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Study of a flexible screw conveyor for reclamation of agricultural soils disturbed by military operations

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Abstract. The article studies the damage and destruction of the fertile soil layer as a result of military operations, in particular the detonation of various kinds of explosives, and examines the level of contamination of agricultural soils with heavy metals and other harmful substances. A method of restoring the surface of damaged land caused by bombing is proposed, which involves first cleaning the craters from damaged and contaminated soil with heavy metals and other dangerous substances. If a dangerous concentration of heavy metals and other dangerous substances is found on the surface of the crater, the removed contaminated soil layer must be disposed of. When disposing of the removed contaminated soil layer, it is proposed to use a flexible screw conveyor with a sectional auger working body. The constructive scheme of the experimental setup with a hitch system of a machine-tractor unit and a flexible screw conveyor is shown. To select the rational design parameters of the screw sections of the working body, computer modeling of the influence of power loads on the corresponding deformations depending on the conditions of their operation was carried out.

KEYWORDS: AGRICULTURAL SOILS, CONTAMINATION, RECLAMATION, CRATER, AUGER

More than 5 million hectares of arable land in Ukraine have been damaged by the war. Explosion craters, trenches, toxic substances from missiles and the movement of heavy machinery all affect the quality of the soil and the food we grow. During explosions and the operation of military equipment, a large amount of toxic substances, including explosives and heavy metals, enter the soil. This causes chemical damage to the soil [1].

There are four types of soil destruction. Mechanical – a change in the structure of the soil cover. It occurs when the fertile layer is destroyed or mixed with other layers due to digging trenches or trenches. After such changes, the soil loses its fertile properties, retains moisture worse, and becomes less suitable for growing crops. Mechanical pollution is also caused by the movement of military equipment – the soil is compacted and becomes more dry.

The second type is physical pollution, which is a change in soil properties. Military equipment causes vibrations, and explosions or fires, in addition to direct destruction, disrupt the temperature regime that determines the moisture supply of plants [2, 3].

The third – chemical – is caused by fuel leaks, combustion products that settle on the soil from the air, and toxins from explosives in shells. However, an ammunition explosion is not only a chemical pollution, but also a mechanical one. The blast wave leads to soil erosion, which further exacerbates the issue of climate change and adaptation to it.

The fourth type is biological – the death of all living things in the soil, primarily the microbiota, which is responsible for its health and fertility. It dies both from soil compaction, thermal shocks, destruction of soil horizons, and explosive toxic substances [4].

Based on the results of previous studies, it was decided to consider all craters from shelling, places of explosion and fall of unexploded rockets with rocket fuel spills, places of fuel spills from military equipment, and places of burnt-out equipment as dangerous to the life and health of citizens and the environment. Craters from explosions and the area around craters, depending on the radius of the debris, are contaminated with heavy metals (nickel, zinc, lead, cadmium, copper, etc.). Hazardous substances can get through the soil into water or plants grown on it, they can migrate in the environment and accumulate in the bodies of plants and animals. The ingestion of such substances into the human body can lead to damage to the functioning of internal organs, in particular the liver and kidneys, damage to the nervous system, and general poisoning of the body [5].

The combination of various impact factors leads to a cumulative negative effect. The consequences are the loss of the soil's buffering capacity for recovery, loss of humus, and a decrease in natural fertility [1].

Substances that enter the soil during explosions remain in the crater without special treatment.

If we do not take post-war restoration measures, we will get soils with flooding, salinity, erosion processes, etc. This can undoubtedly lead to devastating consequences in crop production,

soil cover disturbance, lack of natural moisture, desertification, and the development of wind and water erosion [6].

Plowing will have no effect because the land itself is not alive in this place. The scorched earth – the biological component of the soil, the humus, and the bacteria that should be there and make the earth alive – are practically destroyed.

To restore the fertility of the affected soils and put them into operation, it is not enough to demine and then fill in all the existing sinkholes [7].

To restore the areas damaged by explosions, it is necessary to remove or clean the surface layer of soil, as in addition to chemical contamination with heavy metals, the fertile soil layer burns out, dehydration and “sterilization” occur, killing both pathogenic microorganisms and beneficial biota. If the surface contaminated layer is not cleaned off, but the sinkhole is mechanically sealed with bulldozers and graders, soil fertility restoration will take decades, requiring serious investments in organic fertilizers, ameliorants, phytomelioration, etc. [8, 9].

If a dangerous concentration of heavy metals and other dangerous substances is found on the surface of the funnel, the removed contaminated soil layer must be disposed of. If the removed layer of the sinkhole surface contains an acceptable concentration of pollutants, the peeled layer can be left at the bottom of the sinkhole [10, 11].

Shallow craters (up to 0.5 m) can be filled with soil mass remaining at the explosion site (at the permissible concentration of pollutants) or mineral soil (loam, loess loam, sandy loam, sand), followed by leveling the surface.

Deep sinkholes (more than 0.5 m) should be filled with soil mass, but the order of soil layers should be close to the undamaged areas, so the sinkhole should be filled with mineral soil first, and the top layer (20-30 cm) should be covered with fertile black soil. If backfilled in a chaotic manner, such a site will be low-productive for crops, and its restoration will require additional measures (application of organic fertilizers, ameliorants, phytomelioration, etc.). Based on the measurements of the parameters of the explosion craters, the need for mineral and fertile soils is calculated in the working land management project.

To remove and clean the damaged surface soil layer in the crater formed as a result of explosions, it is recommended to use a working body that will allow mechanization of this process. This working tool is attached to the boom of an excavator with a hydraulic system.

To utilize the removed contaminated soil layer, a flexible screw conveyor with a sectional auger working body can be used, which will allow it to be transferred to the truck body.

Fig. 1 shows a schematic diagram and general view of such a screw sectional hinged working body. This working body is made of separate sections, to which a cylindrical sleeve 1 is rigidly fixed at the right end. It contains a system of axial parallel grooves 2, which are arranged evenly around the circumference and parallel to the axis of the cylindrical sleeve and the groove and interact with balls 3. At the same time, the balls 3 interact with the inner

spherical surface of the spherical sleeve 4 and have the ability to axially and angularly rotate the spherical pin 5.

At the other end, the welded cylindrical section comprises a connecting sleeve 6 with an internal shaped hole 7, wherein the sleeve 6 is rigidly positioned in the internal hole of the section, perpendicular to the axis. The sleeve 6 is connected to the spherical pin of the neighboring section and is rigidly fixed with a nut 8. Jumpers 9 are welded to the outer diameter of the connecting sleeve 6 evenly around the circumference at one end, and at the other end the jumpers are welded to the outer diameter of the cylindrical sleeve 1. A screw section is rigidly welded to the outer diameter of the cylindrical section, which is actually a continuation of the helical spirals of the neighboring sections.

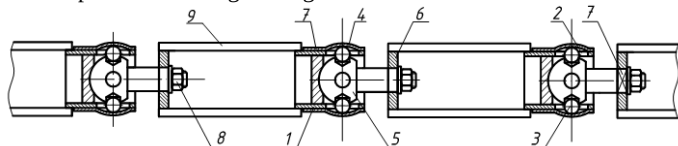


Figure 1. Structural diagram (a) of a flexible screw sectional articulated working body

The operation of the flexible sectional screw impeller is as follows. During the rotation of the spiral section, the rotational motion is transmitted through the rolling elements 3 to the spherical pin 5 and the adjacent sections of the screw working tool.

The reloading of the removed contaminated soil layer using a flexible screw conveyor will allow to mechanize this process.

To study the process of reloading the removed contaminated soil layer, Fig. 2 shows a schematic diagram of the experimental setup with a tractor-machine hitch system and a flexible screw conveyor.

This conveyor contains a loading 1 and an unloading 12 flexible casing with screw sectional hinged working bodies. The loading and unloading covers have openings on one side for self-loading and unloading of soil, respectively, and on the other side they are connected to the drive shafts of the overloading nozzle 2. Co-axially with the flexible covers on the opposite side of the reloading nozzle 2, sprockets 10, 13 are arranged on the drive shafts, which are kinematically connected to the intermediate shaft 11 by means of chain gears.

The lower 8 and upper 3 brackets are mounted on the body of the reloading nozzle, with the help of which the conveyor is connected to the central 5 and longitudinal 8 rods of the hinged system of the machine-tractor unit 6. The output shaft 10 of the unloading line is connected to the gearbox 4 through a chain transmission, which, in turn, is driven by a cardan gear 7 from the PTO shaft of the machine-tractor unit.

To simplify the design of the drive, the intermediate shaft 11 can be the output shaft of the gearbox 4, the axis of which is located in a plane equidistant from the drive shafts of the highways (Fig. 2, b). This installation is universal, since after dismantling it is installed on an autonomous frame driven by an electric motor, and the study of various working bodies can be carried out in stationary conditions.

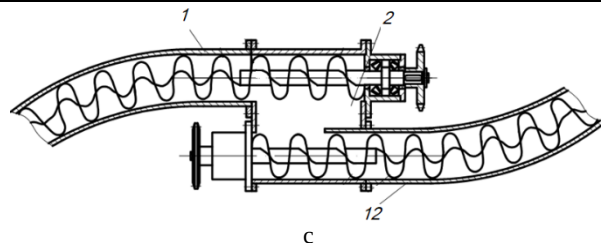
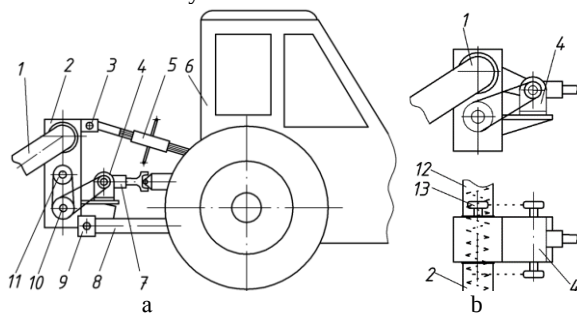


Figure 2. Structural diagram of the experimental setup with a tractor-machine hitch system (a, b) and a flexible screw conveyor (c)

During operation, the kinematically connected drive shafts, intermediate shaft and power take-off shaft of the machine-tractor unit ensure rotation of the flexible screw sectional articulated working members.

To dispose of the removed contaminated soil layer, the loading casing with the flexible screw sectional articulated working body is placed in a pit. The conveyor auger captures the cleaned soil through the self-loading hole and, while rotating the working body, transports it in the casing towards the reloading nozzle of the experimental installation and, using the unloading casing with a flexible screw sectional working body, to the unloading zone in the truck body.

To select the rational design parameters of the screw sections of the working body, we performed computer modeling of the effect of power loads on the corresponding deformations, depending on their operating conditions.

A computer model of a section of the working body of a flexible screw conveyor with articulated transmission mechanisms fixed in it was created using the Solid Works application package. The general view of the model is shown in Fig. 3.

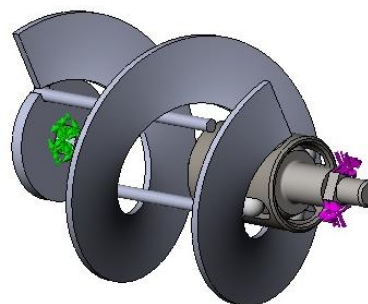


Figure 3. Model of the assembled section with the load applied to it

To calculate the twisting angle of the section φ and obtain the corresponding graphical dependences of the torque, the corresponding test conditions were simulated. One intermediate element was rigidly fixed (shown on the left side in Fig. 3), and a torque was applied to the other (shown on the right side). The variables were: the number of rods of the section base n ; the thickness of the section helix δ ; and the applied torque T .

Next, a graphical display of the movement of the components of the working body (Fig. 4) and the deformation of the components of the working body (Fig. 5) under the action of the applied torque was obtained in the program window.

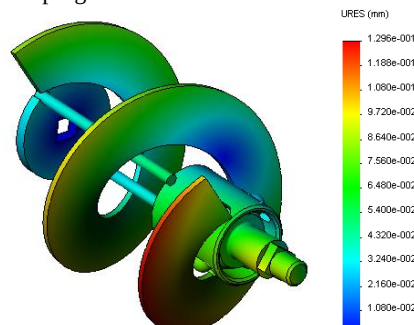


Figure 4. Movement of working body components under the influence of torque

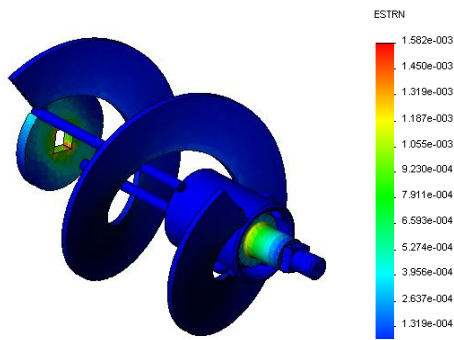


Figure 5. Deformation of working body components under the influence of torque

Based on the obtained values, we calculated the twisting angle of the section φ when changing the number of rods n , the thickness of the helical spiral of the section δ , and the values of the applied torque T . The corresponding graphical dependences are shown in Fig. 6 and 7.

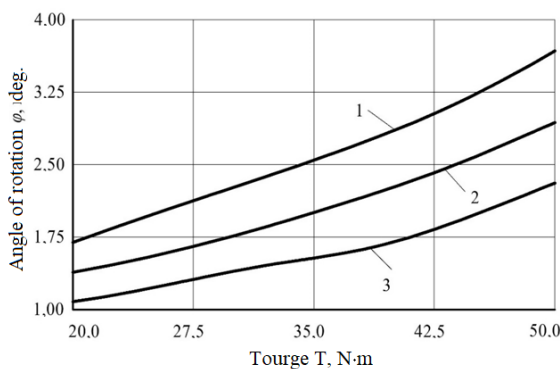


Figure 6. Graphical dependence of the section twist angle φ on the number of rods: 1 – $n = 2$; 2 – $n = 3$; 3 – $n = 4$

Analysis of the graphical dependencies (Fig. 6, 7) shows that the twisting angle of the sections increases with increasing torque. Its largest increase is observed for the number of axial rods of the section base $n = 2$, and the smallest – for $\delta = 4$ mm.

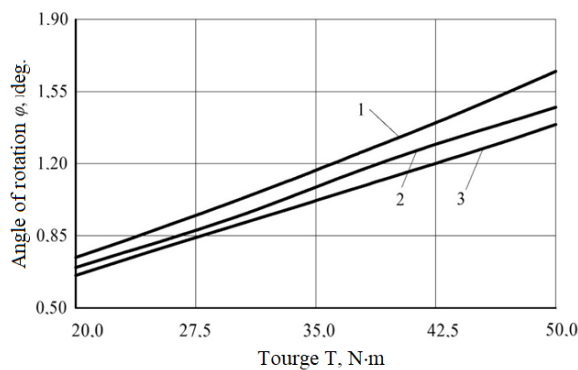


Figure 7. Graphic dependences of the twisting angle of the section φ on the change in the thickness of the helical spiral: 1 – $\delta = 2$ mm; 2 – $\delta = 3$ mm; 3 – $\delta = 4$ mm

As can be seen from the graphical dependence shown in Fig. 7, the number of axial rods of the section base n has a much smaller effect on the twist angle of the section φ compared to the parameter δ , and the graphical dependences are close to linear.

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Optimization of vertical surfaces with continuous and discrete finning

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Abstract: The article deals with the optimization of vertical surfaces with continuous and discrete finning under conditions of natural convection. The optimization was carried out using experimental data obtained for finned surfaces made of steel, taking into account the non-isothermal temperature distribution over the surface of continuous and discrete fins. The dependences of the optimal distance between the ribs on the Rayleigh number and the geometric dimensions of the ribs are found. It was found that with a decrease in the Rayleigh number for discrete non-isothermal fins, the optimal distance between the fins increases compared to the same distance for continuous non-isothermal fins. The differences can be more than 30%. The obtained results for continuous non-isothermal fins are compared with the known results for isothermal fins. It is shown that the presence of non-isothermicity on the surface of continuous fins made of metal materials leads to the need to reduce the inter-fin distance by up to 40%. The results obtained can be useful in the design of finned surfaces under natural convection conditions.

KEYWORDS: CONTINUOUS AND DISCRETE FINNING, VERTICAL SURFACE, NATURAL CONVECTION, NON-ISOTHERMAL, OPTIMIZATION.

1. Introduction

The experimental study of heat transfer of a radiator with flat vertical fins was first conducted by Elenbaas W. [1]. The studies were conducted in a wide range of changes in the geometric and thermal characteristics of the system under study. In [2], the dependence of the surface-averaged Nusselt number Nu_s on the parameter $Ra_s \cdot s \cdot L^{-1}$, L – is the total length of the plate along the length of the fin, was obtained, and the optimal distances between the fins were found.

In subsequent theoretical studies [3], the results obtained in [2] were confirmed by numerical calculation. The author of [4], assuming that the heat transfer coefficient over the surface is constant, determined the efficiency of the fins and found the optimal spacing between the fins depending on the Gr_s number and the thermal and physical properties of the fin material and the external coolant. These dependencies were presented in the form of nomograms.

Levi E. K. [5] determined that in the case of a laminar flow regime, the optimal distance between the plates s_{opt} is 1.2 times the maximum thickness of the boundary layer on a single plate.

Bar-Cohen A. and Rosenau V. M. [6], based on the dependencies obtained in previous studies, determined the optimal inter-rib distances s_{opt} at $T = \text{const}$ and $q = \text{const}$ on the flow surface.

In [7, 8], the heat transfer of radiators was studied, respectively, taking into account the fin thermal resistance of the fins and for large numbers Ra .

In [9], during the experimental study of heat transfer for a smooth and longitudinally finned surface in a channel, local distributions for the Nusselt number, as well as graphical and criterion dependences for the average Nusselt number on the Grashof number at $T = \text{const}$ and $q = \text{const}$ on the surface were obtained. A good agreement with the data of Elenbaas W. [1] for the averaged characteristics was obtained.

In [10], when solving the system of equations for the transfer of mass, momentum, and energy between two vertical plates located on a vertical wall, the correlation dependences $Nu_{cp} = f(s \cdot L^{-1}, Ra)$ were found. It was shown that at $Pr = 0.7$ the longitudinal component of heat transfer in a finned channel should be taken into account at $(s \cdot L^{-1}) < 10$.

In the experimental work [11], the influence of the nonisothermicity of finned surfaces on their heat transfer was investigated and the criterion dependences of the Nusselt number on the Rayleigh number were obtained.

The above studies examined heat transfer for surfaces with continuous fins. The main disadvantage of such systems, especially those with a large length in the vertical direction, is its low thermal efficiency in the upper part of the finned surface. In this area, there is a regime of developed flow in which local values of the heat transfer coefficient are small. The intensity of heat transfer in this area is much lower than in the lower part of the radiator, where the initial boundary layer on the plates is formed and the local heat transfer coefficients are high. To overcome this drawback, it was

proposed to use discrete fins. The discretization of the fins leads to the disruption of the boundary layer on the plates and the formation of a new layer on the subsequent plates. Given the large values of local heat transfer coefficients at the initial sites of boundary layer formation, the use of discrete fins leads to an intensification of heat transfer for the entire system.

Sparrow E. M. and Prakash K. [12] conducted a theoretical study of a system of discrete edges staggered on a vertical surface. In [12], calculations were also performed for a vertical system with continuous flat fins. Local and integral thermal characteristics for both cases were obtained. It is shown that for some fin geometries, the discretization of the fins allows for a 2-fold intensification of heat transfer. An experimental study [13] confirmed the presence of heat transfer intensification when using discrete fins.

However, for real heat transfer conditions that occur in practice, the temperature of the finned wall and the density of the heat flux being removed vary significantly over the surface. In the case of forced or natural flow of the external coolant, a change in the temperature head on the flow surface can in some cases significantly affect the heat transfer conditions of finned surfaces.

An experimental study of the effect of nonisothermicity on the heat transfer of vertical surfaces with discrete fins was conducted in [14]. The dependence of the Nusselt number on the Rayleigh number was found and the results obtained were compared with the results of numerical modeling for discrete isothermal fins [12].

Paper [15] evaluated the efficiency of various rectangular finned heat sinks in 8 orientations. It was found that denser fin arrays are more sensitive to orientation. The experimental results are in good agreement with the current prediction and previous experimental data. We propose correlations in the simple form $Nu = C \cdot Ra_m$ for different orientations, which have rarely been studied before. The exponent m turns out to be almost the same for ordinates 45, 135, 225, and 315. In addition, the calculation results show that the mismatch between the heat transfer area and the natural convection flow and the blocking of the convection flow are the two dominant factors that impair the heat transfer of rectangular finned radiators.

Numerical studies of natural convection heat transfer from radial radiators with a perforated ring have been conducted [16]. The effect of the number of perforations (0 – 6), perforation diameter (0 – 3 mm), perforation length (1.5 – 6 mm), and orientation angle (0 – 180) on thermal efficiency was investigated. The results show that radial radiators with a perforated ring obviously have better thermal performance than those with a non-perforated ring.

Paper [17] proposes and demonstrates a new cross-finned heat sink that improves natural convective heat transfer compared to a reference plate-fin heat sink widely used for electronics cooling. Numerical simulations are performed taking into account both natural convective and radiation heat transfer, and the results are confirmed by experimental data. Compared to the plate radiator, the total and convective heat transfer coefficients of the cross-finned radiator were increased by 11% and 15%, respectively.

Paper [18] discusses the methods used to improve the hydrothermal characteristics of heat sinks. It can be concluded that

the angle of inclination, orientation, and Ra number play an important role in increasing heat dissipation from the radiator.

In this work [19], based on the study of inclined plate fins, a W-type finned heat sink for natural convection was proposed. Taking into account thermal radiation, the efficiency of natural convective heat transfer of W-type fins on a vertical substrate was investigated depending on variations in geometry. In addition, the W-type finned radiator was experimentally investigated. The experimental results show that the W-type finned heat sink achieves a cooling effect with a maximum temperature drop of 4.6 °C and an average temperature drop of 2.9 °C. Compared to the optimized finned heat sink with parallel plates, the heat dissipation area is reduced by 10%.

It should be noted that for vertical finned surfaces, no studies have been conducted on the effect of changes in temperature pressure along the fin height and length on the value of the optimal distance between non-isothermal fins, which is typical for real fins made of metals.

