs have a low level of total humus, 1.28 ± 0.136% in Am and 1.46 ± 0.191% in Sm, respectively. The different design is observed at the content of water soluble form of humus. The soils of Am have higher level of this form (0.006 ± 0.0007%), the soils of Sm, are characterized by the lower level (0.003 ± 0,0002%). The soils of Am have a higher degree of humus solubility (0.51 ± 0.062%), whereas the soils of Sm are characterized by 2.1 times lower values reaching 0.24 ± 0.022%. The content of nitrogen in humus from investigated soils was also determined. The soils of newly irrigated Am were characterized by lower saturation with nitrogen (5,6 ± 0,24%), whereas the saturation with nitrogen in the soils of Sm achieved higher level (6,8 ±0,40%). These results allow us to draw a conclusion about very low humus level in the investigated areas. The humus level decline cause the worsening of soil fertility and decrease its buffer capacity, influencing negatively crop production. Hence the assessment of current humus level in the irrigated soils is an important task in ecology and soil sciences. In case of too intensive dehumification the urgent action leading to the increase of humus level is necessary.

Key words: *Kazakhstan, irrigation, humus level, dehumification.*
Słowa kluczowe: Kazachstan, nawadnianie, humus, dehumifikacja.

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1. Introduction

Soil degradation is an important, undesirable and complex process connected either with natural phenomena or with inappropriate land use practices. The technological backwardness of industry and agriculture, extensive use of natural resources and irrigation have resulted in the significant degradation of soils in

Kazakhstan. One of the major factors of soil degradation is the process of soil dehumification (Zonn, 2005). Dehumification leads to a number of economic and social consequences including the reduction of harvesting capacity, decrease of agricultural sector export potential and slow development of food industry.

Irrigation in Central Asia, including Kazakhstan has been practiced for thousands of years, but the large-scale infrastructure was constructed from the1960s during the period of growing interest in cotton production. During the last 30 years irrigated areas in Syr Darya basin, including southern Kazakhstan, have increased rapidly (Cai et al., 2003). In spite of the impressive achievements of irrigation in ensuring food security and rural welfare, irrigation also leads to some serious problems. Soil salinization in irrigated farms and their vicinity is one of the most important problems (Khakimov, 1989, Funakawa et al., 2000). Soil salinization has caused environmental and human health concerns (Mainguet, 1991; Williams and Aladin, 1991; Ishida et al., 1995). The other serious problem connected with the irrigation is the loss of humus.

In the northern Kazakhstan since the 1960s soils have generally lost 20–30% of humus as a result of natural erosion processes and irrational methods of soil use. In southern Kazakhstan the situation is even worse and the loss of humus makes up already 30–40% in the soils of irrigated massifs in Kyzylorda oblast (Zubairov, 2002).

The process of dehumification development in irrigated soils, its mechanism, and principal causes, leading to dehumification, were considered in previous works (Ibraeva, 2003; Otarov et al., 2007).

The aim of the present study is to investigate and assess the current humus condition in the south of Kazakhstan irrigated soils.

2. Material and methods

Study sites. The investigations were carried out at Shieli and Akdakla massifs. Shieli massif is located in the south of Kazakhstan, in predelta of Syr-Darya River and completely covers the territory of the same region in Kyzylorda oblast, and Akdala massif is located in the south-east Kazakhstan in the ancient delta of the river Ili. Both massifs are used for irrigation agriculture. Rice is the major culture at both massifs.

The location of the investigated massifs is presented in Figure 1.

3. Results and discussion

Our investigations proved that the level of total humus in the soils of newly irrigated Akdala massif of rice cultivation decreased by 19.3–24.7% in comparison with the initial condition. The loss of the most mobile water soluble form of humus achieves 12–36% for one season (Otarov et al., 2007). The loss of humus makes up already 30–40% in the soils of old irrigated massifs in Kyzylorda oblast and its level makes up less