2. Materials and Methods

In [11, 14], as a result of experimental studies, the criterion dependences for the Nusselt number for vertical surfaces with continuous and discrete fins under natural convection were determined (Fig. 1). The studies were carried out for non-isothermal fins, for which the temperature head between the fin surface and the external environment varied along the fin height.

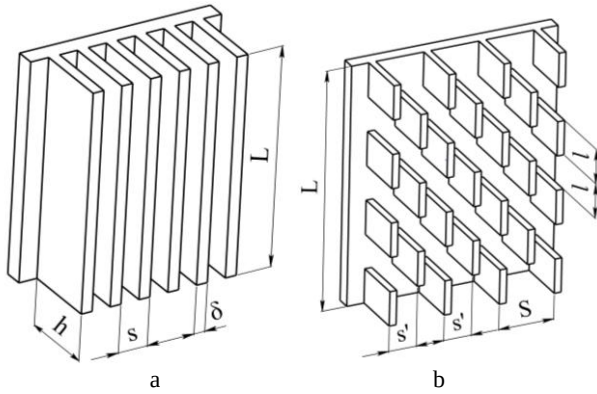


Figure 1. Diagram of vertical surfaces with continuous (a) and discrete (b) finning

For continuous ribbing, the criterion dependence for the Nusselt number is obtained as:

$$Nu_s = 0.7 \left[(Ra_s \cdot s \cdot L^{-1})^{0.25} - 1 \right], \quad (1)$$

which is valid in the following range of parameter changes $Ra_s \cdot s \cdot L^{-1} = 1.5 \cdot 10^4$; $s \cdot h^{-1} = 0.08 - 0.58$.

For discrete fins, the dependence for the Nusselt mean number [14] is as follows:

$$Nu_s = 0.314 \cdot (Ra_s \cdot s \cdot L^{-1})^{0.4} - 0.19, \quad (2)$$

obtained for the following parameter range $10 \leq Ra_s \cdot s \cdot L^{-1} \leq 1.1 \cdot 10^4$. It should be noted that for discrete edges, the distance s is twice the distance between adjacent rows $s = 2s'$.

3. Results and discussions

Using the criterion relations (1), (2), it is possible to determine the optimal inter-rib distances s_{opt} , at which the amount of heat Q , dissipated to the external environment will be maximized. The total amount of heat removed is equal to:

$$Q = \alpha \cdot \Delta T \cdot F_s, \quad (3)$$

where $F_s = m \cdot (2 \cdot L \cdot h + L \cdot s)$ – finned surface area, $m = H \cdot (s + \delta)^{-1}$ – the number of ribs in a system with continuous fins.

The maximum value of the heat flux Q is determined from the condition $dQ/ds = 0$. Taking into account the relation $\alpha = Nu_s \cdot \lambda_g \cdot s^{-1}$

¹ and dependence (1), after differentiating equation (3), we find the condition for determining the optimal inter-rib distance:

$$\left[(2h+s) \cdot (s+\delta) + s \cdot (s+\delta) - (2h+s) \cdot (2s+\delta) \right] \times (Ra_s \cdot s \cdot L^{-1})^{0.25} = s \cdot (s+\delta) - (2h+s) \cdot (2s+\delta). \quad (4)$$

In the limiting case, when the edge thickness δ approaches zero, the solution of equation (4) can be obtained explicitly:

$$\left(\frac{s}{h} \right)_{opt} = \frac{2}{(Ra_s \cdot h \cdot L^{-1})^{0.25} - 0.5}, \quad (5)$$

where $Ra_s = Pr \cdot g \cdot \beta \cdot \Delta T \cdot s^3 \cdot \nu^{-2}$.

From relation (5), it follows that the optimal inter-fin distance for continuous fins depends not only on the temperature head ΔT and the thermophysical properties of the coolant, but also on the size of the fin. We compared dependence (5) with dependence:

$$s_{opt} = 2.714 \cdot P^{-0.25}, \quad (6)$$

where $P = c_p \cdot \rho \cdot g \cdot \beta \cdot \Delta T \cdot (v \cdot \lambda_g \cdot L)^{-1}$, obtained in [6] for isothermal parallel plates and shown in Fig. 2. The analysis of the obtained dependences shows that for the edges with finite thermal conductivity, the value of s_{opt} is somewhat lower and depends on the parameter $Ra_s \cdot h/L$. The differences increase with the growth of $Ra_s \cdot h \cdot L^{-1}$ and for small values can be more than 40%.

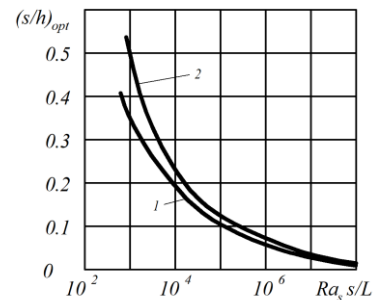


Figure 2. Dependence of s_{opt} on the parameter $Ra_s \cdot h \cdot L^{-1}$ for continuous finning: 1 – calculated curve; 2 – calculation for an isothermal surface [6]

For vertical surfaces with discrete edges, using the same methodology for determining s_{opt} taking into account the relation (2) for the Nusselt number Nu_s we find the equation:

$$\begin{aligned} & \left[0.188 \cdot (2h+s) \cdot (s+\delta) + 0.31 \cdot s \cdot (s+\delta) - \right. \\ & \left. 0.314 \cdot s \cdot (2h+s) \right] \cdot (Ra_s \cdot s \cdot L^{-1})^{0.25} = \\ & = 0.19 \cdot \left[s \cdot (s+\delta) - (2h+s) \cdot (2s+\delta) \right]. \end{aligned} \quad (7)$$

For infinitely thin edges ($\delta \rightarrow 0$), equation (7) becomes simpler:

$$\begin{aligned} & \left(\frac{s}{h} \right)^{2.6} - 1.341 \cdot \left(\frac{s}{h} \right)^{1.6} + 1.011 \cdot \left(\frac{s}{h} \right) \cdot \left(\frac{Ra_s \cdot s}{L} \right)^{-0.4} + \\ & + 4.044 \cdot \left(\frac{Ra_s \cdot s}{L} \right)^{-0.4} = 0. \end{aligned} \quad (8)$$

where $Ra_s = Pr \cdot g \cdot \beta \cdot \Delta T \cdot s^3 \cdot \nu^{-2}$.

The numerical solution of equation (8) with respect to s/h makes it possible to determine the optimal dimensions of the inter-edge distance for a system of discrete edges at different values of the $Ra_s \cdot s/L$ parameter. The results of the numerical calculation are shown in Fig. 3. For comparison, Fig. 3 shows the results of calculating the optimal values of $s \cdot h^{-1}$, which are found by formula (5) for a system of continuous edges.

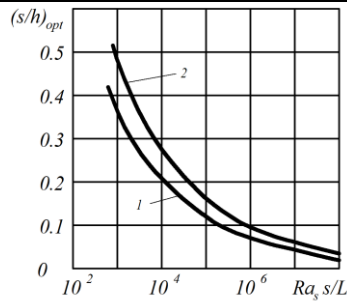


Figure 2. Dependence of s_{opt} on the parameter $Ra_s h L^{-1}$:
1 – continuous finning; 2 – discrete finning

As can be seen from the figure, as the $Ra_s h L^{-1}$ parameter decreases for discrete edges, the optimal distance s_{opt} increases compared to the same distance for continuous edges. At the same time, for small values of $Ra_s h L^{-1}$ the differences can be more than 30%.

4. Conclusion

The optimization of vertical surfaces with continuous and discrete finning under natural convection was performed. The optimization was carried out using experimental data obtained for finned surfaces made of steel, taking into account the non-isothermal temperature distribution over the fin surface. The results obtained for continuous fins are compared with the known results for isothermal fins. It is shown that the presence of nonisothermicity on the surface of continuous fins made of metal materials leads to the need to reduce the inter-fin distance by up to 40%. When the fins are discretized, the optimal distance between adjacent rows of non-isothermal discrete fins increases compared to continuous fins. The differences can be up to 30%. The results obtained can be useful in the design of finned surfaces under natural convection conditions.

5. Acknowledgements

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The main requirements for the modern content of lectures under the condition of direct training in the training of mechanical engineers in the field of agricultural engineering

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Abstract. A new approach for analyzing the content and structural units of modern lectures in a higher educational institution is presented. The requirements that should be presented to the lecture in order for it to meet its modern purpose in the continuous education of students have been analyzed. It is quite natural that individual lectures from certain disciplines may not meet all the listed requirements at the same time. However, any lecture should satisfy the educational, developmental and educational functions as much as possible.

KEYWORDS: COMPONENTS OF THE LECTURE, INSTRUMENTS AND EQUIPMENT, STRUCTURE, ELEMENTS AND FUNCTIONS.

1. Introduction

The lecture, among other forms of education in a modern university, occupies a special place. Many scientists, researchers and famous lecturers consider the lecture as the main form of university education. On this occasion, the distinguished scientist, the first rector of the Kyiv Polytechnic Institute, Professor V.L. Kirpychev said: "As long as humanity lives, the living language and the transmission of the principles of science in this language will not become silent."

However, there is also an opposite opinion about the lecture, as if the lecture teaches to uncritically accept other people's opinions, i.e. passive assimilation of scientific truths; that so-called lecture teaching has no feedback and is therefore unmanageable.

The given evidence cannot be extended to lectures of a problematic nature, which lead to active rather than passive assimilation of knowledge and increase the level of manageability [1].

If we also take into account that the lecturer can convey the educational material to the listener convincingly, emotionally, captivating the listener with a living word, then the positive qualities of the lecture increase even more. Here it is appropriate to mention the well-known expression "berba magistri" - the word of the teacher. The teacher's word is a means of pedagogical influence that neither a textbook, nor technical teaching aids, nor other means can compare with. The teacher's words have a psychological effect on the pupil, student, listener. The great scientist and pedagogue M.E. Zhukovsky characterized this method of imparting knowledge as follows: "By the power of impressions, the lecture method is superior to other methods of teaching and cannot be replaced by anything, at the same time, this method is also the most economical in terms of time" [2].

Keeping in mind that our time is characterized by a rapid update of information ("information explosion"), the transformation of public consciousness, a lecture with its advantages of prompt presentation of material, the possibility of concentrating the latest information in it, differentiating it in relation to different audiences depending on the level of preparedness of the latter, becomes simply irreplaceable [3, 4].

Along with this, the lecture always carries information about the current trends in the development of the issue or phenomenon under consideration, which is very important for scientific orientation and assessment of the state of the issue. Through the lecture, the scientist (lecturer) carries out the educational process of students, conveys his point of view, his ideas, which is characteristic of university activity.

Thus, the lecture should be recognized as the leading form of education, its influence extends to the remaining forms of education (seminars, practical classes, laboratory work, games and other types of classes), it organizes the formation of knowledge into a system, determines the student's attitude to the subject being studied.

2. Results and discussions

It is appropriate to first consider the structure of the lecture. There are various options, but we consider the most acceptable one that distinguishes its three constituent parts: content, structure and elements. The latter should probably be divided into elements and functions, since the elements characterize the quality of the lecture according to certain indicators, and the functions - how far

the lecture corresponds to a certain purpose. Each such part is determined by certain factors. For clarity, the structure of the lecture is presented by us in the form of the following structural diagram (Fig. 1).

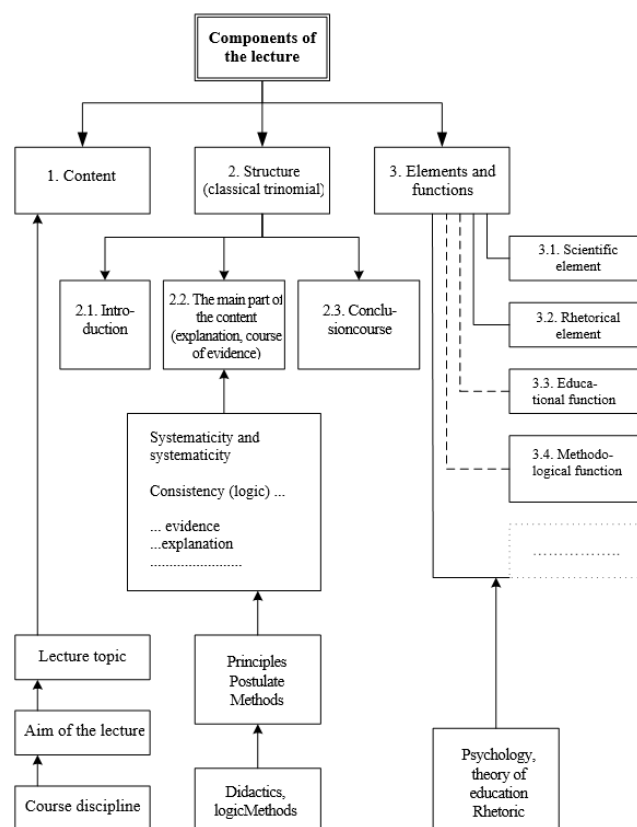


Figure 1. Lecture construction scheme

It can be seen from the scheme that the content of the lecture (1) is determined by the topic, which, in turn, follows from the set goal. The goal is dictated by the program, which provides for the formation of the necessary knowledge.

The structure of the lecture (2) is determined by didactic principles used mainly in the course of proofs and the logic of presentation. Let's point out some principles, postulates, methods that are considered by didactics:

- the principle of learning activity (the fundamental principle that determines the assimilation of knowledge by a student if he has cognitive independence);
- the principle of systematicity and systematicity (logical sequence and systematic approach in studying the material);
- the principle of developing and educational training (formation of mental abilities and cognitive needs of students while simultaneously forming progressive views and beliefs in them);
- the principle of connection with practice (the unity of theory and practice in the acquisition of knowledge, skills and abilities);
- the principle of scientificity (presentation of scientific information in accordance with the state of development of science for the current period);

- the principle of strength of knowledge (clear assimilation and memorization of that knowledge which is the basis, a tool for further knowledge, independently; to a large extent, this includes knowledge that is formed by fundamental disciplines);

- method of analogy (knowledge through comparison, contrast);
- the induction method (a logical method based on the conclusions that arise from the knowledge of individual phenomena and lead to general conclusions: the descent from the particular to the general);

- the deduction method (logical inference that allows you to know the partial on the basis of the general);

- modeling method (spreading conclusions of a certain degree of commonality to new knowledge of the same degree of commonality, i.e. knowledge of a subject, if it is similar in characteristic features to others);

- algorithm (regarding the educational process - knowledge as a result of performing a set of educational operations in a strictly recognized sequence to obtain a solution to any problem of a given type);

- heuristics (cognition based on free thinking when combining the psychological, subjective with the rational-logical, objective);

- invariants (that part of different systems, which is common or invariant to them and allows, based on the study of the invariant, to be freed from the study of sets of individual systems), etc.

Let's consider in more detail the structure of the lecture and its components, as well as the elements and functions of the lecture, in order to formulate the requirements for a modern lecture based on them. In the structure of the lecture, its three main parts are usually distinguished: the introduction, the content part and the conclusions, which have been established as a classic trinomial.

Introductory part (item 2.1). The main thing in the lecture is to awaken the listener's cognitive need and condition his independent mental activity. It follows from this that in the "introductory part" it is advisable to use appropriate methodological techniques: an unusual beginning that intrigues the listener; setting an educational problem that leads to a problematic situation; the beginning of the lecture on a question left unsolved from the previous lecture, etc. In other words, one should look for opportunities for the lecture to be problematic in terms of structure and content.

Let us give an example of the scheme of constructing a problem lecture:

1. Initial data. In previous lectures, it was shown that device (process, substance, method, etc.) U has advantages (a), (b), (c). Property (c), which is inherent in U , limits the limit of its use by some parameter, the maximum value of which is (P).

2. Formulation of the problem situation. It is necessary to propose U^1 (closer to U), which, keeping (a), (b), and (c), would expand the limit of application of U to P^1 (more than P).

The content of the wording is clarified.

3. The general direction of finding a solution. Change (c) in such a way that, while retaining (a), (b) and (c), ensure the implementation of (P^1) and at the same time, if possible, more fully satisfy the requirements (1), (2), (3) and (4) (the higher the serial number of the requirement, the more important it is).

4. Breakdown of the problem into subproblems. The problem can be solved in two ways:

path (A): change (c) due to (t); ,

path (B): change (c) due to (n).

In accordance with (A) and (B), two subproblems are formulated and explained.

5. Solving subproblem (A).

Hypothesis 1. Its content is explained: (c) changes to (c^1); (a), (b) and (c) are retained; (1), (2) are satisfied, and (3) and (4) are not.

Hypothesis 2. Its content is explained: (c) changes to (C^2); (a), (b) and (c) are retained; (3), (4) are satisfied, and (1) and (2) are not.

Hypothesis 3. Its content is explained: (c) is replaced by (c^3); (a) and (b) are preserved, (c) - not; (1), (2), (3) and (4) are satisfied.

6. Analysis of the results of solving subproblem (A). Hypothesis 3 is not acceptable because (c) is missing. Since (1) and (2) are more important than (3) and (4), hypothesis 1 gives the best results.

7. Solving subproblem (B).

8. Analysis of the results of solving subproblem (B).

9. Conclusions.

The results of (A) and (B) are compared, a rational solution is chosen, and the practical significance of the obtained result is clarified.

Other schemes for constructing a problem lecture are also possible.

During lectures, students can take part in solving a problem situation by proposing their own hypotheses or analyzing the results. But even in the case when the solution will be taught by the lecturer himself, students will still be involved in the solution process.

Is it possible to build the entire course from only problematic lectures? This is impossible and unnecessary, because the material is descriptive, axiomatic, factual, classification, in which the problem cannot be identified.

Therefore, problem-based learning, with all its importance, should not be absolutized. It is also worth noting that the activation of students at lectures is impossible without the activation of the teacher himself.

Students, as a rule, are satisfied with such lectures and listen to them carefully. We will also note that such a (similar) lecture has great educational value.

Of course, the "Introduction" should name the topic of the lecture, its place and significance in the system of other topics, consider its main issues, name the bibliography (or make a reference to the bibliography contained in the work program of the course. It is desirable that such methodological support was displayed for student viewing or use).

In the lecture, a systematic approach should be implemented in the presentation of the educational material, and in the lecture course in general - the entire discipline. That is why it is essential for the lecture to inform the audience in the "Introduction" (writing on the board, presenting information with the help of TZN) of the structural elements of the lecture with an indication of their subordination, the adopted systematization of the material taking into account the categorical composition and categorical structure, its internal and intersubject connection. In other words, the student or listener must see a complete picture of his employment in this lecture from the very beginning. At the same time, the knowledge to be learned appears in a systematic form, the method of building this system, its essential features are visible. Such information is extremely important. It determines the mood of the listener for perception, waiting for the solution of the next questions. Thereby, we contribute to the gradual formation of meaningful units and activate the psycho-emotional factor - positive emotions of hope, curiosity, etc. In addition, the student psychologically adjusts to a certain volume of information, internally preventing premature fatigue and loss of attention.

The significance of this technique has been known for a long time. The meaning of its reflection in the phrase: "to teach in such a way that the student, like a swimmer, sees the opposite shore (one who does not see the shore can drown one step away from it)".

Systemic knowledge is better assimilated, well remembered, in contrast to scattered and fragmentary, not logically connected, i.e. unsystematic.

In the presentation of lecture material, it is important not to neglect, but on the contrary, to comprehensively use the methods of classification (processes, phenomena, concepts), which also illuminates the interdependence between these phenomena, processes, organizes ideas, reveals the logic of interconnection. There is an opinion that knowledge begins with classification.

From our point of view, nothing so organizes and brings the lecture presentation of the material into a coherent system and does not contribute to its systematic perception as much as its classification gradation. D. I. Mendeleev's periodic system of chemical elements is an excellent example of this, which shows the enormous cognitive power of classification. A special system of concepts that exists in any classification, called a hierarchy, contains the relationship between the main (general) and the subordinate (less general or partial). Knowing the relations of subordination, establishing the place of a phenomenon or an object on a

hierarchical ladder is not only an unconditional moment in the formation of a concept, but also a necessary condition for its solid assimilation. With this approach, this concept is included in the hierarchy of many concepts that make up the system, and this allows us to penetrate into the essence of the (researched) phenomena being studied, it emerges as a concept with a high degree of generalization and becomes a contribution to the worldview. Classification is the first level of scientific generalization.

In addition to the above, the classification makes it easier to take notes of the material, and in the future, to use it more effectively for further cognitive purposes.

Systematicity is one of the most important qualities, a factor of creative thinking.

In conclusion, we will cite the statement of the great teacher K. D. Ushinsky about the role of systematicity for knowledge: "Only a system, of course, is reasonable, one that comes from the very essence of the subject, gives us full power over our knowledge."

The main part of the content (explanation, course of evidence) (item 2.2). This part is the basis of training.

In this part, the lecturer forms concepts about some objects, processes, phenomena, revealing their essential features. At the same time, the lecturer uses various techniques and methods from the arsenal of didactics (some of them were mentioned), searches for ways of proof, involving students in this process. The provability of advanced scientific propositions, when they come to a conclusion (solution) in a logical way, through the disclosure of the genesis of the phenomenon under study, determines purposeful cognitive activity, not formal perception of knowledge. In other words, the lecture should contain evidence of scientific (theoretical) propositions, and not offer listeners to accept them on faith. Proving the truth in a finished form reduces interest in science. The justification of this or that phenomenon often requires the involvement of knowledge from related sciences (mathematics, physics, chemistry, etc.), since many phenomena have a physical, chemical, or other nature. For example, M.V. Lomonosov, the founder of Russian science, characterized the relationship between chemistry and physics as follows: "These two sciences are so connected that one cannot be perfect without the other." In many cases, a historical excursion is necessary, a story about the ways of scientific research, the evolution of this or that concept, the disclosure of its genesis, biographical information about the activities of the scientist, etc., as mentioned above.

Due to this, the teacher needs knowledge of the historical aspect, the ability to attract the necessary knowledge from related sciences, skillfully using them.

The proof of scientific truths, along with the need to justify them, implies a logical sequence of decisions, which teaches the student to think logically. A truth that is taken for granted (unless, of course, it is obvious, like a postulate or an axiom) does not cause mental activity. "It is impossible to teach only on the basis of authority - you need evidence that sharpens the mind and feelings," said the classic of world pedagogy, Ya.A. Kamenskiy.

Here we must be careful not to get carried away with mathematical proofs, which in some cases leads to formalism, to the loss of the general direction of the lecture in the case of long mathematical expositions.

The lecture should correspond to the unity of theoretical and applied (dialectical unity of theory and practice), because theoretical knowledge is ultimately designed to serve practical needs. The scholastic presentation of the course without an indication of the application of knowledge in practical activities gives rise to the student's perception of the uselessness of knowledge and, as a result, a negative attitude towards its assimilation. That is why it makes sense more often than usual to start the lecture with instructions on the application of the material studied in a specific field of practical activity of the future specialist. It is even better if this beginning is raised in the form of a problem that leads to the emergence of a problematic situation.

Theory becomes pointless if it is not connected with practice, that is, theory should not only generalize already existing practice, but also run ahead, show it the way of further development.

There should be room for analogies in the lecture. Compared to others, the method of analogies is the most common. In lectures in general (and of a problematic nature, in particular, for solving problematic situations), the method of analogies is effective. This or that concept is formed, if it is not firmly "tied" to the ideas, images, objects, concepts already existing in the student's mind, it is poorly remembered and poorly assimilated. It is necessary to include a new concept in the system of established connections that the student already has.

This is easily achieved through analogy, comparison with an already known, usually simpler object or phenomenon, but one that has some common features. In other words, the journey from the known to the unknown through comparison (or contrast) facilitates the establishment of new connections. That is why the method of analogies can be qualified as one of the essential didactic techniques in the process of learning. This is how Y.I. Frenkel determined the importance of the method of analogies in teaching such a complex discipline as "Wave Mechanics": "For didactic reasons, I widely used the method of analogies in teaching, sometimes superficial, but having the advantage of clarity. Analogy, if you treat it rather cautiously, I represent the simplest and most understandable way from the old to the new: one should not forget that every analogy has certain limits."

Along with the above, depending on the specifics, the content of the lecture should reflect:

- connection with the urgent tasks of the present or the future, indications of real ways of solving these tasks (problem-target assignment);
- the state of issues (problems) in our country and abroad, the main directions of scientific (or design) developments, unconditional fixation of attention on unresolved issues.

Conclusions (end) (item 2.3). The part of the lecture called "conclusions" in the classical plan involves the formation of a strictly reasoned result in a systematized form.

However, it is not always possible to finish the lecture in a classical way. In a number of cases, it can be finished with a logically completed material, a question for reflection, a technique for perplexing students. In other cases, in the final part of the lecture, it is useful to sum up the concepts discussed in the lecture and establish new connections between them (consider from other points of view). From the point of view of activating the mental activity of students, the conclusion proposed by the well-known specialist in active learning methods, Doctor of Technical Sciences, Prof. Rybalsky V.I. (KIBI). He practices answering 1-2 questions (in writing) to all present at the end of the lecture. This procedure takes 5-10 minutes, and the questions are formulated in such a way that you will not find the answer in an explicit form in the lecture material: you need to think logically, compare, and this is possible when the material is understood. The questions are asked to everyone the same (the lecturer has thought them through in advance), but the depth of the answers can be different. At the next lecture, the results are announced, 2-3 best answers and the same number of unsuccessful, casual answers are read out. Along the way, the number of attendees at the lecture is controlled, although work is added, of course: you have to evaluate 100-150 answers, it takes personal time. Of course, such an approach disciplines students, encourages them to work actively during the lecture, especially those who, although present, are in "internal exile". For the teacher, this is also an effective method of feedback, the absence of which is characteristic of most lectures. The consequences of such a blitz poll in V.I. There are several Rybalsky: if someone had successful, that is, the most complete answers in all the lectures - there can be a score "automatically", those who missed or answered unsuccessfully - additionally work on these topics, etc.

Elements and functions of the lecture (item 3). Its quality can be judged by the elements of the lecture, and its fulfillment of its purpose by its functions.

The scientific element of the lecture (item 3.1) is that the lecture should be scientific, not dogmatic. Dogmatism, as is well known, is thinking with frozen, unchanging positions, established formulas. Science is dynamic, constantly developing, its concepts sometimes

change; are deepened, supplemented. In other words, science is constantly reassessing scientific accumulations: some scientific facts are developing, others are losing their past significance, new hypotheses are emerging, etc. In this regard, the presentation of scientific information should be in full accordance with the state of development of science for the current period and the trends of its development. A student should not imagine that everything has been decided in science and there is nothing left for him to do in it; on the contrary, he must constantly be aware that the formation of a certain level of knowledge and concepts in his head only corresponds to the current state and is by no means complete once and for all. V. Humboldt perfectly expressed this side of the activity of the higher school: "The peculiarity of universities is that they always present science as a problem that is not completely solved and therefore constantly research it."

The above implies the participation of teachers in research work, interest in scientific and methodological problems (how to teach?), his wide scientific knowledge and erudition in the chosen field of knowledge, as well as the presentation of his scientific research and his own point of view on this or that problem.

This is what distinguishes a higher school from the system of secondary special and general education.

Rhetorical element of the lecture (item 3.2).

"Speak so I can see you." (Socrates).

Language culture, verbal sophistication, well-known oratorical art should be the subject of constant care of the teacher. Language culture should be constantly cultivated in students as well.

Let's turn to some components of this activity of the teacher-lecturer, which should be at his disposal:

- confidence in "what one intends to assure others";
- logic of teaching;
- harmony of thought and word;
- charm of gesture, impulse, facial expressions, voice intonation, body movements, teaching manner;
- a life-giving word, the scope of which is unusually large (it teaches, excites, reassures, disappoints, excites passions, wounds, heals, and many others);
- refusal of extensions when expressing an opinion and the use of clogging words;
- precisely selected terms, expressions, comparisons;
- emotionality, clarity and conciseness of speech;
- clear diction and sufficient literacy. These and other techniques determine eloquence.

What gives eloquence? First, the effects of eloquence are extremely pleasant. Secondly, as Plato claims, "eloquence is the art of controlling the mind and consciousness." Thus, eloquence is a powerful tool for both learning and education. The German poet and public figure I. Becher also places eloquence in the rank of art, who believes that "a report or a lecture can become a work of art."

"Neither art nor wisdom can be achieved if it is not learned" (Democritus).

The educational function of the lecture (item 3.3) (worldview aspect). A worldview is considered to be a system of generalized views, concepts, ideas about the world as a whole. This is a natural-scientific vision, philosophical and socio-political views, ethical and aesthetic concepts, etc.

To the extent that the purpose of a lecture is to convey new knowledge, any lecture is designed to shape a scientific outlook. Thus, education exerts an educational influence and forms a personality. On the educational value of science (learning) K.D. Ushinsky wrote: "The development of consciousness is, without a doubt, one of the most important goals of education, and the truth of science is a tool for this development."

It should be noted, however, that while forming this or that knowledge about the object, the lecturer consciously or unconsciously forms in the minds of the students an attitude towards this object, a concept. This attitude can be different: either it is related to the emphasized meaning of the concept or phenomenon, or on the contrary, its insignificant value, invoking a sense of responsibility, hostility, etc. Therefore, along with the objective factor, there is also a subjective factor that depends on the lecturer

as a person, his beliefs. The sum of these attitudes (relationships) to specific phenomena of the objective world, to material that can be known cannot but influence the formation of a worldview in general.

The content of a worldview is a system of beliefs. In order to turn knowledge into conviction, a deep feeling of it and a personal assessment of this knowledge by the subject as an undeniable reflection of reality are necessary. Without this, knowledge cannot become personal property. In other words: the emotional background (curiosity, interest, need, significance, etc.) is a necessary condition for this.

Arousing inquisitiveness, curiosity, the lecture conditions the feeling of acquired knowledge.

The value of such an approach lies in the fact that in such cases the educational element does not appear in an imperative or intrusive form, but is organically woven into the fabric of the lecture material.

The above example of constructing a problem lecture shows (and similar examples can be presented from almost any discipline, having spent time on it, of course), how in the educational process, through the formation of attitudes to objects, phenomena, the principle of the unity of education and upbringing is implemented. One could cite many examples, in which it is just one step from the essence of the concepts formed by the teacher during lectures to the formation of students' motives for labor and social activity, concepts of thrift, a sense of responsibility, willpower, patriotism, pride for an independent Ukrainian state, etc.

Methodological function of the lecture (item 3.4). Philosophical views are the core of any worldview. Of course, not those dogmatic postulates that have discredited philosophy as a science for more than 70 years. We are talking about a wide, internationally recognized spectrum of philosophical science, which, as is known, is the methodological foundation for all other sciences.

Therefore, any lecture should be aimed at forming a student's philosophical, dialectical thinking. It should be borne in mind that both materialists and idealists cannot do without dialectics: be it engineering, teaching or some other activity. All disciplines, especially the natural sciences, contain many examples to illustrate the categories of dialectical and historical materialism. However, if someone is not satisfied with materialism, then such categories as: matter and motion, time and space, quantity and quality, discontinuity and continuity, new and old, necessity and contingency, form and content, essence and phenomenon, remain equally eternal. base and superstructure, etc.

Categories, since they reflect the most general and essential connections and relationships of objects, allow a person to get to know the surrounding reality more deeply, because cognition is a complex process of assimilating categories, concepts, and laws.

Therefore, with such an approach, natural sciences, general engineering, economics, and other sciences can to a large extent cause knowledge to grow into conviction.

Along with the general methodology, there is also a special one, which is based on the general one, but contains and uses a number of specific principles, theories, methods of research that are characteristic of this science. Let us point out some characteristic features of such methodological preparation.

The amount of information in any science becomes so large that a student is unable to learn and remember everything necessary from this science, which he will need in further practical activities. This necessitates a clear selection of material that would meet the requirements of minimum volume and maximum informational significance on the one hand, and on the other - the possibility of its use for independent learning of new material. An example of a methodological approach can be the study of an invariant (see above), since in this case there is no need to study many separate systems. Academician N.F. In this regard, Talizina points to the need for a new way of preserving information: "instead of preserving a large amount of ready-made knowledge, preserve a method that allows analyzing and re-creating the entire system of individual phenomena."

The methodological function of the lecture requires painstaking selection of educational material, i.e. presentation and assimilation of such knowledge, which are key (knowledge base) and the application of which allows one to understand the factual material independently to one degree or another.

For this purpose, the lecture gives preference to consideration of theoretical issues: categories, principles, laws, definitions, that is, what refers to the elements of the categorical composition and the disclosure of logical connections between the elements of the composition (categorical structure).

The elements of the categorical composition are methodologically general, and the formation of concepts about them and the clarification of their essence should be of primary importance. After all, it is known that the one who undertakes the solution of individual issues without first solving the general ones will inevitably "stumble" on these general issues unconsciously at every step.

The methodological function of the lecture implies a reduction in the volume of factual material in the lectures, which the student must study independently. Academician spoke very aptly about this. M.N. Lavrentiev: "It is necessary to learn to think from the school bench, and for this it is necessary to drastically reduce purely informational material in the curricula of all levels."

A genetic approach to revealing concepts is also essential in cognition. This or that concept about some object, phenomenon, can be formed in its pure form, that is, by describing it, giving ready-made definitions, in other words: by showing what a thing is in isolation from how it became so (or in isolation from what made it so).

Concepts (or knowledge in general) presented in this way are perceived formally by students. At the same time, the purposeful action of the teacher regarding the development of students' thinking is wasted.

Thinking (and above all logical thinking) develops when implementing the technique of genetic disclosure of the content of concepts, following the logic of discovery, researching cause-and-effect relationships, forming generalized concepts about objects, processes, phenomena, that is, professing the thesis that it is important not only what a thing is, but also how it came to be. It is not difficult to guess that such an approach requires mental actions. The cognitive need and mental activity resulting from it, as it was repeatedly noted above, is generated by a problematic structure.

By following the logic of discoveries, that is, by bringing the stages of research to students, the teacher gives him the opportunity to apply them in similar situations that require the same or similar stages.

The importance of acquiring knowledge through the illustration of the development of concepts (a genetic method of revealing a concept instead of a description) can be figuratively defined as follows: "not bare conclusions, but on the contrary, study is what we need most; conclusions are nothing without the development that led to them."

Thus, the methodological function of the lecture is that the method of presenting knowledge teaches the student, and their content creates prerequisites for further independent acquisition of knowledge. In other words, the methodological function of the lecture involves teaching methods, methods of self-mastery of knowledge, teaches logical thinking (developmental function of education).

3. Conclusion

Thus, based on everything stated, the main requirements for the lecture are:

1. In most lectures, you should look for opportunities to create problem situations; in other words, lectures of a problematic nature (in terms of structure and content) should be predominant in lecture courses.

2. In the lecture, a systematic approach to the selection of material and the teaching of the course should be implemented.

3. A mandatory requirement for a lecture is the provability of scientific propositions, and not their communication by the lecturer in the form of ready-made truths.

4. The constant implementation of the principle of the unity of theoretical and applied, i.e., the combination of theory with the future practical activity of a graduate specialist on examples of consideration of specific material - this is an attribute of a modern lecture.

5. In lectures, there should be a place for the method of analogy, which is quite effective in assimilating new knowledge.

6. An important function of the lecture is its methodological orientation: to teach a way of knowing, to master the method, to develop thinking.

7. The lecture should be scientific in nature, not dogmatic, form knowledge that corresponds to the current level, bearing in mind that they correspond to the state of the not fully resolved problem.

8. Any lecture through the formation of the relationship to concepts, phenomena, objects fulfills the necessary worldview function, and through the examination of philosophical categories is designed to form a philosophical worldview (even on non-materialistic grounds) and dialectical thinking.

9. The lecture should be rhetorical and effective.

Fulfillment of these requirements in education (first of all, in lecture teaching) will allow a comprehensive approach to the implementation of its corresponding functions: teaching, developing and educating, which are the subject of didactics, psychology and theory of education, that is, the psychological and pedagogical cycle of sciences.

All these requirements, which can be considered basic, are designed to awaken the cognitive need of students, to cause them to think, to condition the strength of knowledge, to teach methods of independent knowledge, to form a philosophical outlook and dialectical thinking, to realize the unity of the process of education and upbringing.

It is quite natural that individual lectures from certain disciplines may not meet all the listed requirements at the same time. However, any lecture should satisfy the educational, developmental and educational functions as much as possible.

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Research on the possibilities of restoring agricultural land damaged by military operations

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Abstract. The article presents an analysis of the impact of armed aggression and military operations on soil cover, in particular, damage and chemical contamination. It shows the approaches most commonly used when sampling bombed soil, provides possible levels of contamination of agricultural land, and suggests measures for the use of such land depending on the level of chemical contamination.

KEYWORDS: AGRICULTURAL SOILS, CONTAMINATION, RECLAMATION, EXCAVATION, CONCENTRATION FACTOR.

Currently, Ukraine's land fund is suffering from exorbitant damage and destruction, as a large proportion of land, including agricultural land, is severely damaged by rocket attacks and hostilities. As a result, the quality of the soil has deteriorated significantly.

Each shell explosion on the field creates a blast wave and chemical pollution. The blast wave results in sinkholes, soil compaction, destruction of vegetation and death of soil fauna. All of this causes a change in the hydrolytic regime and destruction of the soil structure, and ultimately provokes soil erosion and desertification. Military weapons and explosives use chemical compounds that are not biodegradable and can contaminate soil and surface water [1].

Harmful chemical contamination of agricultural soils as a result of hostilities can be considered from three perspectives: contamination with potentially toxic elements, explosives and other substances.

Chemical contamination of land as a result of hostilities can be of varying degrees: from permissible to moderately dangerous and hazardous. According to DSTU 7243- 2011 SOIL QUALITY. Land is technogenically contaminated. Inspection and use, land plots with very hazardous and extremely hazardous chemical contamination are subject to conservation for a certain period of time depending on the decomposition of chemicals or their decontamination [2].

The degree of land contamination with chemicals is determined based on the results of the inspection of such land and rapid soil analysis on the land plot based on the results of the analysis of samples taken on the land plot [3].

Soil samples should be collected from every area where the presence of explosive ordnance is suspected, such as known target areas, firing lines, and open detonation zones.

The approaches most commonly used in soil sampling are discrete sampling, systematic random sampling, simple random sampling, and others. These approaches can also be combined to improve the quality of information collected during sampling [4].

Discrete sampling involves taking soil samples from a specific location where the information obtained gives reason to suspect contamination. One of the specific features of this sampling method is that it detects the highest levels of contamination at the site, rather than the average level of contamination [5].

Systematic random sampling involves dividing the study area using a square, triangular or herringbone grid and taking samples from nodes (intersections of grid lines). The start and direction of the grid is set using an initial random point. From this point, the coordinate axis and the grid over the entire area are built. The distance between the sampling points in a systematic grid is determined by the size of the area to be sampled and the number of samples to be collected. Systematic grid sampling is often used to determine the level of pollution and to determine the concentration of pollutants [5].

Fig. 1 shows a scheme of systematic random sampling on a rectangular grid [5].

This sampling is a flexible method for estimating the average concentration of a contaminant in grid cells and is sometimes also referred to as stratified random sampling. To reduce the influence of warfare sources on the average concentration estimate for the study area, it is recommended that 30 or more evenly spaced increments are taken to form a pooled sample. A small number of discrete samples will almost always result in a lower estimate of

the average concentration than a sampling strategy with many increments [5].

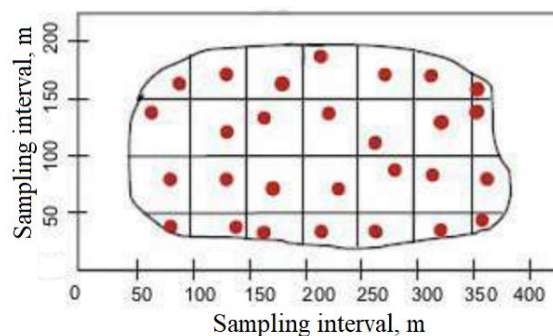


Figure 1. Scheme of systematic random sampling on a rectangular grid

Simple random sampling involves taking samples from randomly selected locations on the site. From a statistical point of view, it can be used to estimate the average level of contamination in an area. Due to the internal variability of soils, it can provide high accuracy if the soil is suspected to be homogeneously contaminated. Sampling locations are selected using a random sampling procedure (Fig. 2) [5].

The random selection of sampling points implies that each of these points should be selected independently of the location of all others. As a result, all points within the relevant area have an equal opportunity to be sampled.

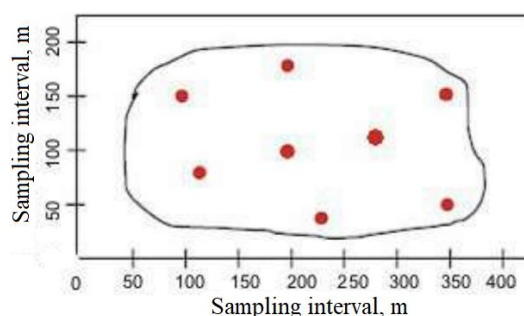


Figure 2. Scheme of simple random sampling on a rectangular grid

In addition, the interpretation of the results of analyses of samples taken by simple random sampling can be time-consuming. Therefore, systematic random sampling is preferred.

For areas of several types of battle damage, a field sampling strategy called multi-stage sampling is also used, where a 100-incremental soil sample is taken (from the 0-5 cm layer) at evenly spaced intervals (50 × 50 m) at each decision unit to form one sample (Fig. 3) [5].

In areas where anti-tank missile systems are used for direct fire, the highest concentrations of explosive residues are recorded around targets and behind the line of fire.

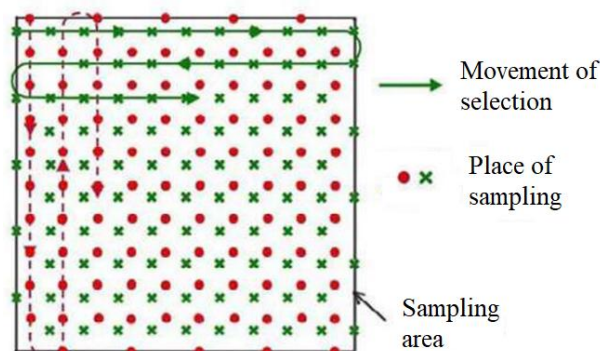


Figure 3. Scheme of 100-incremental sampling using a systematic random approach

Other sampling approaches are used to estimate average explosive concentrations. The first is a "box" sampling scheme, where a 7×7 -m sampling unit is used to form a pooled sample of five increments, with samples taken from the centre point and four corners, as shown in Figure 4, a. The following Figure 4, b uses a "wheel" sampling scheme of seven increments, with six samples taken from the periphery of a 1.2-m diameter circle and the seventh from the centre point [5].

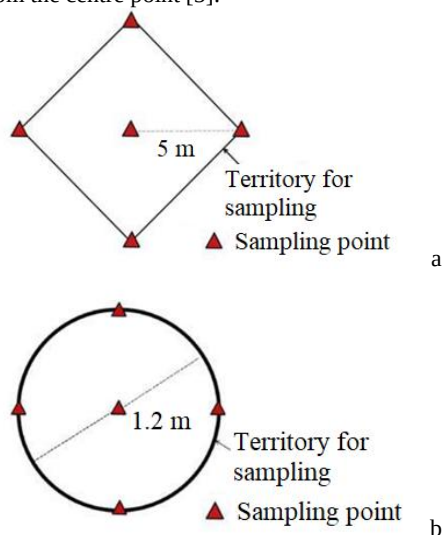


Figure 4. Soil sampling schemes: a) box sampling plan; b) wheel sampling plan

Direct fire artillery combat zones are among the most common in military operations. The high explosives used in artillery shells and mines typically contain mainly TNT, sometimes tetryl. When the munitions are detonated, the detonation often creates an explosive crater in the ground, the size of which depends on the type of munition, the physical properties of the soil, and the type and setting of the fuze. Impact zones can therefore be identified by the presence of targets, debris from former targets and areas with a large number of explosive craters.