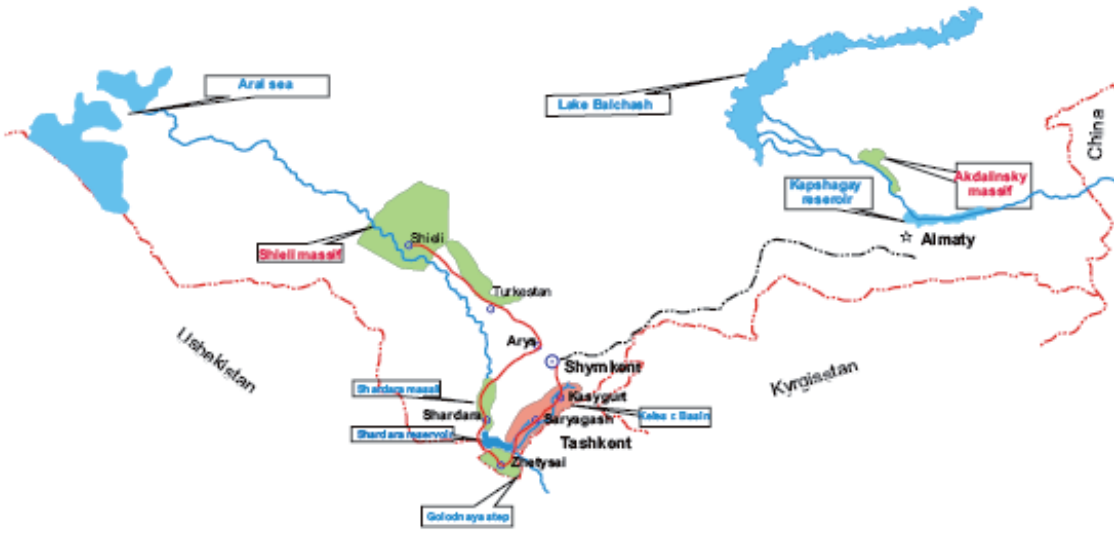

Fig. 1. Location of the study areas
Ryc. 1. Położenie terenów badawczych

than 1% on the 60% of the arable lands in the oblast (Zubairov, 2002). The loss of humus is promoted by mobilization and migration processes, which are rather intensive in the conditions of permanent flooding. The domination of reduction conditions and high alkaline medium are the main mobilization processes. The constant descending current of irrigation water is the main migration process, promoting the removal of mobilization process products into the profile depth and drainage waters (Otarov et al., 2007). These losses, undoubtedly, cause the worsening of soil fertility, decrease of their buffer capacity and resistance to unfavorable anthropogenic factors. In this connection the research and assessment of modern humus level in the irrigated soils is one of the most urgent tasks in modern biology and soil science.

Soil survey works on studying of soil humus conditions have been carried out on selected study areas within the framework of the international project "Coordination of scientific activities towards elaboration of common strategy for environmental protection and sustainable management in Syr-Darya River Basin, in Uzbekistan and Kazakhstan". Humus condition was estimated by the total humus level in soils, contents of humus water soluble part, degree of its solubility and saturation with nitrogen.

Alluvial-meadow, meadow-boggy, boggy soils were mainly used for rice cultivation at Shieli massif and takyr-like soils – at Akdala massif. The soils had an initial salinity. As a result of the long-term use of the soils for rice cultivation, the soils of both massifs developed according to the classification of Kazakhstan soil scientists (Borovsky, 1959; Karazhanov, 1973; Volkov, 1983) and have turned into irrigated (paddy) boggy soils. The changes of soils under this culture are provided with the specific conditions of its cultivation – constant flooding. The major part of the massifs has a favorable relief for irrigation.

Soil formation rocks are closely connected with the relief elements. The alluvial deposits are represented by light loams, loamy sands and fine granular silt sands on the raised elements of the relief and by heavy loams and clays – in depressions. The soil formation on the territory of both massifs proceeds under the conditions of a desert continental climate which is characterized by significant continental parameters and a small quantity of atmospheric precipitation (not more than 100 mm per year), high value of evaporation (1500–1700 mm per year). Therefore, the development of agriculture on these massifs is possible only under irrigation. The availability of moisture is a decisive condition that determines the direction of the soil formation process and efficiency of agriculture. The temperature regime is characterized by a long-term warm period and provides the favorable conditions for the cultivation of different crops under irrigation.

The application of statistical data analysis is of great importance for the determination of the contents value, peculiarities of soil properties spatial variation or average contents of these or other elements in certain soil types or in their complex for the increase of the reliability of received data and conclusions. Furthermore, the application of the statistical analysis also increases the interpretation capacities of the data. It is necessary to recognize that all the conclusions on the absolute values of soil properties, received from one or several typical pits without the statistical treatment of the received data can often be improbable and lead to a wrong interpretation of the received data (Dmitriev, 1995).

In statistical science an investigated random value is mainly characterized by two groups of constants. The constants of the first group characterize the average level of the investigated value and the second one – the degree of variability and both groups present the law of a random value distribution. Among the constants characterizing the distribution of these or other elements in soils, the average arithmetic constant, characterizing the average level of their contents, occupies a special place. The main aim of most works is to study the characteristics and determine the exact significance of the average value. Furthermore, under the statistical treatment of the received analytical data, the average value acts as an initial one for the calculation of other not less valuable constants, characterizing the distribution of the investigated value.