In general, high-order detonations consume the explosives in the warhead very efficiently, leaving only micrograms to milligrams per hundreds of square metres of surface per shot. Low-order detonations result in a different type of soil contamination, which is also confirmed by our research: 70 per cent of soil samples collected from individual explosive craters in Zaporizhzhia, Donetsk, Kyiv and Sumy regions did not contain explosive residues, but only heavy metals. In almost all cases, the surface layer of the sampled soils was affected by low-order detonation [5].

In a relatively small number of cases, a projectile partially detonates on impact, resulting in a low-order detonation. In these cases, only a portion of the explosive filler is consumed, sometimes leaving a significant portion of the explosive in the ruptured case or near the ruptured jacket. Sometimes a close high

explosive detonation causes a low explosive detonation at a certain distance. In this case, a significant portion of the explosive will accumulate on the ground surface. These events are generally rare for most munitions, so their distribution is random. Low-order detonation results often exist in the form of distributed point sources with very high concentrations of contaminant residues. Furthermore, unlike anti-tank targets, there is usually no well-defined explosive gradient around artillery munitions explosion sites. This random spatial array in the event of low-order detonations is explained by indirect fire and the large distance between the firing position and the target. However, the concentrations of explosive residues in the surface soil layer in areas where shells have experienced low-order detonations can reach hundreds of $\text{mg}\cdot\text{kg}^{-1}$ [5].

For direct fire artillery battlefield sampling, it is recommended to use a decision unit size of 50×50 m centred on each target and to collect 100-incremental samples from the top 5 cm of soil using a systematic random approach [5].

If low-order detonations are present or fragments of explosive remnants are visible and identifiable by field screening methods, then a 10×10 m grid or smaller decision unit should be used for sampling, centred on each target and a 30-increment sample taken from the top 5 cm (Figure 5) [5].

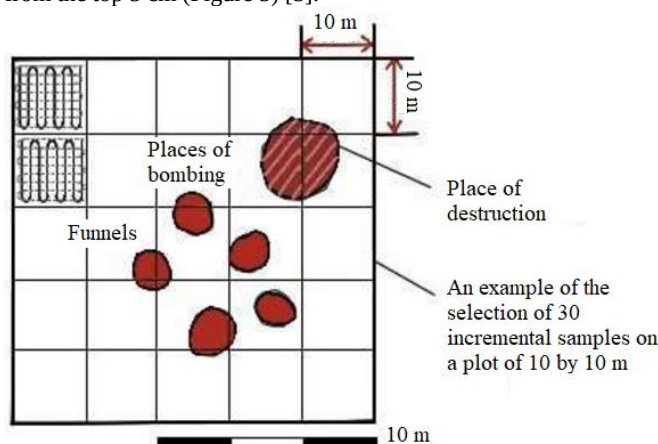


Figure 5. Scheme of taking 30 incremental samples on a 10×10 m plot

To assess the risk to human health, the initial sample is taken from the soil surface to a depth of 0-5 cm. After that, the sampling intervals should be close enough to each other, e.g. 5-10 cm or 20-30 cm, to ensure relevant depth segregation. Almost all studies show heavily contaminated topsoil profiles (0-10 cm). With increasing depth, the level of contamination decreases, with the exception of those potentially toxic elements that have relatively higher accumulation levels with increasing depth. Contamination is generally limited to the first half metre of depth [4].

It is also necessary to take into account the depth of groundwater when determining the sampling site, as the mechanisms of migration of pollutants in the zone saturated with organic or mineral substances are different. In the case of surface contamination, the presence of organic matter can affect the migration of contaminants to deeper layers.

Samples to determine the level of contamination should be taken in a way that limits the possibility of contamination itself during the sampling process.

For one thing, sampling should start from the least contaminated to the most contaminated area. This minimises the risk of contamination from the sampling equipment.

Once the soil sample is collected, it is transferred to a suitable container for storage and transport to the laboratory [5].

Depending on the contaminant parameters to be analysed, the container may be a plastic bag or a glass or rigid plastic container. In general, plastic containers are only acceptable when soils are analysed for inorganic contaminants, while glass containers are intended for organic contaminants.

It is always advisable to collect more soil than required for repeat analyses if necessary. For the analysis of organic and inorganic contaminants, 1 kg of soil is generally sufficient.

All sampling equipment should be of sufficient quality to prevent contamination of samples (e.g. painted surfaces that may chip and enter the sample). In addition, the sampling equipment should either be easy to disinfect or cost-effective if it is considered costly.

Several types of tools can be used for soil sampling, depending on whether shallow sampling is intended.

Depending on the sampling method, different types of samplers are used (Figure 6) [5].



Figure 6. Tools for taking samples

When the sample to be taken is very close to the surface, a shovel or trowel is used to take the required volume of soil.

The sampler is used as systematically as possible to be able to reproduce the same sampling conditions at successive points. The main disadvantage of this method is that it mixes the soil considerably during sampling, which can lead to volatile compounds evaporating. This soil sampling tool is easy to use in cohesive (clay, loamy) soils. However, they are not practical for non-cohesive (sandy) soils, so metal trowels are more suitable for sampling.

Hand-held auger. This sampling system consists of an auger, an extension and a T-handle, which are connected together and can be easily dismantled. The auger models are designed to take samples from a variety of soil types, from sandy to clayey. To take a sample, the auger is inserted into the soil by turning it clockwise. As a rule of thumb, two to three turns will drive the auger approximately 10 cm. Once the auger has been inserted to its full length, it is removed from the soil and a sample is taken. The auger is removed from the soil and the sample is taken by turning the auger over. We recommend using augers with a diameter of 5 cm or more. **Sampling tube.** This method involves taking a sample by inserting a tube into the soil from the surface. After the tube is pushed as far as it will go, it is pulled out and a soil sample is taken [5].

There are different models of sampling tubes on the market, depending on the type of soil. The length of the tube itself varies from 20 to 52 cm in different models. The inner diameter should be 2-3 cm. Although the sampling tube is typically used for surface sampling, the use of additional extensions can allow for sampling from greater depths [5].

The preparation of soil samples in the field should generally involve a minimum of measures to preserve the integrity of the sample.

A composite sample consists of a set of point samples combined in proportion to the weight each sample represents. A pooled sample can be prepared in the field or in the laboratory using an inert, clean and sufficiently large container. The first step is to collect each of the subsamples (increments) using the same sampling method, mixing the subsamples in the container, and

then transfer the pooled sample to a suitable container for storage and transport to the laboratory [5].

Once collected, soil samples should be stored in a cool place in suitable, hermetically sealed containers in a manner that ensures sample integrity and protects them from light as far as possible.

Depending on the sampling requirements, additional controls should supplement the interpretation of the results, such as

- background sample: a field sample taken from a nearby site that has not been affected by military-technological contamination, which allows for the establishment of a reference value or basis for comparison.

- replicate sample: a sample divided into several representative subsamples used to assess the repeatability of results obtained over a long sampling period.

Soils are classified according to the degree of contamination by comparing the maximum permissible concentration and background content of substances that pollute the soil. The main calculated indicators of the degree of contamination are the concentration coefficient K_c and the total contamination index Z_c [2].

The concentration factor K_c is calculated by the formula:

$$K_c = \frac{C_i}{C_f}, \quad (1)$$

where C_i is the actual content of the i -th element; C_f is the background content of the i -th element.

The total pollution index Z_c is calculated by the formula:

$$Z_c = \sum_{i=1}^n K_c - (n-1), \quad (2)$$

where n is the number of chemical elements that meet the condition $C_i > C_f$.

Heavy metal contamination can take decades to be felt. For example, bullets can release lead, which is then absorbed by plants [4]. Lead distributed in different soil fractions may initially be inert, but then become reactive due to changes in soil conditions (e.g. pH, moisture). In addition to lead, metals such as chromium (Cr), arsenic (As), mercury (Hg), nickel (Ni), zinc (Zn) and cadmium (Cd) are also released into the soil with weapon residues. There are lead-free weapons made of iron, steel and various metals. However, they can become a source of contamination with other heavy metals, such as bismuth, chromium, and nickel [4].

The specific characteristics of acidic soils, sandy particle size distribution, low cation exchange capacity or low organic matter (individually or in combination) will enhance the mobilisation of heavy metals. Whereas alkaline soils, loam/silt loam/clay texture, high capacity and high organic content limit the mobility of potentially toxic elements."

A study of the impact of hostilities in Amvrosiivka and Shakhtarsk districts of Donetsk region using satellite imagery identified the size and number of craters, the type of shell whose explosion led to the formation of the crater, and assessed the extent of soil destruction and estimated the damage caused to the state [4].

It was found that on the territory of 225 km², shell bursts led to the formation of 15,505 craters. In places of high density, the craters contained mixed layers of soil, bedrock, and a lot of debris. In addition, tonnes of toxic substances formed during the detonation were released into the environment. No less than 392 tonnes of metal fragments were scattered over the area. In addition, oxidation products from at least 58 tonnes of explosives, as well as 70 tonnes of aluminium oxide formed as a result of the oxidation of powdered aluminium used in conjunction with TNT as an explosive, were released into the environment [4].

Metal fragments are also hazardous to the environment. Cast iron with sulphur and copper impurities is commonly used to produce ammunition casings. Copper is a heavy metal and some of its compounds can be toxic and affect the functioning of living organisms.

Table 1 shows the amount of elements that enter the soil from shells [4].

Table 1. Number of elements entering the soil from shells

Projectile calibre, mm	Number of funnels of this type	Mass of iron, t	Carbon mass, t	Mass of sulfur, t	Mass of copper, t
82	4342	12.50	0.20	0.23	0.09
120	2775	47.95	0.75	0.90	0.35
152	8347	312.51	4.88	5.86	2.28
220	41	3.90	0.06	0.07	0.03

Based on the analysis of soil samples taken in fields near the towns of Sloviansk and Shchastia, directly in the areas where shells hit and 500 metres away, the average value of chemical contamination indicators was generally at the level of background values. Soil samples were taken from the test site using the "envelope" method with averaging over 5 points. Systematic exceedances of 1.1 - 1.3 times were recorded for mercury, vanadium, cadmium, non-radioactive strontium and gamma radiation. The maximum exceedance for some indicators was 1.2-2 times the background level, and only in some cases the exceedance reached 7-17 times [4].

As for the chemical analysis of the soil conducted on the territory of the Kreidova Flora reserve as part of the same study, the concentration of titanium in the soil sample at the site of the shell burst was 150 times higher than the background. The concentration of vanadium was 100 mg·kg⁻¹, and there was no vanadium in the clean sample at all. Titanium-based alloys with vanadium additives are used in aviation and missile technology. We also detected a 2.3-fold excess of sulphates and mobile forms of heavy metals: lead - 1.3 times, cadmium - 1.5 times. In addition, strontium was found to be exceeded in Zakvitne village at the site of shell bursts. Its concentration was 150 mg·kg⁻¹. The content of sulphates in the same sample exceeded the standard by more than 4 times, and cadmium - by 9 times. At the site of shell bursts in Donetsk region, excesses were recorded for mobile forms of heavy metals, including manganese, copper, iron, lead, cadmium, chromium and zinc [6].

Heavy metals can get into crops from the soil and then into food. Therefore, it is impossible to give up on soil analysis and cultivate the fields. Otherwise, people will simply refuse to buy your products.

Commission Regulation (EC) No. 1881/2006 of 19 December 2006 laying down maximum levels of certain contaminants in foodstuffs sets the following permissible levels of lead (mg·kg⁻¹ of raw weight):

- Cabbage vegetables, leafy vegetables and cultivated mushrooms - 0.30;
- Cereals, wheat, rice, legumes, soya, and berries - 0.20;
- Fruits and vegetables (except cabbage and leafy vegetables) - 0.10.

Strict restrictions in this document also apply to other heavy metals, including cadmium, tin, etc. If animal feed is grown on the fields, contaminated soils can indirectly affect the quality of livestock products.

Table 2 shows the possible levels of agricultural land contamination and proposed measures for the use of such land depending on the level of chemical contamination [2].

Based on the findings of the analysis, the optimal reclamation option can be selected. To select a land reclamation methodology, a cumulative assessment of the level of damaged land is required, which involves determining the category of land use suitability.

To restore the fields damaged by explosions, it is necessary to digitise the areas using satellite / UAV / ground monitoring with reference to the coordinate system. All areas need to be digitised, regardless of the scale of the damage. Even if the physical damage to the soil is minor, severe chemical contamination is possible. If the surface damage is 75-100% of the area, it is possible to preserve the damaged areas and allow nature to start the process of self-healing, as it is costly to import good quality soil.

Table 2. Категорії придатності забруднених земель

Total soil contamination index Z _c	Level of contamination (% of the site area)	Land suitability categories	Areas of use	Proposed remediation measures
Acceptable. Contamination index Z _c is less than 16	Very low level of contamination up to 10 % of the land area	Definitely suitable	Cultivation of crops without restrictions	Not allowed
Moderately hazardous. Contamination index Z _c up to 32	Low-level contamination (10-25% of the land plot area)	Suitable	Cultivation of crops without restrictions subject to product quality control	Agricultural practices, liming, application of organic and mineral fertilisers
Hazardous. Contamination index Z _c from 32 to 64	Medium level contamination (25-50% of the land area)	Poorly suitable	Use for industrial crops without food production	Agrotechnical measures, phytoremediation, chemical reclamation
Very unsafe. Contamination index Z _c from 64 to 128	High level pollution (50-75% of the land plot area)	Conditionally suitable	Use for pastures and cultivation of essential oil crops	Physical and chemical reclamation
Extremely hazardous. Contamination index Z _c is more than 128	Very high level of contamination (75-100% of the land area)	Not suitable	Withdrawal from intensive use. Conservation	Remediation or natural recovery

If the damage amounts to 50-75% of the area, the land is subject to reclamation.

Next, samples should be taken from the affected area (separately) and the surrounding area (separately) and analysed for contaminants. First of all, heavy metals.

Based on this data on the level of contamination of agricultural land, a decision should be made on the possibility of farming and further intended use.

After the sites have been cleared of the source of contamination and debris, it is necessary to restore the soil damaged by the explosions. Shallow sinkholes (up to 0.5 m) can be filled with soil mass remaining at the explosion site (at an acceptable concentration of pollutants) or mineral soil (loam, loess loam, sandy loam, sand), followed by levelling the surface [7, 8].

Deep craters (more than 0.5 m) should be covered with soil mass, but the order of soil layers should be close to the undamaged areas, so the crater should be covered with mineral soil first, and the top layer (20-30 cm) should be covered with fertile black soil. If filled in a chaotic manner, such a site will be low-productive for crops, and its restoration will require additional measures (application of organic fertilisers, ameliorants, phytomelioration, etc.). Based on the measurements of the parameters of explosion craters, the need for mineral and fertile soils is calculated in the working land management project [7, 8].

In order to restore areas damaged by explosions, it is necessary to remove or clean the surface soil layer, as in addition to chemical contamination with heavy metals, the fertile soil layer burns out, dehydration and "sterilisation" occur, killing both pathogenic microorganisms and beneficial biota. If the surface contaminated layer is not cleaned off, but the sinkhole is mechanically sealed with bulldozers and graders, it will take decades to restore soil fertility, requiring serious investments in organic fertilisers, ameliorants, phytomeliorants, etc. [9, 10]. Subsequently, after levelling the surface of the damaged area, to restore its fertility, it is possible to loosen the soil to increase oxygen penetration and redox reactions, apply organic and mineral fertilisers and sow grasses to intensify natural biochemical treatment processes.

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Study of moisture conditions of chernozem in the left-bank forest-steppe of Ukraine

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Abstract: The article analyzes the dynamics of moisture content of the chernozem soil and the accumulation of productive moisture reserves in its thickness based on the data set from 1947 to 2022. Changes in the moisture regime within the periodically flushing water regime of the central part of the Left-Bank Forest-Steppe of Ukraine are analyzed. The central Forest-Steppe zone is characterized by a periodically flushing water regime, when an average of 165 mm of moisture accumulates in the meter thick chernozem, and therefore tends to the values of the moisture reserve under the non-flushing water regime, which exceeds its value by 25 mm, which is a stable trend of aridization of soil conditions in the spring. In the current climatic conditions of the central part of the Left-Bank Forest-Steppe, a regime of black soil moisture has been formed in the long-term time interval, which, under the influence of agrotechnical influences, cannot be shifted beyond the parameters of the non-flushing or periodically flushing water regime in the agroecosystem. The process of self-regulation of the Forest-Steppe zone's resistance to active aridization and the Steppe's "advance" on the Forest-Steppe is manifested.

KEYWORDS: PRODUCTIVE MOISTURE RESERVE, EVAPOTRANSPIRATION, COLD-SEASON PRECIPITATION, MOISTURE INDEX, FACTOR ANALYSIS, CLIMATE.

1. Introduction

In the family of soils of non-washing and periodically washing type of water regime, typical chernozems of the Forest-Steppe zone are the most optimally moistened, as they do not have the disadvantages of soils of washing regime and the disadvantages of soils of non-washing regime of moisture, which contributes to the manifestation of the chernozem type of soil formation. The formation of the water regime of chernozems in agroecosystems is determined primarily by changes in the nature of consumption of the root system of crops in agroecosystems, which varies in depth and volume. The water balance of chernozems in agroecosystems is formed at a lower level compared to virgin chernozems. Agroecosystems manifest the consequence of "aridization" of chernozems, i.e., less soil moisture supply to the chernozem layer than is possible under the given climatic conditions. In agroecosystem chernozems, the water regime is formed in two opposite directions: the total volume of moisture is reduced, and at the same time, the moisture of the lower horizons is not completely consumed, but accumulates in a multi-year cycle [1, 2].

In the Forest-Steppe, virgin chernozems and agroecosystem chernozems differ in the nature of moisture consumption during the growing season: in virgin analogues, there is a gradual and consistent moisture consumption from spring to autumn with the deepening of the drying front deeper into the profile, and in the hydrological profile of chernozem in agroecosystem, there are three zones with differently directed soil moisture dynamics compared to natural chernozems: The upper half meter is characterized by an unstable actively changing water regime, the middle part of the profile, which corresponds to the accumulative carbonate horizon, is drier in all seasons, and the lower part of the profile is always wetter than in virgin soils, even in dry years. [3-5].

The negative change in water-physical properties naturally leads to a decrease in the profitable items of the water balance of chernozems in agroecosystems and the moisture-release capacity of the agro-horizon, where the bulk of crop roots are concentrated [6-9]. The lack of precipitation and active physical evaporation of soil moisture is facilitated by the low permeability of the topsoil, which is close to critical (about 50 mm/h) and does not sufficiently ensure the absorption of moisture from the soil, the absorption of moisture from the cold season in spring and the moisture of intense rainfall during the growing season of crops in the agroecosystem [9, 10]. An important feature of the moisture supply of crops in agroecosystems during the growing season, associated with changes in water-physical properties, is manifested in the sharply variable nature of the moisture content of the till layer: relatively short periods of waterlogging, when there are no air-occupied gaps in the thickness of 0-30 cm, repeatedly alternate with periods of complete drying [11, 12].

The relevance of the study is that in order to deepen the fundamental understanding of the impact of global climate change on the development and functioning of agroecosystems, it is necessary to conduct a comprehensive analysis of the available long-term data

on the state of the black soil moisture regime, especially on the formation of spring moisture reserves, within the framework of the non-flushing and periodically flushing water regime, and the nature of the formation of spring moisture reserves in agroecosystems is an indicator of the response to synoptic changes in the composition of climatic factors in the central part of the Left Bank Forest. It is important to carry out a comprehensive analysis of the data obtained in the long term (76 years) on moisture accumulation on chernozems and climatic indicators in the agroecosystems of the central part of the Left Bank Forest-Steppe agrolandscape, as well as to normalize the processes of formation of productive moisture reserves in the thickness of the chernozem under the influence of changing climatic factors and conditions.

2. Results and discussions

The research was carried out in the central part of the Left-Bank Forest-Steppe of Ukraine in a long-term stationary experiment of the Drabivske experimental field of the Cherkasy State Agricultural Research Station "NSC "Institute of Agriculture of NAAS".

Geographically, the research was conducted in the Sredniodniprovske-Seym agro-soil district, which covers the lands of Kyiv, Poltava, Sumy, Chernihiv, and Cherkasy regions.

According to the results of the research, it was found that the stock of productive moisture in November for the period 1947- 2023 averaged about 62 mm, and the median was 10 mm less. The amplitude range of the moisture reserve was 128 mm, and the normalized range was 24.5 mm (50%) and 33 mm (10%). At the same time, the median moisture reserve tended to $L_{0.25} = 44$ mm, which indicates a decrease in the moisture reserve in the meter-long soil layer from 1947 to 2023. The coefficient of variation was 54.4%, which corresponds to a very high level of variation. The variability of the moisture reserves in the meter-long soil layer in November was 2.3 times higher than the variability of precipitation. The amount of precipitation for April-August during the observation period averaged 257 mm, and the median average precipitation was 9 mm higher, and the median precipitation itself was more inclined to the upper typical value, which is due to their increasing amount from 1947 to 2023.

The amplitude range of precipitation for November-March was 145 mm, and the normalized $\Delta H = 49$ mm (at a 50% significance level). During the observation period, the average amount of precipitation was about 191 mm, and the median amount was 4 mm higher. The amplitude range of $A_H = 129$ mm. The coefficient of variation exceeded 20%, which indicates a slight variability. The average reserve of productive moisture in the one-meter soil layer in April was about 156 mm, and the median value was about 158 mm. The amplitude range was 58 mm. The normalized range was 20 mm (50%) and 35 mm (10%), which is close to the normalized range of the moisture reserve of 0-100 cm in November.

The coefficient of variation of moisture reserves in April was 10%, which was 5.3 times lower compared to the variation of reserves in November. The variation in precipitation between November and

March was 2.3 times higher than the productive moisture reserves formed in April. On average, during the cold season, the soil accumulated about 94 mm of precipitation moisture, and the median was 5 mm more.

The accumulation of moisture in the soil tended to the upper typical value ($L_{0.25} = 105$ mm) and indicates that the less moisture was accumulated before entering winter, the more moisture from precipitation was absorbed by the soil column in spring, which is more typical for the early periods of observation, while in 2020-2023 the pattern was reversed. The amplitude range of moisture inflow into the meter-thick soil was 92 mm, and the normalized range was 13 mm (50%) and 35 mm (10%) with a coefficient of variation greater than 25%, indicating a high level of variation.

The average potential moisture reserves (April water content in the one-meter soil layer + April-August precipitation) were 421 mm, with a median of about 420 mm. The amplitude range was 111 mm, and the normalized range was 36 mm (50%) and 69 mm (10%). The moisture potential at the median was more inclined to $L_{0.25} = 405.5$ mm, which indicates a steady downward trend in its level from 1947 to 2023. The coefficient of variation of the moisture potential was 7.3 %, which is 3.5 times lower than the variability of productive moisture accumulation in April and indicates a high level of stabilization (by legalization) of vegetation conditions by precipitation in April-August.

The stock of productive moisture in the meter thickness in July during the observation period was about 50 mm, and the median was 5 mm less, which led to a shift in the value to $L_{0.25} = 39$ mm and indicates a decrease in the amount of moisture in the meter layer of soil in July from 1947 to 2023. The amplitude range of the moisture reserve in July was 56 mm, and the normalized range was 24 mm (50%) and 35 mm (10%). The coefficient of variation of moisture reserve formation in the 0-100 cm layer in July exceeded 30%, which indicates a high level of variability, which exceeded the variability in April by 3.2 times, and was 1.65 times lower than in November.

The consumption of the productive moisture reserve from the meter thick soil in April - July by the average value and median was 105 mm. The moisture consumption from the soil by both statistical indicators tended to the upper typical value ($L_{0.75} = 122$ mm), which indicates an intensive consumption of moisture from the soil over the entire observation period. The amplitude range of soil moisture consumption was $\Delta a = 35$ mm, and the normalized range was $\Delta n = 8.5$ mm (50%) and $\Delta n = 23$ mm (10%). The coefficient of variation of the productive moisture reserve consumption was less than 10%, which indicates the stability of the growth of moisture consumption from the soil thickness over time. The average moisture potential discharge for April-August was 363 mm, and the median discharge was 13 mm higher. The median discharge tended to the upper typical value of $L_{0.75} = -384$ mm, which indicates an increase in moisture potential discharge from 1947 to 2023. The amplitude range of moisture consumption was $\Delta a = 84$ mm, and the normalized range was $\Delta n = 43$ mm (50%) and $\Delta n = 72$ mm (10%). The closeness of the $\Delta(10\%)$ flow rate to the amplitude range indicates the stability of this parameter, which is reflected in the coefficient of variation, which, being less than 10%, was 1.2 times lower than the moisture flow from the soil.

The average evapotranspiration for April-August was 428 mm, and in terms of amplitude, the evapotranspiration reached a maximum value of 561 mm and a minimum value of 325 mm. The amplitude range was $\Delta a = 236$ mm. The normalized evapotranspiration range was $\Delta n = 122$ mm (50 %) and $\Delta n = 185$ mm (10 %), and the coefficient of variation of evapotranspiration was 18.2 %. The median value of evapotranspiration tended to the upper typical value ($L_{0.75} = 507.5$ mm), indicating an increase in evapotranspiration from 1947 to 2023.

The mean value of the moisture coefficient (K_{3B}) was at $K_{3B} = 1.02$ (optimal moisture), and the median value $K_{3B} = 0.98$, which was more inclined to the lower typical value ($L_{0.25} = 0.88$) or increasingly dry conditions. The amplitude range $\Delta K_3(a) = 0.66$, and the normalized range $\Delta n/p = 0.25$ (50%) and $\Delta n/p = 0.45$ (10%). At the same time, the coefficient of variation K_v was 18.6 %, which

indicates a progressive increase in drought conditions over the observation period from 1947 to 2023.

Over the observation period (1947-2023), the moisture index for November averaged $P_3 = 0.42$, and the median $P_3 = 0.35$. With an amplitude range of $\Delta P_3(a) = 0.90$ and normalized $\Delta P_3(n) = 0.16$ (50%) and $\Delta P_3(n) = 0.23$ (10%), the coefficient of variation was high, exceeding 50%. The average value of P_3 in April was $P_3 = 1.05$, which corresponds to optimal moisture. According to the amplitude range, $\Delta P_3(a) = 0.71$, while the normalized range at 50 % and 10 % significance level was $\Delta P_3(n) = 0.12$ and $\Delta P_3(n) = 0.42$, respectively, at a level of variation of 17.5 %, which indicates a stable level of P_3 in April for the entire observation period with a weak tendency to decrease P_3 in the period 2010-2023.

On average, the humidification index in July was 1.23 times lower than in November, and compared to April, P_3 was 3.1 times lower. The amplitude range was $\Delta P_3(a) = 0.38$, and the normalized $\Delta P_3(n) = 0.16$ (50%) and $\Delta P_3(n) = 0.25$ (10%), with an increase in the coefficient of variation to 32.9%, indicating a rapid increase in legalization in the meter thick soil in July.

The moisture deficit coefficient (D_B) in November averaged $D_B = 0.59$ with a median value of $D_B = 0.65$, which indicates that the D_B indicator in November tended to the upper typical value, and the high range in amplitude and normalized values was associated with a high value of the coefficient of variation, which exceeded 30%. The moisture deficit coefficient in July was $D_B = 0.66$, and with a median value of $D_B = 0.69$, which tended to the upper typical value, and the level of amplitude and normalized value corresponding to D_v in November provided a coefficient of variation of 17 %, indicating the formation of more arid conditions in the soil in July.

The normalized Selyaninov parameter shows that in the period April-May over the period of observation (75 years), the SCC was 1.0, and the median SCC was 0.95, which was more inclined to the lower typical value and the formation of arid conditions. In terms of amplitude range, the spring period was characterized by excessively moist conditions ($HCC > 1.5$) to dry conditions ($HCC = 0.79$) with an amplitude range $\Delta HCC(a) = 0.86$. The normalized range was $\Delta HCC(n) = 0.40$ (50%) and $\Delta HCC(n) = 0.60$ (10%) with a coefficient of variation of more than 25%, indicating high variability and an increase in high droughts, especially since 2010. The average value of the HST for the summer period was $HST = 0.97$ with an amplitude range of $\Delta HST(a) = 0.57$ and a normalized range of $\Delta HST(n) = 0.35$ (50%) and $\Delta HST(n) = 0.49$ (10%) with a coefficient of variation of more than 20%, which is 1.2 times lower. On average, in April- August, the HST was 0.99 with an amplitude range of $\Delta HST(a) =$

0.45. The normalized range was $\Delta HST(n) = 0.18$ (50%) and $\Delta HST(n) =$

0.34 (10%). The HCC indicators for the minimum value of the spring and summer periods were $HCC = 0.61-0.76$ (arid conditions), and for the normalized range of $L_{0.1}$ and $L_{0.25}$, $HCC = 0.78-0.91$ and $HCC = 0.66-0.79$, which corresponds to arid and acutely arid conditions. The indicator of hydrothermal conditions for the summer period had a coefficient of variation of 13.5 %, which indicates the stability of the prevailing conditions for 1947-2023 with a steady trend of increasing arid conditions in the summer period

Between the amount of moisture in the meter thickness in November and the moisture reserve in April, it was found that the lower the moisture reserve before entering winter, the higher its reserve in April and July ($R = +0.78-0.84$). A direct correlation was found between the April soil moisture reserves and the moisture reserves in July ($R = +0.82$).

A direct correlation ($R = +0.95$) was found between precipitation in April-August and the consumption of moisture potential during this period. A direct correlation ($R = +0.65-0.84$) was found between the reserves of productive moisture in November and April and moisture content ($R = -0.80-0.84$), and an inverse strong correlation with moisture deficit ($R = -0.80-0.84$). The soil moisture reserve in July correlated with P_3 in November with a direct strong correlation of $R = +0.83$, in April $R = +0.65$, and in July at the level of direct functional relationship.

The correlation between moisture content in July and April was at the level of a direct average correlation, and between P₃ in November and July the correlation was at the level of a direct strong correlation ($R = + 0.83$). The relationship between soil moisture deficit and P₃ in November-July was inverse at the level of strong correlation: $R = + 0.65-0.87$.

The calculation showed that correlations were found between evapotranspiration and thermal climate indicators. With GWC (IV-XIII) and GWC (VI-XIII) at the level of inverse average correlation ($R = + 0.74-0.96$). The relationship between evapotranspiration in April-August and the moisture coefficient was at the level of an inverse strong correlation ($R = - 0.91$).

The block of thermal indicators (average monthly air temperature and the sum of active temperatures) by observation periods correlated with each other at the level of direct correlations ($R = + 0.86-0.99$), and the indicator K_{3B} had correlations with the block of thermal indicators at the level of strong inverse correlation ($R = - 0.83-0.91$). The relationship between the humidification index (K_{3B}) and the GTC for the spring-summer period was at the level of a direct strong correlation ($R = 0.68-0.72$).

It should also be noted that the cluster analysis made it possible to establish the affinity of semi-thicknesses (0-50 cm, 50-100 cm, 100-150 cm, 200-250 cm, 250-300 cm) and thicknesses of 0-100 cm, 0-150 cm, 0-200 cm, and 0-300 cm. These objects formed two clusters: semi-thick and thick. Thus, the half-meter soil layers formed a cluster at the level of 25% similarity, and the semi-thicknesses 100-150 cm, 200-250 cm, 250-300 cm formed clusters at the level of 18% and 10% similarity, and the unification of all semi-thicknesses occurred at the level of about 29%. 100 cm, 0-150 cm, 0-200 cm, and 0-300 cm thicknesses clustered with a higher degree of similarity from 58% to 70%. The clusters of strata and semi-strata were clustered at a high distance of $> 90\%$ (Fig. 1).

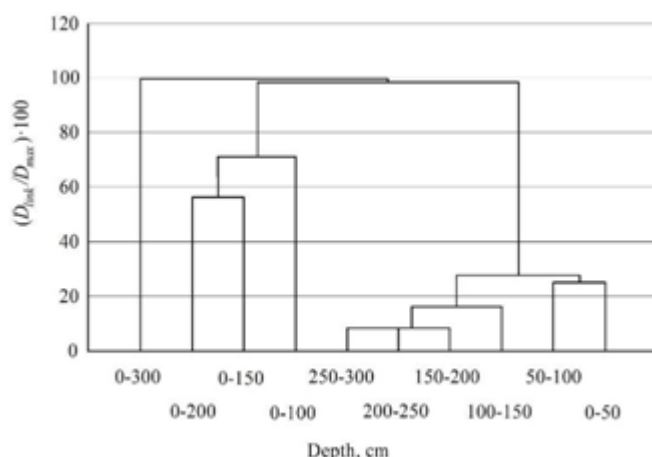


Fig. 1. Clustering of soil horizons within the periodically flushing water regime

There is a probability (10 %) of the formation of a through flushing water regime when the moisture reserve in the thickness of 0-100 cm exceeds 190 mm ($> NV$) at $P_3 = 1.33$, in the thickness of 0-150 cm - 265 mm ($> NV$) according to $P_3 = 1.21$, in the thickness of 0-200 cm - 320 mm ($> NV$) according to $P_3 = 1.08$ and in the thickness of 0-300 cm - 435 mm (0.85 % of NV) according to $P_3 = 0.98$.

3. Conclusion

In order to form a non-flushing moisture regime, it is necessary to accumulate 117-135 mm in the 0-100 cm thickness, which will correspond to a reserve in the 0-200 cm thickness of 167-117 mm. For the periodic flushing water regime, 160-165 mm of moisture should be accumulated in the 0-100 cm thickness, which will provide a moisture reserve of 300 mm of moisture in the 0-200 cm

thickness. The flushing water regime is formed when the moisture reserve in the 0-100 cm layer is 175 mm, which provides a moisture reserve in the 0-150 cm and 0-200 cm layers of 250 mm and 315 mm, which corresponds to the NV -VRK reserve, and the 0-300 cm layer is saturated with moisture over 400 mm (NV -VRK).

2. The calculation of pairwise coefficients showed that an inverse strong correlation was found between the amount of precipitation in November - March and the supply of moisture to the meter-long soil layer ($R > - 0.70$), and the moisture consumption from the soil in April - July correlated with precipitation in November - March at the level of direct strong correlation ($R \geq + 0.70$). The relationship with the moisture consumption from the moisture potential in April - August was at the level of inverse strong correlation ($R < 0.70$), i.e. the higher the amount of precipitation in the autumn - winter - spring period (cold period), the less moisture is recorded in the meter thickness, the greater its consumption in April - July from the soil and the lower the consumption of moisture potential in April - August

3. The zone of the central Forest-Steppe is characterized by periodically flushing water regime, when an average of 165 mm of moisture accumulates in the thickness of 0-100 cm, which corresponds to the median values, and therefore tends to the values of moisture reserves under the non-flushing water regime, which exceeds its value by 25 mm, which is a stable trend of aridization of soil conditions in the spring

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Integrated low-carbon practices for managing key resources in agriculture, soil and water

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Abstract : *The purpose of this report is to present the possibilities, goals and benefits of implementing integrated low-carbon practices for managing basic resources in agriculture, soil and water and achieving the main goals of the EU programs - "circular economy" and "green deal", as well as and mitigating the causes of climate change.*

KEYWORDS: INTEGRATED LOW-CARBON PRACTICES, CIRCULAR ECONOMY, GREEN DEAL AND AND CLIMATE CHANGE

1. Introduction

The strategic directions laid down in the visions, strategies, programs and guidelines for development in the field of environment and agriculture for the next program period up to 2030 developed at the national and European Commission level. They are aimed at mitigating the causes and overcoming the consequences of climate change.

Basic developments directly related to achieving the goals during the program period until 2030 in the fields of environment and agriculture are concentrated in the strategies for implementing the Circular Economy and the European Green Deal. Their basis is the "4 per 1000: Soils for Food Security and Climate" initiative adopted at the World Climate Summit in Paris, December 2015, supported by the Republic of Bulgaria, putting on the agenda the introduction of low-carbon decentralized practices, with the purpose of regenerating the basic nutrients of the soils to guarantee their soil fertility and the nutrition of the population, creating conditions for permanently guaranteeing the irrigation conditions for agricultural areas and retaining the necessary moisture in them, creating conditions for mitigating the causes of climate change

To realize the objectives of the "Circular Economy" and that of the "Green Pact" substantiating the need to introduce regenerative Low-carbon and socially acceptable practices to reduce and mitigate the causes and effects of greenhouse gas emissions from agriculture and land use and from here the consequences of climate change in our national agriculture, it is necessary to introduce the new policies of the European Union related to climate change and the reduction of carbon emissions and defining the goals that Bulgaria must achieve by 2030, namely: a significant reduction in net CO₂ greenhouse gas emissions and the commitment to collectively achieving climate neutrality by 2035 in the land use, forestry and agriculture sector. .

One of the main priorities of the Common Agricultural Policy for the program period is defined as the introduction of low-carbon agriculture and carbon sequestration in agricultural areas . The Commission will propose an EU regulatory framework for the certification of carbon sinks, based on robust and transparent rules and carbon accounting requirements. With the introduction of these innovative approaches for implementing the principles of the "Circular Economy" in agriculture and forestry, as well as in the sectors that process the products produced in them, it will be possible to utilize the biodegradable waste generated in them by applying decentralized and decarbonized practices for retention and storage of organic carbon in soils (**BioCCS practices**) [5].

2. Problem discussions

What problems arise from the current policies and the challenges facing Bulgarian agriculture?

In accordance with the objectives of the CAP for the development of rural regions in the current program period, two strategic groups of objectives are set:

1.1. Increasing the competitiveness and balanced development of agriculture and the food industry;

1.2. Protection of ecosystems and sustainable management, use and restoration of natural resources in agriculture and forestry and the food industry;

1.3 Prevention, adaptation and mitigation of the consequences of climate change;

1.4. Socio-economic development of rural areas, social inclusion and better quality of life;

2. Problems related to the development of agriculture and climate changes in our country:

2.1. Restoration of basic elements of the environment to guarantee sustainable regional development of agriculture: soils (soil fertility), water resources (soil moisture, moisture retention and protection of groundwater), micro and macro flora, air.

2.2. Climate, climate change, adaptation and mitigation of the consequences of climate change.

According to representative data published in the Third National Climate Change Action Plan for the period 2013-2020, the delta of emissions generated by the agriculture sector is 10.4% of the volume of total greenhouse gases (GHG) in Bulgaria.

According to the National Inventory of GHG (2011), methane (CH₄) emissions are 36% of emissions in the sector (CO₂eq./2009), and nitrous oxide (N₂O) emissions are 64%, respectively. Main sources of emissions from the agriculture sector are:

- Agricultural soils – 56.08% ammonium gases from the use of mineral fertilizers
- Biological fermentation in animal husbandry – 21.78%

- Manure management – 19.34% .

The remaining 2.8% is due to stubble burning (1.68%), and rice production – 1.13%.

The specified main GHG polluters in the Agriculture sector are also defined as the main problem for the protection of groundwater from nitrate pollution as a result of excessive and disproportionate use of mineral nitrate fertilizers, the formation of both nitrate-vulnerable zones, and purified ammonium emissions into the atmosphere.

In order to overcome the above-mentioned problems related to the generated GHG in agriculture and the protection and restoration of the main elements of the environment used in it - soil, water and atmosphere, it is necessary to implement priority measures for the sectors of agriculture, land use and forestry and industry. They are grouped into two directions:

Direct measures: to reduce generated ammonium emissions from the application of nitrate fertilizers and with the expected effect of preserving and restoring organic carbon in soils, improving the balance between emissions and absorption of GHG by using the potential possibilities of soils, forests, pastures and meadows to fulfill the role of "Carbon Sink", to guarantee soil moisture retention, fertility and soil quality.

Indirect measures: regarding soils, the capacity and the ability to apply integrated practices to improve the quality of soils, energy-saving and water-saving technologies to improve productivity in the sector and the efficiency of the resources used.

The groups of measures indicated above were aimed at promoting the efficiency of natural resource use and creating conditions for the transition to a low-carbon and climate change-resistant circular economy. With their implementation, modern innovative approaches and cross-sectoral integrated policies in environmental management, agriculture and climate change actions would be implemented through a system of low carbon practices for climate change adaptation management actions.

Regrettably, our current national documents lack a realistic assessment and adequate measures to overcome the increasingly clearly manifested consequences of climate change threatening the fulfillment of strategic tasks in the management of the national economy - guaranteeing the nutrition of the population, ensuring public health through management for the main components of the environment - soils, water and atmospheric air, guaranteeing sustainability of ecosystems and territories.

Moreover, in none of the problematic directions of the current agricultural policy mentioned in [4], [5], [6] are the measures necessary to achieve real results for the adaptation and overcoming of the consequences of climate change foreseen in the three the priority for climate action: climate change mitigation, climate change adaptation, climate-related governance and information. The main problem stems from the lack of innovative approaches for the utilization of generated waste in agricultural production, processing enterprises, from logging and other sectors of the economy that generate biodegradable waste.

There is a lack of analyzes and evaluations of low-carbon innovative global practices for their feasibility in the conditions of Bulgaria, construction and functioning of horizontal management systems for regional adaptation to climate change for sustainable development of regions in Bulgaria.

Introducing a similar approach in the management of activities to mitigate the causes and overcome the consequences of climate change through feasible low-carbon practices would prevent and significantly reduce economic damage caused by recent natural manifestations such as:

- large-scale forest fires caused mostly by burning stubble (application of carbon negative practices to restore and maintain soil fertility);
- losses - quantitative and qualitative in the production of basic cereals and especially spring crops due to permanent droughts (low-carbon practices to guarantee soil moisture retention and soil fertility);
- the permanent reduction of the content of organic carbon in soils (1.29% at a critical minimum of 2% to guarantee soil fertility) in our main agricultural regions;

Particularly impressive is the inaction and reluctance of the Ministry of Environmental Protection to introduce the fair European principle "the polluter pays" and legal mechanisms for the recovery of resource costs for the management of a basic element of the environment - water services.

The lack of scientific research and innovation, including and in the direction of analysis and evaluation of existing European practices, the lack of actually functioning systems for the utilization of waste from agriculture and forestry and the processing industry through socially acceptable regenerative practices for the protection and restoration of basic elements of the environment - soils and water, the dilution of the planned measures under Priority Area 5 of the current OPSRDP led to the lack of funding projects for training and introduction of low-carbon practices to mitigate the causes and overcome the consequences of climate change, introduction of control and monitoring systems for the results of low-carbon practices, preparation and development of projects for the improvement of existing normative documents and methodologies, methodological and informational materials on the individual regional low-carbon practices for:

- soils and soil fertility, limiting direct pollution by partially replacing mineral fertilizers with microbiological, composts and biological carbon in land use, improving the moisture-retaining characteristics of the soil to adapt to droughts;
 - utilization of biodegradable agricultural waste to restore and maintain soil fertility, to restore and increase soil carbon content;
 - efficient technologies and systems for the carbonization of waste biomass for decentralized energy production and soil improvers to overcome the effects of climate change;
 - cessation of stubble burning and prevention of large-scale forest fires and atmospheric pollution, creation of economically justified incentives for utilization of waste biomass, improvement of soil quality and introduction of highly efficient production of biological products;
- Actions needed to introduce low carbon practices for climate change adaptation management actions.