The statistical analysis of parameters of humus, nitrogen and their derivative forms level in soils is presented in Table 1. The calculated values of Student's t-criterion show that t_{actual} is greater than t_{table} in the given soils under 95% level of significance. These prove the statistical reliability of the received data.

Rather narrow limits of confidential interval ($t_{0,\ 05x}$m) can serve as an indirect confirmation. The coefficient variation values of the investigated attributes (they do not exceed an average value) show the statistical stability of the received data.

Thus, the analytical data received as a result of the researches, are characterized by a statistical stability and can be used for the assessment of the current humus condition of the soils investigated at the massifs of rice cultivation.

The soils of both massifs have a low level of total humus, which is showed in Figure 2.

Tab. 1. Statistical analysis of chemical features
Tab. 1. Analiza statystyczna właściwości chemicznych

Parameters ***Cecha***	**Statistics parameters** ***Parametry statystyczne***					
	n	M ± m	t-criterion *współczynnik*		± $t_{0,05}$ * m	V, %
			$t_{actual r.}$	$t_{0,05}$		
Shielisky massif/*Masyw Shielinski*						
Humus total, %	6	1,45 ± 0,191	7,9	2,4	0,49	32,3
Soluble in water humus, %	6	0,003 ± 0,0002	19,0	2,4	0,0004	12,9
Solubility humus, %	6	0,24 ± 0,022	10,9	2,4	0,06	22,5
Easy hydrolyze nitrogen, mg/kg	6	39,2 ± 0,72	54,2	2,4	1,9	4,5
Total nitrogen, %	6	0,1 ± 0,01	9,7	2,4	0,03	25,2
Saturation humus nitrogen, %	6	6,8 ± 0,40	16,9	2,4	1,0	14,5
Akdalinsky massif/*Masyw Akdaliński*						
Humus total, %	12	1,28 ± 0,136	9,4	2,2	0,3	36,8
Soluble in water humus, %	12	0,006 ± 0,0007	9,0	2,2	0,002	38,7
Solubility humus, %	12	0,51 ± 0,062	8,2	2,2	0,1	42,4
Easy hydrolyze nitrogen, mg/kg	12	48,5 ± 4,01	12,1	2,2	8,8	28,6
Total nitrogen, %	12	0,07 ± 0,007	9,9	2,2	0,02	35,2
Saturation humus nitrogen, %	12	5,6 ± 0,24	22,8	2,2	0,5	15,2

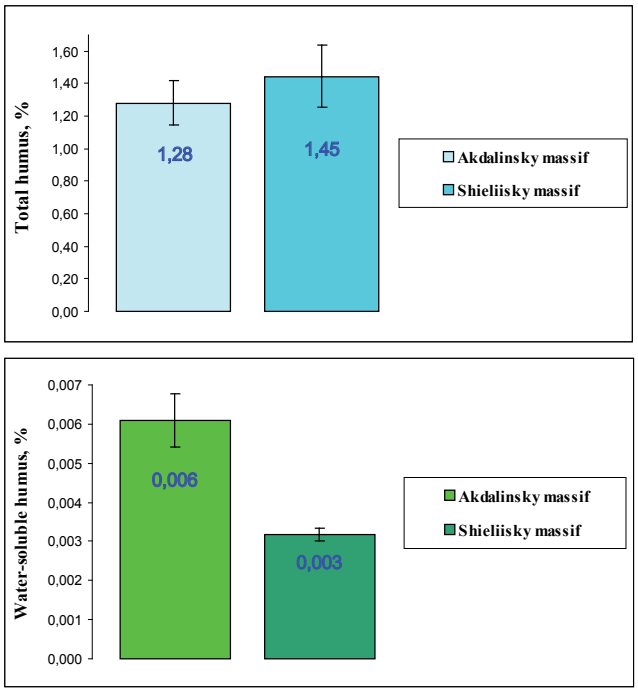

Fig. 2. Contents of total and soluble in water forms humus in soils irrigated massifs
Ryc. 2. Zawartość całkowitego i rozpuszczalnego w wodzie humusu w glebach nawadnianych masywów

According to the soil classification on the total humus level (Methodical manual, 2005) the soils from all the surveyed territories can be referred to the group with low humus level. Despite of this fact, a small difference is observed among the soil of both massifs according to the level of total humus. The soils of Akdala massif are characterized by a relatively low level of humus (1.28 ± 0.136%), and the soils of Shieli massif – by a higher relative level, equal to 1.45 ± 0. 191%.