For this purpose, it is necessary to be developed, demonstrated and evaluated for subsequent introduction through specific regional systems for the analysis, evaluation and monitoring of waste generated in the specified sectors with the aim of their utilization as resources in the introduction of integrated decentralized low-carbon practices for sustainable adaptation to climate change. introducing the principles of the circular economy and regenerative agriculture, creating conditions for the realization of the goals of the European Commission for the implementation of the European Green Deal

The specific goals set for implementation are grouped in the development and implementation of integrated approaches for actions to mitigate the consequences of climate change at the local, regional or national level, with proven feasibility for the specific region and climatic conditions and are feasible through low-carbon regional practices in the areas :

- **Agriculture** - soils and soil fertility, limiting direct pollution by replacing mineral fertilizers with microbiological ones, composts and biological carbon in land use, improving the moisture-retaining characteristics of the soil to adapt to droughts;
- **Waste management** - utilization of biodegradable waste to restore and maintain soil fertility, to restore and increase soil carbon content;
- **Renewable energy sources** – efficient technologies and systems for the carbonization of waste biomass for decentralized energy production and soil improvers to overcome the effects of climate change;
- **Forests and forestry** - assessment of basic eco-services guaranteed by forests and creation of objective and evaluable mechanisms for their compensation in infrastructure projects that violate forest areas and use of basic eco-resources - soil and water. Learning about effective practices for restoring forests with the utilization of waste generated during their management.
- **Sustainable development of the regions** - Introducing justified systems for the sustainable development of the region and mitigating the consequences of climate change through low-carbon practices such as: stopping stubble burning and preventing large-scale forest fires and atmospheric pollution, creating economically justified incentives for the utilization of waste biomass for regeneration and improvement of the qualities of basic elements of the environment related to one of the main sectors for the region - agriculture, including soils, groundwater, guaranteeing soil fertility for the introduction of highly efficient productions in agricultural practice, animal husbandry and processing industry;
- **Introduction of practices accredited and certified according to current European legislation for the removal and retention of carbon dioxide from the atmosphere and issuance of carbon certificates.**

With the implementation of such systems of viable low-carbon decentralized practices, it is possible to quickly and effectively multiply the effects in purely economic and social terms by

introducing low-carbon technologies for soil recarbonization, the development of decentralized and decarbonized systems for the production of alternative energy, to build the foundations for introducing an economically justified circular, low-carbon economy.

Below are the main directions for implementing integrated low-carbon practices in various sectors of the economy and show (fig. 1 and fig. 2) part of realized technological schemes and technical means for introducing integrated low-carbon BioCCS practices in agriculture and forestry, as well as and to generate low-carbon decarbonized energy..



Fig.1 Realized installation for utilization of biodegradable waste, production of biochar for application in **BioCCS practices**

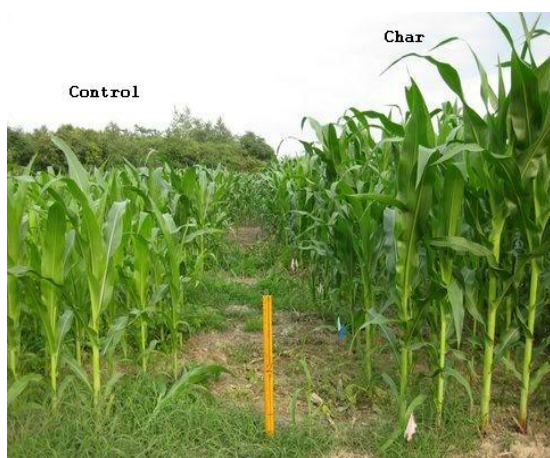


Fig.2 Application of **BioCCS** practices in the production of water-loving agricultural crops - for example, in corn and in afforestation in reforestation projects with highlighted yield and economic effects.

3. Conclusion

With the application of BioCCS practices in soil management by introducing biological carbon into them, permanent improvements of their qualities are achieved and especially the overcoming of degradation processes in soils is stimulated which includes :

- improving the structure of the soil;
- increased water retention and aggregation;
- reduction of acidity;
- reduction of nitrogen oxide emissions;
- improving porosity;
- decentralized wastewater treatment for direct use in agricultural production;
- production of decarbonized energy from agricultural waste;
- mandatory construction of scientific structures accredited and certified according to the current European legislation of practices for removing and retaining carbon dioxide from the atmosphere and for issuing valid carbon certificates
- expanding the scope of scientific research on a global scale and introducing BioCCS practices in sectors: metallurgy, construction products, including building elements and materials for plastering internal walls (with particular efficiency in wine cellars), the production of road surfaces, etc. sectors.

Influence of soil organic matter on the water-soluble forms of technogenic radionuclides in soils – a model study

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Abstract: Soil contamination with radionuclides poses a serious threat to the health of the population. It can occur in radioactive incidents and accidents and improper management of radioactive waste. The mobile and bioavailable forms of radioactive contaminants are critical in predicting their transfer through food chains. This study presents the influence of soil organic matter on the leaching of ^{241}Am , ^{60}Co and ^{137}Cs by distilled water from soils, taken from six regions in Bulgaria. The experiment was carried out by Chromic Cambisol, Eutric Fluvisol, two Calcaric Chernozem soils, Gleyic Fluvisol and Vertisol, taken from the surface soil layer 0-10 cm. The initial soil samples did not contain radionuclides and were contaminated by radioactive solution in the laboratory. The soil organic matter was removed from aliquot of the samples by treatment with 6 % NaClO and heating at 96 °C. The investigation aimed to examine the water-soluble forms of the radionuclides in soils, containing aliquots with removed organic substances as well as in natural soils. The contaminated soils were stored at 18 °C and water extraction of the radionuclides was performed after 75 min and 3 weeks after radioactive pollution. The radioactivity of the samples was measured by gamma spectrometry. The results showed that removing soil organic matter has different effects on the water-soluble forms of radiocesium and radiocobalt. No changes in the water-soluble forms of americium were measured. Adding soil with removed organic matter to Calcaric Chernozem soil was found to be an efficient approach to decrease the water-soluble forms of ^{60}Co in the first three weeks after contamination.

Keywords: AMERICIUM-241, COBALT-60, CESIUM-137, SOILS, ORGANIC MATTER REMOVAL, WATER EXTRACTION

1. Introduction

Contamination of soils with technogenic radionuclides is a serious problem of radiation protection and radioecology. The danger of external irradiation of the population and possible internal exposure to radioactivity requires the implementation of timely control of the specific activity of the soil and the geochemical forms of radioactive isotopes. Water-soluble forms of radionuclides represent the most mobile fraction. They can penetrate deep into the soil layer thus reducing the external exposure to radiation and becoming unavailable to the plant roots. At the same time, the water-soluble forms that are found at the level of the root system can be absorbed by plants and enter the food chain. Numerous investigations have been focused on various methods of immobilizing radioactive contaminants that have entered the environment [1-5] in order to exclude their spread and entry into the food and drinking water of the population.

Finding an effective sorbent to bind radionuclides in forms that are more difficult to migrate and bioaccumulate can limit the danger of their entering into the food chain.

It is known from the literature that soil particles are often coated with a layer of organic matter, which may inhibit the sorption of radionuclides on the soil minerals [6].

Therefore, preparing an additive consisting of soil with removed organic matter and applying it to the contaminated soil could improve and accelerate radionuclide immobilization. For this purpose, it is necessary to study the effect of removal of soil organic matter on the water-soluble forms of technogenic radionuclides in soils with different characteristics.

The aim of the present work was to determine the influence of soil organic matter on the water-soluble forms of ^{241}Am , ^{60}Co and ^{137}Cs . A model experiment was conducted in which a radioactive solution, containing the isotopes of interest was introduced into soil samples taken from six different regions in Bulgaria. In aliquot parts of the soils the organic matter was removed. The water-soluble forms of the radionuclides were studied in natural soils and soils without organic matter, as well as in soils with mineral soil matrix of different mass concentration.

2. Materials and Methods

Soils from six different regions in Bulgaria were selected for this study. The soil samples were taken from the surface 0-10 cm layer and characterized as described in [7]. They were classified according to the World Reference Base for Soil Resources [8].

The main characteristics of the soils, used in this study are presented in Table 1.

Table 1. Main characteristics of the studied soils

Soil order/Texture class	Soil pH		CEC (meq/100 g)	% Sand	% Silt	% Clay	% Humus
	H ₂ O	KCl					
Chromic cambisol/Loam	6.6	6.3	32.0	43	31.7	25.3	2.35
Eutric fluvisol/Loamy-sand	7.7	7.2	33.2	74.3	21.5	4.2	4.50
Calcaric chernozem (1)/Clay loam	7.8	7.1	38.1	32.9	36.8	30.3	2.59
Calcaric chernozem (2)/Silt loam	7.8	7.4	13.2	24.7	70.2	5.11	3.18
Gleyic fluvisol/Loamy sand	7.9	7.7	9.80	77.7	19.1	3.14	3.09
Vertisol/Sandy loam	7.3	7.0	12.8	64.9	31.2	3.84	4.95

It can be seen, that the soils can be divided to two groups according to their cation exchange capacities (CEC):

- Soils with normal values of CEC (15-40 meq/100 g): Chromic Cambisol, Eutric Fluvisol, Calcaric Chernozem 1 and
- Soils with low values of CEC (< 15 meq/100 g): Calcaric Chernozem 2, Gleyic Fluvisol and Vertisol.

Aliquot parts of the soil samples were treated with 6 % NaClO at 96 °C for 60 min in order to remove the organic matter, referring to the procedure, described in [6]. After the end of heating, the samples were rinsed several times with distilled water and dried to a constant weight. Thus, the obtained soil samples without organic matter were added to the respective order of natural soil in different mass concentrations and were contaminated with a radioactive solution.

Aqueous solutions of ^{241}Am , ^{60}Co and ^{137}Cs in chloride forms were used to simulate radioactive contamination. The specific activity of the contaminated soil samples was $S = 45 \pm 0.01 \text{ Bq g}^{-1}$ for ^{241}Am , $S = 15 \pm 0.01 \text{ Bq g}^{-1}$ for ^{60}Co ; and $S = 18 \pm 0.01 \text{ Bq g}^{-1}$ for ^{137}Cs . The samples were stored at 18 °C and 15-20 % humidity.

The water-soluble forms of ^{241}Am , ^{60}Co and ^{137}Cs were determined after 75 min and 3 weeks after the radioactive contamination by using the following extraction procedure [9]:

2 g dry weight of the studied soil samples were mixed with 20 cm³ of distilled water. End-over-end extraction was performed by shaking at about 20 °C for 2 h at 200 rpm, followed by vacuum filtration of the leachates through 0.2 µm cellulose nitrate filters.

All the extracts were measured by γ -spectrometry. HPGe detector Canberra 7221 coupled to a 16000-channel analyzer DSA-1000 was used to measure the activities of ^{241}Am , ^{60}Co and ^{137}Cs . Gamma peaks of ^{241}Am at 59.54 keV and of ^{60}Co at 1173.2 keV and 1332.5 keV were used to measure their activities. The radioactivity of ^{137}Cs in the samples was determined, using the gamma peak of $^{137\text{m}}\text{Ba}$ (daughter product of ^{137}Cs) at 661.5 keV, 25 min after the extraction.

The radionuclide content in the different fractions was measured in the supernatant, and the extraction yield was determined by the ratio of the extracted and the initial radioactivity of the sample. The amounts of radionuclides remaining in the soil after the aqueous extraction was calculated by the difference between the total activity and the extracted activity.

3. Results and Discussion

The results obtained for the content of the radionuclides (in %) remained in the soils after the water extraction, 75 min after their introduction into the soils are presented in Figs. 1-2. It can be seen that ^{241}Am and ^{60}Co were rapidly bound into non-water-soluble forms. Almost all of the americium and 82-92 % of radiocobalt were found to be retained to the soil after the extraction. The retention of radiocesium amounts from 58 to 68%, which indicates that 32-42% of it is in a soluble state, in the form of ions or soluble fulvate complexes 75 min after its entry into the soil.

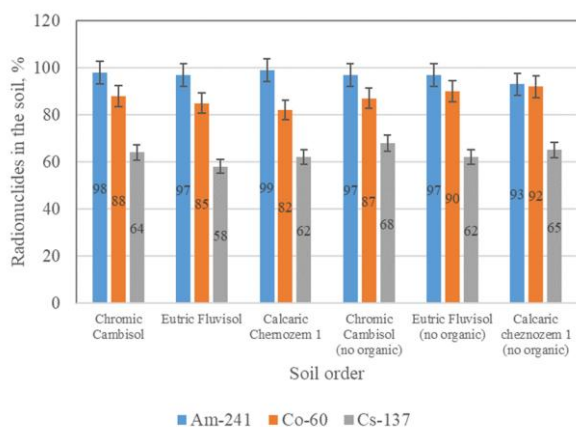


Figure 1 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction, 75 min after the contamination of natural soils with normal CEC and after removal of their organic matter.

The data presented on Fig. 1 showed that no statistically significant difference was observed in the retention of ^{241}Am and ^{137}Cs by the soils with normal CEC. Slight increase (12 %) of the retention of ^{60}Co by Calcaric Chernozem 1 soil with removed organic matter was registered.

The results for the soils with low CEC (Fig. 2) confirmed that there is no influence of the soil organic matter on the retention of ^{241}Am at the 75th min after the contamination.

Nearly twice lower retention of ^{60}Co in Vertisol soil and of ^{137}Cs in Gleyic Fluvisol soil without organic matter was observed.

Increase of the retention of ^{137}Cs by 66 % in Vertisol soil with removed organic matter, compared to the natural soil was registered.

Figures 3-8 present the retention of the radionuclides (in %) after the water extraction of the six soils, containing from 0 to 50 % mass concentration of soil without organic matter, 3 weeks after the contamination.

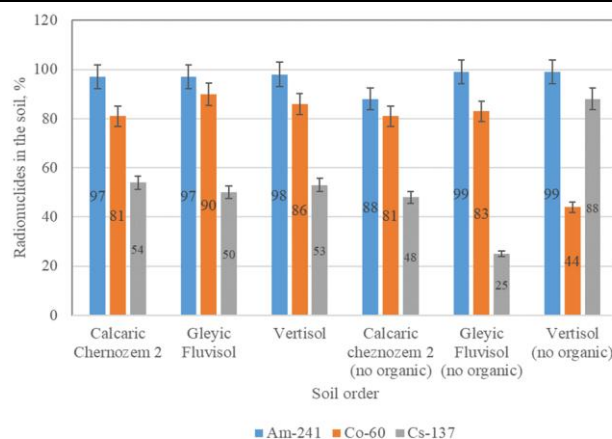


Figure 2 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 75 min after the contamination of natural soils with low CEC and after removal of their organic matter.

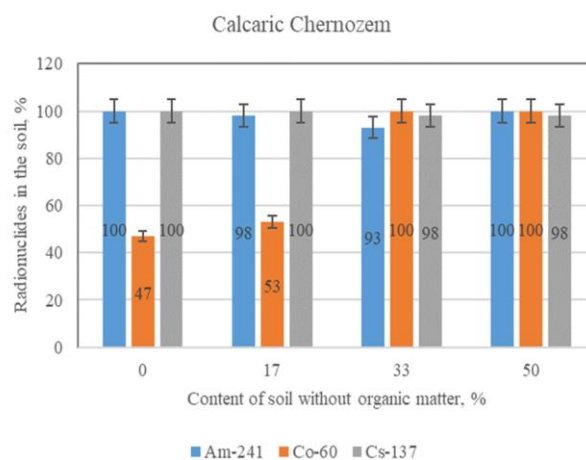


Figure 3 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Calcaric Chernozem 1 soil, containing different content (%) of soil without organic matter.

The data showed that the retention of ^{241}Am and ^{137}Cs in the soils was not influenced by the organic matter content in all the studied soils, 3 weeks after the contamination.

The addition of organic matter-free soil up to 33 % and 50 % in the Calcaric Chernozem 1 soil (Fig. 3) increased twice the retention of ^{60}Co , while no influence in the other soils was found.

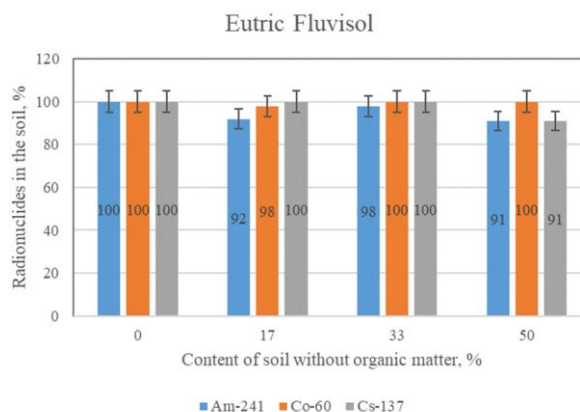


Figure 4 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Eutric Fluvisol soil, containing different content (%) of soil without organic matter.

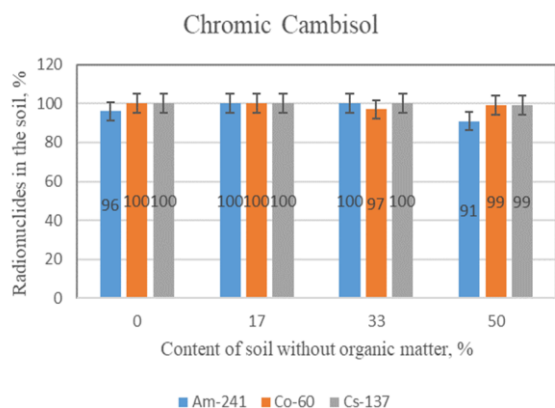


Figure 5 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Chromic Cambisol soil, containing different content (%) of soil without organic matter.

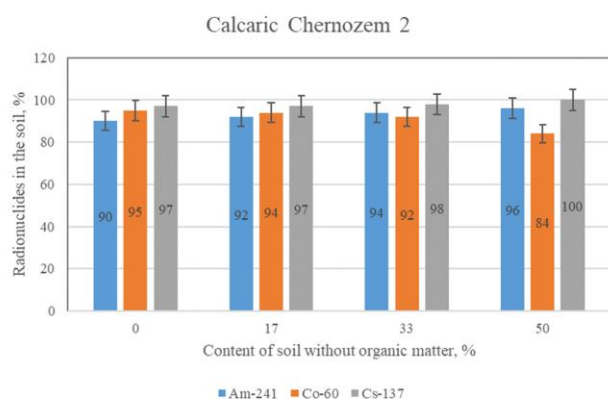


Figure 6 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Calcaric Chernozem 2 soil, containing different content (%) of soil without organic matter.

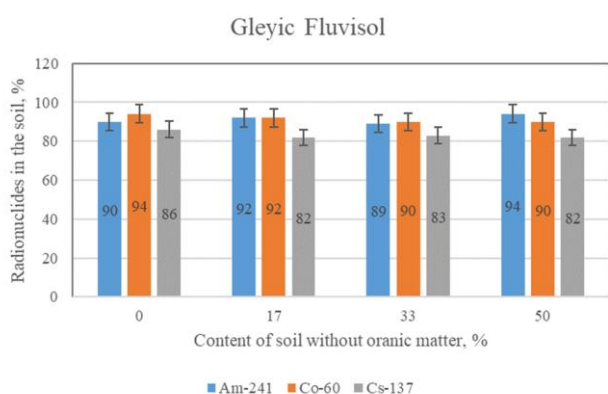


Figure 7 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Gleyic Fluvisol soil, containing different content (%) of soil without organic matter.

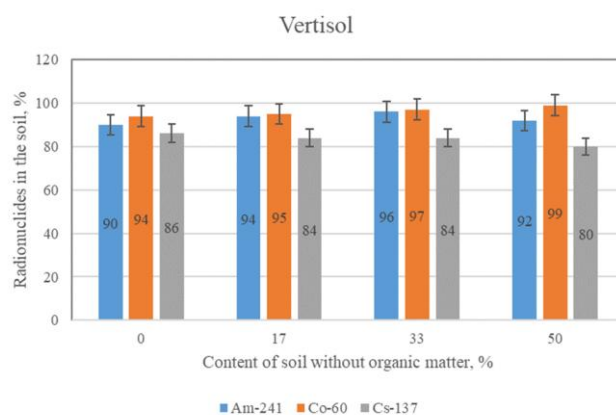


Figure 8 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Vertisol soil, containing different content (%) of soil without organic matter.

These results confirmed our hypothesis that adding soil with removed organic matter can be used to lower the mobility of radionuclides in some soils. This depends on the soil characteristics and the geochemical behavior of the radionuclides. Establishing the appropriate mass concentrations of soil mineral additives (soil with removed organic matter) as well as the mineral composition of soils will contribute to the development of a successful remediation strategy. An advantage of this approach would be the preservation of the mineral composition of the contaminated soil without introducing chemical substances that are not characteristic for the ecosystem.

4. Conclusions

The present study found a fast fixation of more than 80 % of ^{241}Am and ^{60}Co in forms, not extractable by water in all the studied natural soils and soils without organic matter. The results from the water extraction of the radionuclides 75 min after the contamination showed that:

- Removing soil organic matter increased of the retention of ^{60}Co in Calcaric Chernozem and ^{137}Cs in Vertisol soil.
- The water-soluble forms of ^{60}Co in Vertisol and ^{137}Cs in Gleyic Fluvisol soils increased after the removal of the soil organic substances.

Adding 33 % to 50 % organic matter-free soil to Calcaric Chernozem soil caused twice decrease of the water-soluble forms of ^{60}Co 3 weeks after the contamination, while no changes in the other soils were detected.

Further studies are needed to clarify the impact of organic matter content in soils with different characteristics on the retention and immobilization of radionuclides in case of radioactive contamination.

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The influence of the method of agricultural production on the state of surface water

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Abstract: According to various researchers, the ever-increasing pollution of water resources in the world by wastewater from agricultural sectors poses a great challenge to human health, especially in economically developed areas. Agriculture and its methods of operation constantly influence the water quality of surface water bodies. It was established that in Lithuania, 63% of water bodies in the categories of rivers and 64% of lakes are classified as risk water bodies and do not meet the criteria of good condition. One of the main group of factors that led to the deterioration of the condition of water bodies is the continuous and increasing pollution, mainly from agricultural activities. This study aims to find out how much the ecological method of agricultural production affects the nearby surface water bodies. The obtained results show that the larger the area of organic farms from the entire area of the lake's nutrient basin, the lower the values of biochemical oxygen consumption, total phosphorus, phosphate phosphorus, nitrate nitrogen and total nitrogen concentrations. It was established that most of the surface water bodies in southern Lithuania corresponded to the values of the class of very good and good ecological status. The ecological method of agricultural production has a positive effect on the condition of surface water bodies.

Keywords: WATER BODY, CONDITION CLASS, ORGANIC FARM

1. Introduction

The increasing level of use of water resources by polluting them with wastewater from the domestic, industrial and agricultural sectors, according to various researchers, poses a great challenge to human health, especially in economically developed areas [2]. Various studies show that excessive use of chemical fertilizers and pesticides has caused serious non-point source water pollution [1]. Diffuse and other water pollution is a major problem in many agroecosystems, especially in irrigated areas associated with ecosystems of high ecological value [3]. Modern agriculture is increasingly dependent on chemical fertilizers, especially in developing countries [4]. Fertilizers and manures applied to crops to increase yields are often lost through surface erosion, soil leaching, and runoff, and water quality is degraded as nutrients are added to surface and groundwater.

According to the requirements of the General Water Policy Directive, surface water bodies are divided into the categories of rivers, lakes, intermediate and coastal water bodies and are assigned to UBR. After assessing the state of water bodies, it was found that in Lithuania, 63% of water bodies in the categories of rivers and 64% of lakes are classified as risk water bodies and do not meet the criteria of good condition. 57% of rivers and 62% of lake water bodies in the Nemunas RBD, 94% and 95% in the Lielupa RBD, 66% and 90% in the Venta RBD, and 22% and 44% in the Dauguva RBD do not meet the criteria of good condition.

The condition of surface water bodies is most negatively affected by diffuse pollution, mainly from agricultural activities (42% of significantly affected bodies). Diffuse agricultural pollution consists of leaching of nitrogen and phosphorus compounds into the soil with animal manure and mineral fertilizers into surface water bodies. The extent of the impact is determined by the intensity of agricultural activity. Crop production in Lithuania has greatly intensified compared to the period of 2010-2013. According to statistics, on average, in the period 2016-2022, agricultural land was used 5.3% more than in the previous period. The area of intensively cultivated crops (cereals and rape) also increased by 21%. Compared to the previous period, the sales of mineral nitrogen fertilizers in Lithuania increased by 14%, phosphorus - by as much as 31%. Also, the areas of extensively used crops (meadows and herbaceous plants) decreased by 14%. The number of contracted animals decreased by about 9%. Since the areas of intensively cultivated crops have increased, the use of mineral fertilizers has also increased. These changes led to the increasing impact of agriculture and a significant impact on water bodies. In order to assess the influence of organic agriculture on the quality of underground and surface water, surface water of rivers or other water bodies and drainage water are usually studied in Lithuania [5-6].

Phosphorus (P) and nitrogen (N) compounds added to the soil with organic and mineral fertilizers have the greatest influence on surface water quality and eutrophication processes in surface water [8-9], therefore, in order to assess agricultural impact of production on the quality of surface water, phosphorus and nitrogen content in the soil is evaluated.

The purpose of the study: to evaluate the influence of the ecological agricultural production method on the state of surface water.

2. Materials and methods

To assess the influence of ecological methods of agriculture on the quality of surface water, the surface water bodies of southern Lithuania, the Nemunas RBD, located near farms whose agricultural production method is ecological and meets the established requirements (certified), were studied in this work. A comparative analysis of the results was carried out. The lakes researched included Alovė, Aviris, Galstas, Pabezninkai, Giluitis, Dusia, and Guostus. (Figure 1). The studied surface water bodies were analysed according to the data obtained from the database of the Environmental Protection Agency from the research results of the state program of monitoring of rivers, lakes and ponds. The ecological condition of surface water was assessed according to physico-chemical quality indicators: total nitrogen (N), total phosphorus (P), phosphate phosphorus (PO₄-P), nitrites (NO₂), nitrate nitrogen (NO₃-N), biochemical oxygen consumption during Day 7 (BOD₇).

The assessment of surface water is based on the methodology for determining the condition of surface water bodies (total nitrogen (N), total phosphorus (P) and biochemical oxygen consumption within seven days (BOD₇), criteria for classes of the ecological condition of lakes based on the values of the indicators of physico-chemical quality element. Phosphate phosphorus (PO₄-P) and nitrites (NO₂) were evaluated according to the requirements for the protection of surface water bodies where freshwater fish can live and breed.

The 2021-2022 data on the areas of organic farms from certification institutions (databases) are used, which include all declared and certified areas of organic farms in Lithuania located near the surface water bodies studied.

The water bodies studied are evaluated according to the values of hydro morphological indicators: the water body area, in square kilometers; maximum depth, in meters; average depth, in meters; the area of the nutrient basin, in square kilometers; length of coastline, in kilometers. The intensity of economic activity in the basin is assessed according to the area of organic farms in the basin, in square kilometers; the area of organic farms in the total area of the basin, as a percentage, and the number of organic farms in the basin of the water body.

Correlation coefficients were calculated to assess the relationship between the values of surface water quality indicators and the area, maximum and average depth of water bodies, the area of the nutrition basin, the length of the shoreline, the area of organic farms in the basin, the area of organic farms in the total area of the basin, and the number of organic farms in the water body basin, $p < 0.05$, with STATISTICA 10 software.

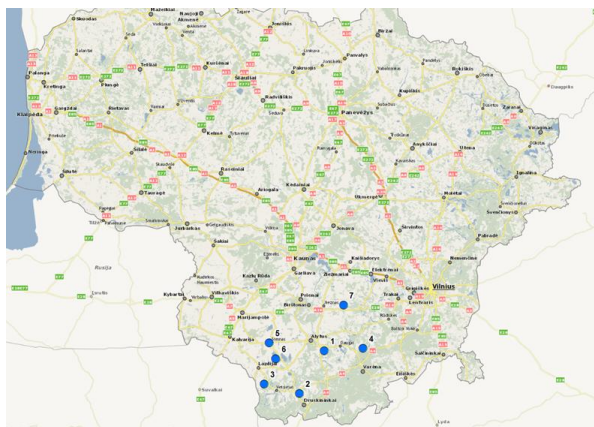


Fig. 1 The lakes researched included Alovė, Aviris, Galstas, Pabezninkai, Giluitis, Dusia, and Guostus in Lithuania

3. Results and discussion

In order to evaluate the influence of ecological agricultural production on surface water bodies, the results of water monitoring studies were analyzed.

The research results of the above-mentioned lakes from 2006 to 2022 were examined. The state of surface water was assessed by systematizing physic-chemical quality indicators: total nitrogen (N), total phosphorus (P), phosphate phosphorus (PO₄-P), nitrites (NO₂), nitrate nitrogen (NO₃-N), biochemical oxygen consumption during 7 days (BOD₇) and dissolved oxygen concentration (O₂). The assessment of the condition of the investigated surface water bodies is presented in Table 1.

Tyrimų metai	N mg/l/N	P mg/l/P	PO ₄ -P mg/l/P	NO ₂ -N mg/l/N	NO ₃ -N mg/l/N	BOD ₅ , mg/l O ₂	Prisotinimas deguonimi %
Alovės ežeras							
2009	2,45	0,088	0,037	0,29	0,025	5,52	0,97
2013	1,44	0,055	0,008	0,55	0,007	5,75	1,24
2016	1,65	0,041	0,006	0,18	0,138	5,65	1,27
2019	1,13	0,057	0,014	0,58	0,007	4,48	1,21
2022	1,01	0,046	0,022	0,23	0,0065	3,95	0,91
Avirio ežeras							
2006	1,38	0,038	0,009	0,27	0,007	3,62	1,102
2011	0,75	0,024	0,012	0,05	0,003	3,18	1,087
2016	0,5	0,027	0,007	0,10	0,001	2,75	1,069
2022	0,7	0,027	0,012	0,09	0,003	2,2	1,091
Galstos ežeras							
2010	0,75	0,044	0,031	0,04	0,004	2,65	1,045
2014	0,65	0,022	0,009	0,04	0,001	2,38	1,007
2022	0,32	0,024	0,009	0,08	0,005	2,23	1,004
Pabezninkų ežeras							
2008	1,48	0,055	0,051	0,35	0,003	4,1	0,891
2016	1,35	0,074	0,009	0,24	0,006	4,8	0,972
2019	1,55	0,073	0,015	0,19	0,006	2,08	1,015
2022	1,6	0,064	0,015	0,14	0,009	3,3	0,697
Gilučio ežeras							
2010	1,73	0,025	0,012	0,54	0,007	2,98	1,116
2014	0,95	0,032	0,013	0,3	0,006	2,38	1,001
2022	1,65	0,024	0,008	1,16	0,030	3,2	1,023
Dusios ežeras							
2007	0,9	0,028	0,010	0,03	0,002	2,53	0,956
2013	0,45	0,0195	0,005	0,02	0,005	1,05	0,978
2017	0,45	0,024	0,003	0,02	0,007	2,23	0,964
2022	0,41	0,029	0,009	0,05	0,003	2,08	0,973
Guostos ežeras							
2008	1,15	0,021	0,007	0,11	0,003	2,73	0,944
2012	0,88	0,017	0,005	0,05	0,003	1,78	0,962
2015	0,5	0,011	0,006	0,03	0,001	1,53	1,041
2022	0,66	0,033	0,013	0,14	0,005	3,05	1,013
Labai gera ekologinės būklės klasė							
Gera ekologinės būklės klasė							
Vidutinė ekologinės būklės klasė							

Table 1 The condition of the investigated surface water bodies

After analyzing the data and based on the 2007 decision of the Minister of the Environment of the Republic of Lithuania April 12 No. According to the order D1-210 "On the approval of the methodology for determining the condition of surface water bodies", the surface water bodies tested in terms of N and P concentrations corresponded to the values of the class of very good and good ecological status, except for Lake Alovė according to N and P in 2009, it corresponded to the values of the class of average ecological status, Lake Pabezninkai in terms of P concentrations in 2016, 2019 and 2022 corresponded to the values of the average ecological status class. According to BDS₇ values, all studied water bodies corresponded to the values of the class of very good and good ecological status, except for Lake Alovė, according to the years 2009, 2013, 2016 and 2019, it corresponded to the values of the class of average ecological status, and Lake Pabezninkai in 2016 corresponded to the values of the class of average ecological status.

Since phosphorus (P) and nitrogen (N) compounds introduced into the soil with organic and mineral fertilizers have the greatest influence on surface water quality [8-9] and nitrogen (Nb, mg/l) and total phosphorus (Pb, mg/l) indicators, and are presented in diagrams. Fig. 2 - 8 the variation of total nitrogen (Nb, mg/l) content in the investigated surface water bodies is presented.

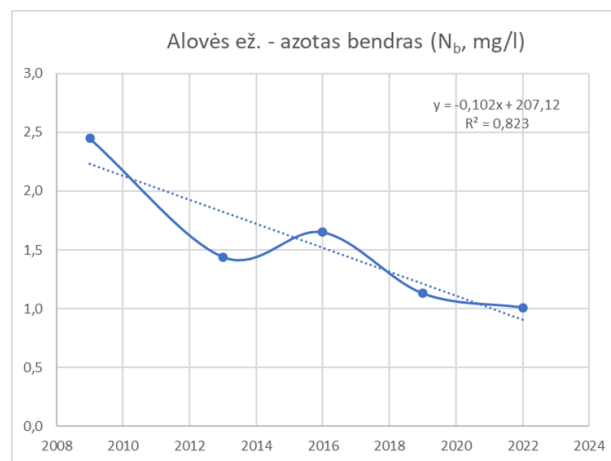


Figure 2 Total nitrogen in Alovė Lake (Nb, mg/l)

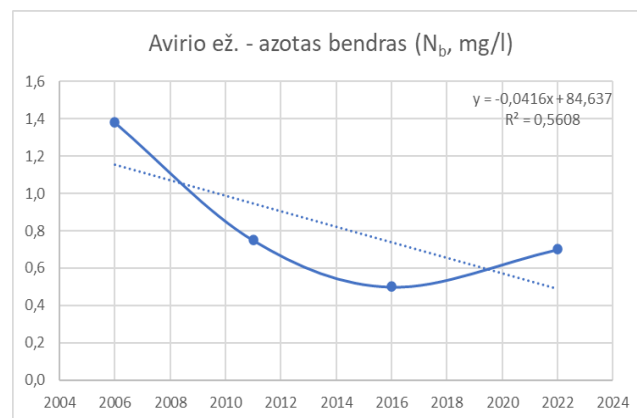


Figure 3 Total nitrogen in Aviris Lake (Nb, mg/l)

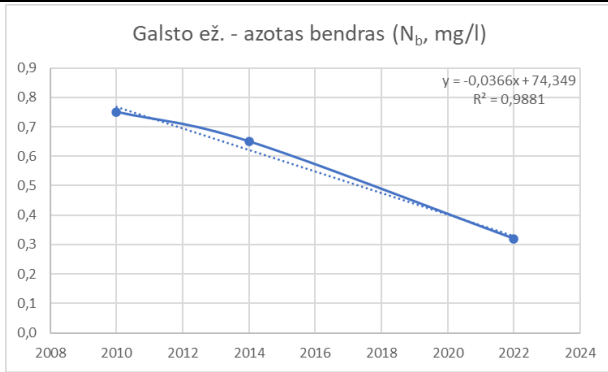


Figure 4 Total nitrogen in Galst Lake (N_b , mg/l)

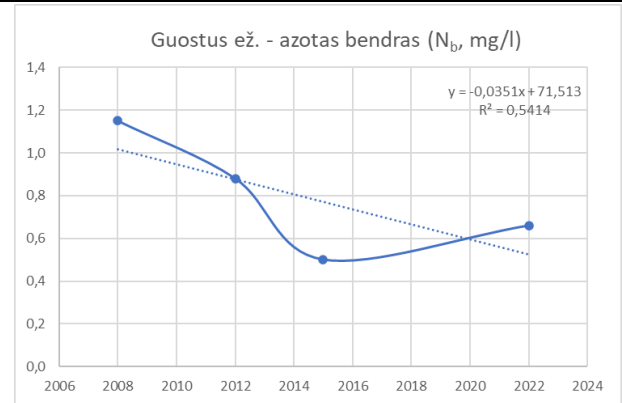


Figure 8 Total nitrogen in Lake Guostus (N_b , mg/l)

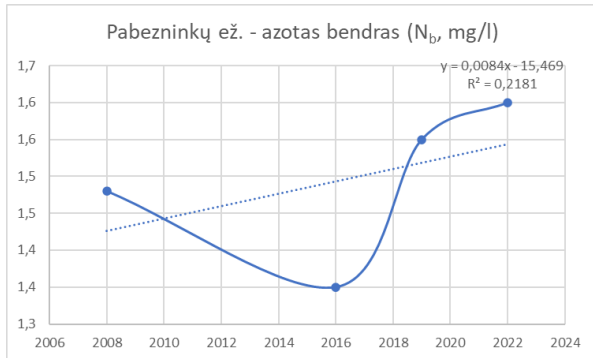


Figure 5 Total nitrogen of Lake Pabzninkai (N_b , mg/l)

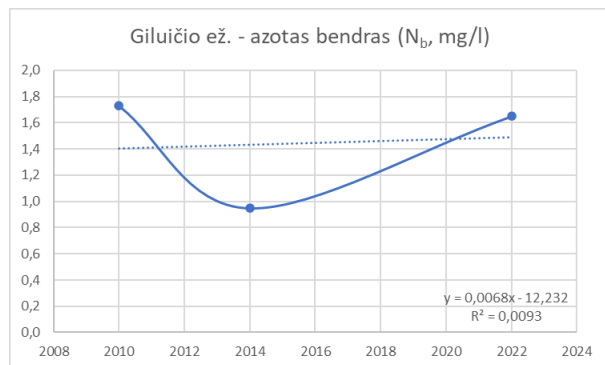


Figure 6 Total nitrogen of Lake Giluitis (N_b , mg/l)

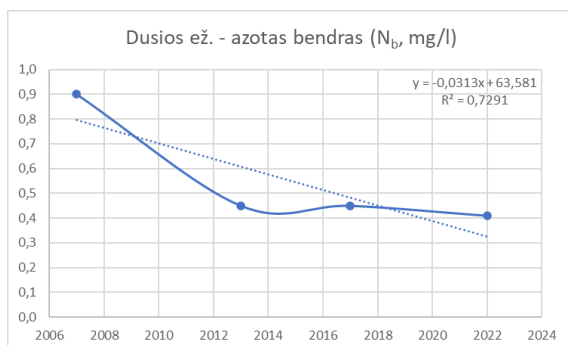


Figure 7 Total nitrogen in Lake Dusia (N_b , mg/l)

From the presented diagrams of total nitrogen, it can be seen that the curve rises in Pabzninkai and Giluitis lakes, which indicates an increased entry of nitrogen (N) compounds into the mentioned surface water bodies. In all other studied surface water bodies, the curve does not rise.

Fig. 9 – 15 the variation of total phosphorus (P_b , mg/l) content in the investigated surface water bodies is presented.

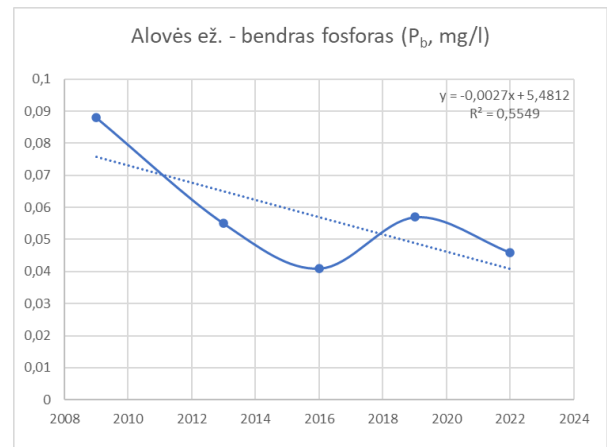


Figure 9 Total phosphorus of Alovė Lake (P_b , mg/l)

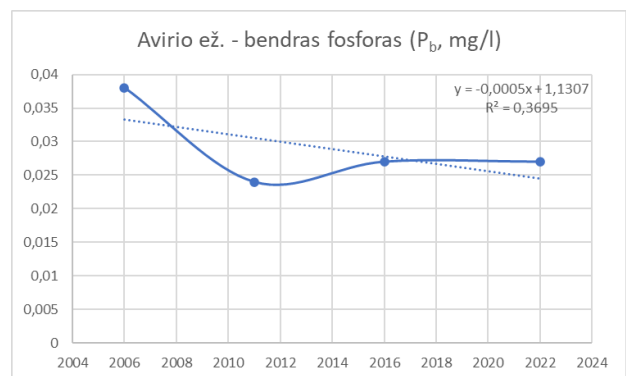


Figure 10 Total phosphorus of Lake Aviris (P_b , mg/l)

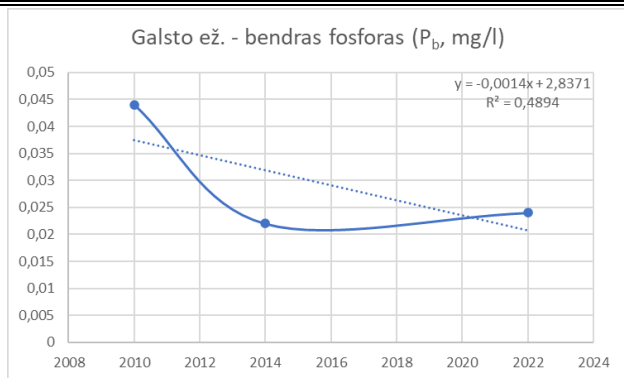


Figure 11 Total phosphorus of Galst Lake (P_b , mg/l)

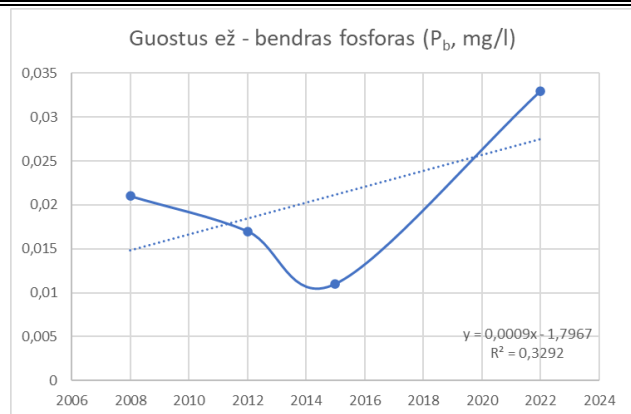


Figure 15 Total phosphorus of Lake Guostus (P_b , mg/l)

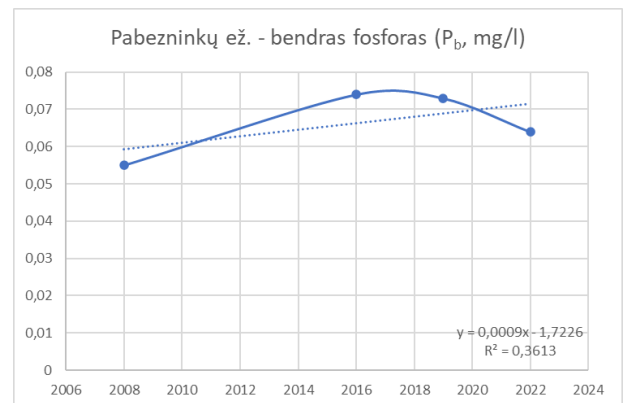


Figure 12 Total phosphorus of Lake Pabėzninkai (P_b , mg/l)

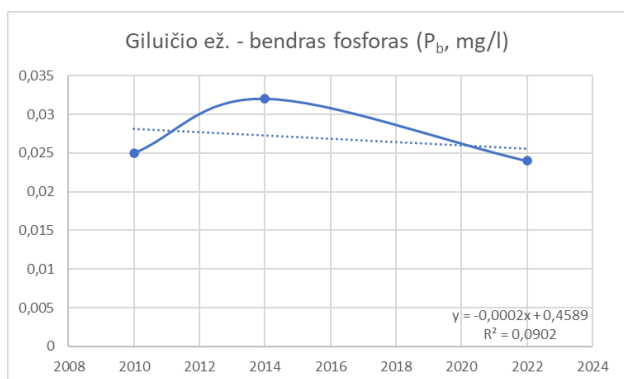


Figure 13 Total phosphorus of Lake Gilučiū (P_b , mg/l)

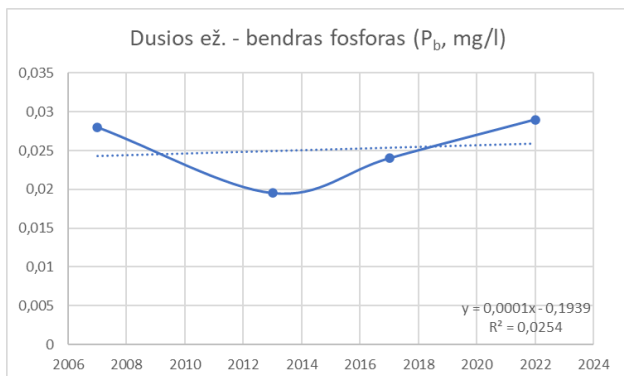


Figure 14 Total phosphorus in Lake Dusia (P_b , mg/l)

From the presented diagrams of total nitrogen, it can be seen that the curve rises in Pabėzninkai, Dusios and Guostas lakes, which indicates an increased entry of phosphorus (P) compounds into the mentioned surface water bodies. In all other studied surface water bodies, the curve does not rise.