A different picture is observed when contents of water soluble form are considered. The soils of Akdala are characterized by relatively high contents of this form (0.006 ± 0.0007%) and the soils of Shieli massif – by relatively low contents. These data prove the conclusion, made earlier that the loss of humus in paddy soils is caused by specific conditions, provided with a constant flooding and due to its mobile water soluble form. This conclusion is also supported by the value of humus solubility in the investigated soils. These data are presented in Figure 3. The soils of Akdala massif have a high degree of humus solubility (0.51 ± 0.062%). Humus solubility in the soils of Shieli massif is lower by 2.1 times. From this, it is possible to draw an important conclusion, that the increase of mobile water soluble form of humus is provided with the increase of its solubility. This value can serve as a diagnostic factor of the fact that the soils are subjected to dehumification.

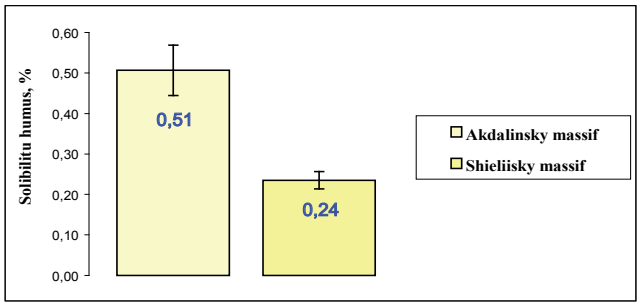

Fig. 3. Solubility humus in soils irrigated files
Rys. 3. Zawartość rozpuszczalnego humusu w glebach terenów nawadnianych

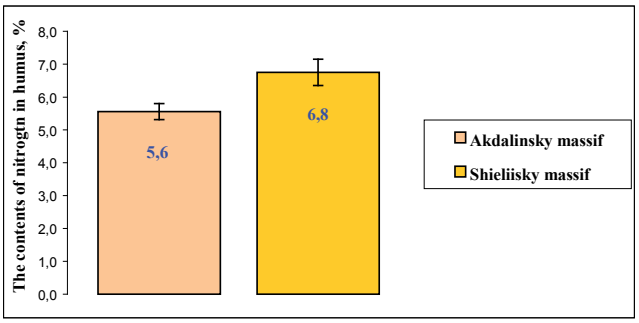

Fig. 4. Contents of nitrogen in humus structure in soils of irrigated files
Rys. 4. Zawartość azotu w strukturach humusowych w glebach terenów nawadnianych

One of the main parameters of a qualitative humus composition is the presence of nitrogen in its composition, as one of the main nutritive element for plants. The regularity, analogous to the composition of total humus, is observed in the soils of both investigated massifs – humus saturation with nitrogen. The saturation of the paddy soils with nitrogen is practically directly proportional to the level of total humus, what id presented in Figure 4). The soils of newly irrigated Akdala massif have the least saturation with nitrogen (5.6 ± 0.24%) and the soils of Shieli massif have a relatively high saturation, the level of nitrogen saturation is 6.8 ± 0.40%.

On the basis of the obtained data it is possible to draw a conclusion that the current humus condition of the irrigated soils in the south Kazakhstan is characterized by a very low degree of protection of total humus. One of the reasons leading to the dehumification of these soils is the intensity of the formation and value of humus mobile water soluble form and the value of humus solubility. The humus of the soils has different degrees of solubility depending on the start of the massif irrigation. The degree of solubility is higher in the soils of newly irrigated Akdala massif than in the massifs irrigated for a long time.

The correlation between the levels of total nitrogen and total humus is observed under the grapho-analytical method of analysis. The level of easy hydrolyzed form of nitrogen in the soils of the investigated massifs resembles the level of humus water-soluble form and the degree of its solubility. The obtained analytical data were subjected to a correlation analysis in order to check the direction and narrowness of the bonds. Complex dependences of different directions were revealed among the investigated parameters and presented in Table 2.

The number of narrow reliable correlation bonds for the investigation of paddy soils properties is the following: total humus – 5, water soluble humus – 3, humus solubility – 3, and easily hydrolyzed nitrogen – 3, and total nitrogen 3, nitrogen level in humus – 1.

Tab. 2. Correlation coefficients of chemical features
Tab. 2. Współczynniki korelacji dla cech chemicznych

Compared features ***Porównywane cechy***	**Humus total** ***Humus całkowity***	**Soluble in water humus** ***Humus rozpuszczalny w wodzie***	**Solubility humus Stopień rozpuszczalności humusu**	**Easy hydrolyze nitrogen** ***Azot łatwo hydrolizujący***	**Total nitrogen** ***Azot całkowity***	**Saturation humus nitrogen** ***Wysycenie humusu azotem***
Humus total	1.00					
Soluble in water humus	0.43	1.00				
Solubility humus	-0.50	0.47	1.00			
Easy hydrolyze nitrogen	0.71	0.57	-0.18	1.00		
Total nitrogen	0.88	0.26	-0.50	0.57	1.00	
Saturation humus nitrogen	-0.33	-0.24	0.26	-0.17	0.08	1.00

A positive correlation with the total (r = 0.88) and easily hydrolyzed (r = 0.71) nitrogen is found for the total humus. An average bond exists in decreasing order of correlation coefficients value with humus solubility (negative), water soluble form of humus and le vel of nitrogen in humus (negative). High values of pair correlation coefficient among the indicated parameters enable to consider such interdependence of paddy soils fertility elements (irrigated massifs) as an objectively existing regularity.

The investigation and assessment of the current humus condition of the southern Kazakhstan irrigated soils are very important. Similar investigations are also necessary for the determination of the soil degradation reasons and development of practical measures for the stabilization and improvement of soil humus condition. It is known that the soils with a stable high humus level promote the reception of stable high and ecologically pure yields of crops. Furthermore, it is necessary to begin works on the development of the methods for the regulation and optimization of humus condition in the irrigated soils, located in the south and south-east of Kazakhstan.

The necessity of transition to the sustainable systems of the agricultural development, gradual transition to biological methods of struggle with weeds of fields and pests of cultivated cultures, replacement of mineral fertilizers by organic ones, increase of the soil fertility at the expense of a deepening of the humus horizon and increase of the humus contents at the first stage up to natural levels of the zone soils are substantial for Kazakhstan agriculture. The duration of these stages are about 35–50 years.

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POZIOM HUMUSU W GLEBACH NAWADNIANYCH MASYWÓW POŁUDNIOWEGO KAZACHSTANU – CHARAKTERYSTYKA STATYSTYCZNA

Streszczenie

Rozwój intensywnego nawadniania gruntów rolnych w suchych rejonach południowego Kazachstanu, który rozpoczął się w Związku Radzieckim w latach sześćdziesiątych ubiegłego stulecia, spowodował nie tylko wzrost zasolenia gleb, ale także ich dehumifikację. Proces dehumifikacji został stwierdzony we wszystkich gruntach rolnych, jednak w południowym Kazachstanie, gdzie sektor rolniczy ma kluczowe znaczenie, jest szczególnie istotny. W celu opracowania odpowiednich działań zapobiegawczych został określony poziom substancji humusowych w glebach dwóch terenów położonych w południowym Kazachstanie, tzn. na obszarze Masywu Akdalińskiego (Am) i Masywu Shilińskiego (Sm). Uzyskane wyniki zostały opracowane statystycznie. Gleba obu masywów charakteryzuje się niskim poziomem humusu całkowitego (odpowiednio 1,28 ± 0,136% w Am i 1,46 ± 0,191% w Sm). Zaobserwowano zróżnicowany poziom rozpuszczalnych w wodzie form humusu. Wyższy poziom takich substancji stwierdzono w glebach Am (0,006 ± 0,0007%), niższy w glebach Sm (0,003 ± 0,0002%). Gleby Am wykazują wyższy stopień rozpuszczalności humusu (0,51 ± 0,062%, podczas gdy gleby Sm charakteryzują ponaddwukrotnie niższe wartości (0,24 ± 0,022%). Oznaczono także zawartość azotu w humusie badanych gleb. Gleby krócej nawadnianego obszaru Am charakteryzowały się niższym udziałem azotu w strukturach humusowych (5,6 ± 0,24%), podczas gdy wysycenie humusu azotem w glebach Sm osiągało poziom 6,8 ± 0,40%. Przedstawione wyniki pozwalają na stwierdzenie bardzo niskiej zawartości humusu w glebach badanych terenów. Spadek zawartości humusu powoduje pogorszenie żyzności gleby, jak również zmniejszenie jej zdolności buforowej, co wpływa negatywnie na wysokość plonów. Zatem ocena aktualnego poziomu humusu w nawadnianych glebach jest istotnym zadaniem ekologii i gleboznawstwa. W przypadku zbyt intensywnej dehumifikacji należy podejmować pilne działania w celu podniesienia poziomu humusu.