Area of studied water bodies, km²; maximum depth, m; average depth, m, area of the nutrition basin, km², length of the shoreline, km, area of organic farms in the basin, km²; the area of organic farms from the total area of the basin, % and the number of organic farms in the basin of the water body are presented in Table 2.

Ežero pavadinimas Name of the lake	Plotas, km ² Lake area, m	Maksimalus gylis, m Max depth, m	Vidutinis gylis, m Average depth, m	Baseino plotas, km ² Pool area, km ²	Ekologinių ūkių plotas, km ² Area of organic farms, km ²	Ekologinių ūkių plotas nuo viso baseino ploto, % The area of organic farms from the total area of the basin, %	Kranto linijos ilgis, m Length of the coastline, m	Ekologinių ūkių sk. vnt. Number of organic farms, units
Alovė	0.797	4.40	2.5	7.75	0.5121	6.61	5.42	1
Avirio	1.500	32.8	9.6	26.2	1.4598	5.57	11.4	4
Galstė	3.918	50.0	14.1	68.0	2.1087	3.10	18.99	1
Pabėzninkų	0.661	3.00	1.9	11.8	0.9119	7.73	4.6	1
Gilučiū	2.350	22.0	8.9	34.8	2.7300	7.85	9.15	1
Dusios	23.46	32.4	15.4	107.8	0.3807	0.35	23.46	1
Guostus	0.756	33.7	18.5	23.2	0.2019	0.87	4.85	1

Table 2 Hydromorphological and economic indicators of the studied surface water bodies

The largest in terms of area is Lake Dusios (23.46 km²), the smallest is Lake Pabėzninkai (0.661 km²). The deepest lakes in terms of maximum and average depth - Galstė (50/14.1 m); Avirio (32.8/9.6 m); Guostu (33.7/18.5 m) and Dusios lake (33.7/18.5 m). The shallowest lakes are Pabėzninkai (3/1.9 m) and Alovė lake (4.4/2.5 m). The largest area of the nutrition basin is Lake Dusios (107.8 km²); the smallest - Alovė lake (7.75 km²). The longest shoreline length - Dusios lake (23.43m); the shortest of Lake Pabėzninkai (4.6 m). The largest area of organic farms is in the basin of Lake Gilučiū (2.72 km²), the smallest is in the basin of Lake Guostus (0.2019 km²). After evaluating the area of organic farms as a percentage of the entire lake nutrition basin, it was found that the largest percentage of organic farms is in the basin of Lake Gilučiū (7.85%), the lowest is in the basin of Lake Dusios (0.35%). In the basins of all studied lakes, only one organic farm was registered, only in the basin of Lake Aviris were registered two.

Correlation coefficients were calculated in order to evaluate the relationships between the surface water quality indicator values and the area of water bodies, maximum and average depth, area of the nutrition basin, the length of the shoreline, the area of organic farms in the basin, the area of organic farms from the total area of the basin, and the number of organic farms in the basin of the water body. The results are presented in Table 3.

Vandens kokybės rodiklis Water quality indicator	Ezero plotas, m Lake area, m	Maksimalus gylis, m Max. depth, m	Vidutinis gylis, m Average depth, m	Kranto linijos ilgis, m Length of the coastline, m	Baseino plotas, km ² Pool area, km ²	Ekologinių ūkių plotas, km ² Area of organic farms, km ²	Ekologinių ūkių plotas nuo viso baseino ploto, % The area of organic farms from the total area of the basin, %
N, mg/l	r=-0.538 p=0.213	r=-0.897 p=0.006	r=-0.854 p=0.014	r=0.750 p=0.042	r=0.73 p=0.049	r=0.122 p=0.795	r=-0.862 p=0.013
P, mg/l P	r=-0.339 p=0.458	r=-0.828 p=0.021	r=-0.899 p=0.006	r=0.488 p=0.266	r=0.53 p=0.217	r=-0.197 p=0.672	r=-0.739 p=0.042
PO ₄ -P, mg/l P	r=-0.487 p=0.268	r=-0.554 p=0.197	r=-0.779 p=0.039	r=0.395 p=0.381	r=0.48 p=0.272	r=0.115 p=0.806	r=-0.744 p=0.020
NO ₃ -N, mg/l N	r=-0.374 p=0.409	r=-0.519 p=0.233	r=-0.520 p=0.232	r=0.451 p=0.310	r=0.43 p=0.331	r=0.535 p=0.216	r=-0.755 p=0.049
NO ₂ -N, mg/l N	r=-0.247 p=0.593	r=-0.632 p=0.128	r=-0.613 p=0.144	r=0.391 p=0.385	r=0.43 p=0.337	r=-0.093 p=0.842	r=-0.469 p=0.289
BDS ₇ , mg/l O ₂	r=-0.494 p=0.259	r=-0.786 p=0.036	r=-0.858 p=0.014	r=0.598 p=0.156	r=0.69 p=0.047	r=-0.131 p=0.779	r=-0.676 p=0.045

Table 3 Correlation matrix of the values of surface water quality indicators and the area of water bodies, maximum and average depth, the area of the nutrition basin, the long shoreline, the area of organic farms in the basin, the area of organic farms from the total area of the basin, and the number of organic farms in the water body basin.

After calculating the correlation coefficients, a statistically strong negative relationship was found between the maximum lake depth and total nitrogen concentration (N) ($r=-0.897$, $p=0.006$), total phosphorus concentration (P) ($r=-0.828$, $p=0.021$), biochemical oxygen consumption values (BDS₇) ($r=-0.786$, $p=0.036$). The higher the maximum water depth, the lower the values of biochemical oxygen consumption, total phosphorus and total nitrogen concentrations.

A statistically strong negative correlation was found between the average lake depth and total nitrogen concentration (N) ($r=-0.858$, $p=0.014$), total phosphorus concentration (P) ($r=-0.899$, $p=0.006$), phosphate phosphorus concentration (PO₄-P) ($r=-0.779$, $p=0.039$), and biochemical oxygen consumption values (BDS₇) ($r=-0.858$, $p=0.014$). The greater the average water depth, the lower the values of biochemical oxygen consumption, total phosphorus, phosphate phosphorus and total nitrogen concentrations.

A statistically strong positive relationship was found between the length of the shoreline and total nitrogen concentration (N) ($r=0.750$, $p=0.042$), the longer the shoreline, the higher the total nitrogen concentration.

A statistically strong positive correlation was found between the area of the nutrient pool and the concentration of total nitrogen (N) ($r=0.730$, $p=0.049$), and the value of biochemical oxygen consumption (BOD₇) ($r=0.690$, $p=0.047$). The larger the area of the nutrient basin of the water body, the higher the values of biochemical oxygen consumption and total nitrogen concentrations.

A statistically strong negative correlation was found between the area of organic farms from the total basin area and total nitrogen concentration (N) ($r=-0.862$, $p=0.013$), total phosphorus concentration (P) ($r=-0.739$, $p=0.042$), phosphate phosphorus concentration (PO₄-P) ($r=-0.744$, $p=0.020$), nitrate nitrogen concentration (NO₃-N) ($r=-0.755$, $p=0.049$) and biochemical oxygen consumption values (BOD₇) ($r=-0.676$, $p=0.045$). The larger the area of organic farms from the total basin area, the lower the values of biochemical oxygen consumption, total phosphorus, phosphate phosphorus, nitrate nitrogen and total nitrogen concentrations.

4. Conclusions

1. It was established that the investigated surface water bodies according to N, P and BOD₇ values corresponded to the values of the class of very good and good ecological status, with the exception of Alovės lake according to N and P in 2009, which corresponded to the values of the class of average ecological status, Pabėzninkai lake according to P concentrations in 2016, 2019 and in 2022 corresponded to the values of the average ecological status class. According to BDS₇ values, Lake Alovės in 2009, 2013, 2016

and 2019, Lake Pabėzninkai in 2016 corresponded to the values of the medium ecological status class.

2. After calculating the correlation coefficients, a statistically strong negative relationship was found between the maximum lake depth and N ($r=-0.897$, $p=0.006$), P ($r=-0.828$, $p=0.021$), BDS₇ ($r=-0.786$, $p=0.036$). A statistically strong negative correlation was found between average lake depth and BDS₇ values of N ($r=-0.858$, $p=0.014$), P ($r=-0.899$, $p=0.006$), PO₄-P ($r=-0.779$, $p=0.039$) ($r=-0.858$, $p=0.014$). A statistically strong positive correlation was found between shoreline length and N) ($r=0.750$, $p=0.042$). $p=0.047$.

3. The larger the area of organic farms from the total basin area, the lower the values of biochemical oxygen consumption, total phosphorus, phosphate phosphorus, nitrate nitrogen and total nitrogen concentrations. A statistically strong negative correlation was found between the area of organic farms from the total basin area and total nitrogen concentration (N) ($r=-0.862$, $p=0.013$), total phosphorus concentration (P) ($r=-0.739$, $p=0.042$), phosphate phosphorus concentration (PO₄-P) ($r=-0.744$, $p=0.020$), nitrate nitrogen concentration (NO₃-N) ($r=-0.755$, $p=0.049$) and biochemical oxygen consumption values (BOD₇) ($r=-0.676$, $p=0.045$).

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Agro-Climatic Suitability of Albanian Arable Land for *Nigella Sativa* L.: Analyzing Soil Structure and Organic Matter Effects

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Abstract: Soil conservation is paramount to sustainable agriculture, particularly in regions facing environmental challenges. *Nigella sativa* L., commonly known as black cumin, is a versatile annual crop recognized for its nutritional and medicinal properties. This study investigates the potential of integrating *N. sativa* cultivation into Albanian agriculture to assess its impact on soil quality and conservation. Employing a comprehensive approach encompassing field experiments, laboratory analyses, and geospatial modeling, this research evaluates the adaptability of 8 diverse *N. sativa* genotypes to the agro-climatic conditions of three distinct Albanian regions: Tirana (central), Shkodra (northwestern), and Korca (eastern). The study particularly emphasizes the influence of soil structure, organic matter content, and water-use efficiency on *N. sativa* growth and yield.

Preliminary results indicate that the genotype originating from Turkey demonstrated superior performance, achieving a seed yield of 12.8 g in the Tirana region, characterized by silt-loam soil structure and an organic matter content of 1.78 %.

KEYWORDS: SOIL CONSERVATION, GIS-BASED ANALYSIS, NIGELLA SATIVA L., SUSTAINABLE AGRICULTURE, AGRO-CLIMATIC ADAPTATION

1. Introduction

Sustainable agricultural practices that prioritize soil health are crucial for ensuring long-term food security and environmental resilience [1]. *Nigella sativa* L., a versatile annual crop with a wide range of food, medicinal, and pharmaceutical applications, [2], has gained increasing attention as a potential contributor to agro-ecosystem stability [3]. Albania, a country facing complex environmental and agricultural challenges, may benefit from the integration of *N. sativa* L. Cultivation into its cropping systems. The application of GIS methods provides a reliable framework for generating detailed databases and suitability maps, offering essential insights to local farmers and decision-makers for the effective management of arable land in Albania. [4]. Despite its potential, there remains a significant gap in the literature regarding the land suitability of *N. sativa* L. based on GIS methodologies, particularly in the context of Southeastern Europe. This study represents the first attempt to address this gap in Albania by assessing the agro-climatic suitability of the country's arable land for *N. sativa* L. cultivation. By combining field experiments, laboratory analyses, and geospatial modeling, the research aims to provide a comprehensive evaluation of the crop's adaptability under diverse environmental conditions. This novel approach highlights the role of advanced technological tools in modern agriculture, offering a model for integrating innovative practices to improve resource management and crop productivity. The study underscores the potential of *N. sativa* L. not only to enhance soil health and biodiversity but also to contribute to the sustainability and resilience of Albania's agricultural systems.

2. Materials and Methods

2.1 Collection of population

Eight different populations were collected from the following sources: 1-Nabial MORSI.CO sample NO:136; 2- Jeddah Kindom of Saudi Arabia Sifa international Mfg.; 3- Medical plant Tirana; 4- Egypt; 5- Syria Almnarco.com; 6-Turkey; 7- Syria code 353 Natural dry nuts& herbs; 8- Turkey product No 012 Sakli Doga

2.2 Field experiment

The present research was carried out at three different areas of Albania, 1- Didactic Experimental Field of the Agricultural University of Tirana (DEF-AUT) 41.3998180, 19.7285460, 2- Didactic Experimental Field of F.S.Noli University Korce (DEF-Korca), 3- Shkoder Agricultural Technology Transfer Center (TTC-Shkoder), during May- September 2023, for the first time in Albanian arable land. The agro-climatic zones of the three regions are categorized as follows: Ana e Malit falls under the Moist Mediterranean (Category 2), Preza is classified as Dry Mediterranean (Category 1), and Priska belongs to the Sub-Montane Dry zone (Category 4), The experiment was design using

a randomized complete block with three replications. Each population in each replication consisted of three rows with 30cm apart and 2.5m in length with inter row plant distance of 5cm. Sustainable agricultural practices were applied to the experiment throughout the growing season.

2.2. Soil physical and chemical analysis

The chemical and physical properties of soil at a depth of 0-40 cm were analyzed at the Agroenvironment and Ecology Laboratory of the Agricultural University of Tirana. Soil pH was determined according to [5] Soil Quality methodology. Soil texture was assessed using the Hydrometer Method for particle size analysis [6]. Organic matter (OM) content was evaluated by the Walkley-Black method for Soil Organic Carbon. Assimilable phosphorus (P.a) and exchangeable potassium (K.ex) were quantified through Mehlich 3 extraction for extractable elements [7]. Total nitrogen (N) content was measured in accordance with ISO 11261:1995/R-2021 Soil Quality standards [8].

2.3 Methodology for Thematic Map creation:

Inverse Distance Weighting (IDW) interpolation technique was used in QGIS environment, for mapping soil fertility and soil texture. The slope raster was created in the QGIS environment using a 30-meter resolution Digital Elevation Model (DEM) sourced from the Shuttle Radar Topographic Mission (SRTM). The IDW approach is a deterministic spatial interpolation technique used in many GIS-based location selection application for mapping various parameters [9]. IDW will use the values surrounding the prediction location to predict a value for any unmeasured location. The points closest to the target location are given more weight [10]. All thematic maps were developed in QGIS format (either as shapefiles or rasters) and transformed into layer maps, which were then converted and georeferenced to the Universal Transverse Mercator (UTM) projection, specifically zone 34 N of the WGS 1984 coordinate reference system, to facilitate the mapping of Albanian territory. Three suitability criteria including soil texture, soil fertility (organic matter, Ph, K, P), topography(slope) was selected, based on FAO framework for land evaluation [11], and are as follows: *Class S1 (highly suitable); Class S2 (moderately suitable); Class S3 (marginally suitable); Class N (not suitable)*. The output maps are according to FAO framework.

2.3.1 Data sources

The physical-chemical soil data (Organic matter, K, P, pH, H₂O, texture) for three region 1-Priske Tirana, 2-Ana e Malit Shkodra, 3-Pirg Korce, were obtained from Agriculture Technology Transfer Center, Fushe Kruje, part of Ministry of Agriculture and Rural Development of Albania.

3. Result

3.1 Result of onsite experiment

Physical and chemical analyses of the soil were determined in Table 1.

The physical and chemical properties of soils in the three regions significantly influenced the growth and yield of *Nigella sativa L.* In the Tirana region, a silt-loam texture with 1.78% organic matter and a slightly alkaline pH of 7.71 supported satisfactory yields, although increasing soil organic matter could further enhance productivity. Population 8, originating from Turkey, achieved the highest seed yield per plant in this region 12.8 g. In Korça, the clay-loam texture, higher organic matter content (2.72%), and a pH of 7.55 provided optimal conditions, with Population 8 again achieving the highest yield, likely due to improved water retention and nutrient availability. Conversely, in Shkodra, loam soil with 2.25% organic matter and an acidic pH of 6.21 restricted germination, with soil acidity likely restricting nutrient uptake. However, Population 8 achieved the highest seed yield per plant (5.75 g) in this region as well.

Table 1. Chemical and physical properties of the soil

Code	Physical properties (%)			
Unit	San d %	Clay %	Loa m %	Texture
DEF-AUT	15.18	19.28	65.54	Silt-Loam
TTC-Shkode	40.89	12.85	46.26	Loam

r					
FDE Korca	36.8	27.65	35.55	Clay-Loam	
Chemical properties					
Unit	pH pH unit	N total mg/kg	O. M %	P mg/kg	K mg/kg
DEF-AUT	7.71	1.732	1.78	23.95	175.379
QTTB Shkodra	6.21	2.006	2.25	98.33	87.754
FDE Korca	7.55	2.318	2.72	207.78	236.372

3.2 Result of land suitability based on GIS approach

Table.2 provides GPS coordinates of the sampled profiles and key soil parameters, including bottom horizon depth (cm), pH (H₂ O), organic matter (OM, %), available phosphorus (P, ppm), exchangeable potassium (K, me/100g), exchangeable sodium (Na, me/100g), and detailed particle size distribution (% clay <0.002 mm, % silt 0.002–0.05 mm, % sand 0.05–2.0 mm, fine sand 0.05–0.10 mm, coarse sand 0.1–2.0 mm). Additionally, it includes soil texture classifications based on analysis, offering a comprehensive overview of soil fertility and physical properties across the study areas.

Table 2. Soil Profile Characteristics: GPS Coordinates, Fertility Parameters, and Texture Analysis

The table summarizes soil profiles by GPS coordinates, fertility parameters (organic matter, pH, available phosphorus, exchangeable potassium and sodium), and texture classifications. Textures are categorized into Sandy (LS, S), Coarse-Loamy (SL, SCL), Loamy (L, ZL), Fine-Loamy (CL, ZCL), and Clayey (C, ZC, SC).

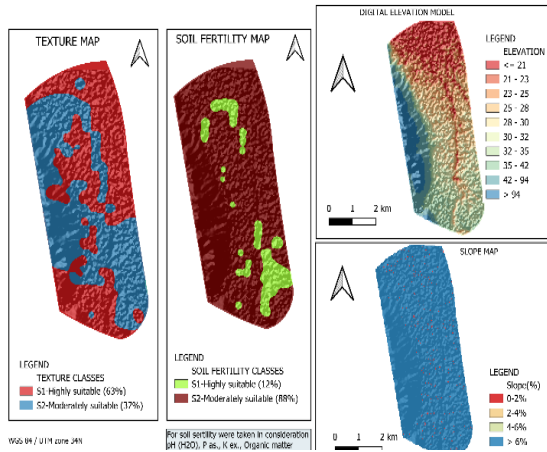
	Profile No.	GPS Co-ordinates		horizon, cm	ph (water)	Organic matter, %	Available P, ppm	Ex. K, me/100g	Ex. Na, me/100g	% clay <0.002mm	% silt 0.002 - 0.05mm	% sand 0.05 - 2.0mm	fine sand, 0.05 - 0.10, %	sand, 0.1 - 2.0, %	Texture by analyses
Ana e Malit	1	4372645	4654349	23	8.5	1.0	7.0	0.2	0.1	6.8	25.7	67.5	0.0	0.0	SL
	2	4370746	4651345	30	8.2	2.3	7.7	0.7	0.2	32.5	47.7	19.8	0.0	0.0	CL
	3	4370467	4652376	24	8.2	1.4	7.1	0.2	0.1	7.5	40.2	52.3	0.0	0.0	SL
	4	4369633	4653216	27	8.5	1.1	7.1	0.2	0.1	9.6	63.3	27.1	0.0	0.0	ZL
	5	4366435	4654548	25	8	1.1	8.8	0.48	0.15	34.88	50.1	15.0	0.0		ZCL
	6	4369168	4654680	20	8.2	2	6.4	0.39	0.24	17.2	51.8	31.0	0.0	0.0	ZL
	7	4363010	4656017	23	8.4	1.1	9.5	0.28	0.1	9.44	53.3	37.3	0.0	0.0	ZL
Pirgu	1	4475705	4517468	35	6.9	1.6	15.4	0.33	0.1	0.0	100	0.0	0.0	0.0	SCL
	2	4476027	4515947	35	5.7	1	8.4	0.15	0.08	0.0	100	0.0	0.0	0.0	SCL
	3	4476856	4517658	35	7.5	1	10.7	0.11	0.11	0.0	100	0.0	0.0	0.0	L
	4	4477608	4517782	35	8.2	1	6.6	0.15	0.16	0.0	100	0.0	0.0	0.0	SL
	5	4477916	4517769	30	8.5	1.8	18.1	0.18	0.22	0.0	100	0.0	0.0	0.0	CL
	6	4477308	4515635	25	7.1	2	8.1	0.24	0.12	0.0	100	0.0	0.0	0.0	C
	7	4475348	4512116	25	6.4	0.6	19.3	0.42	0.1	0.0	100	0.0	0.0	0.0	CL
Preza	1	391224	4584974	27	8.1	2	6.6	0.3	0.14	19.72	60.56	19.72	19.72	0.0	ZL
	2	391437	4584497	30	8.2	2.3	6	0.41	0.15	47.12	48.16	4.72	4.72	0.0	ZC
	3	390819	4587153	25	8.5	2.2	4.9	0.65	0.15	48.24	41.92	9.84	9.84	0.0	ZC
	4	390801	4587446	27	8.4	1.2	4.2	0.2	0.16	28.68	62.52	8.8	8.8	0.0	ZCL
	5	387624	4588018	30	8.4	1.4	2.7	0.49	0.11	28.56	54.96	16.48	16.48	0.0	ZCL
	6	387173	4587931	30	8.4	1.1	4.8	0.53	0.12	29.44	45.32	25.24	25.24	0.0	CL

These details provide insights into soil properties critical for assessing suitability for *Nigella sativa L.* cultivation.

Table 3 Land suitability for *Nigella Sativa L.* under different classes

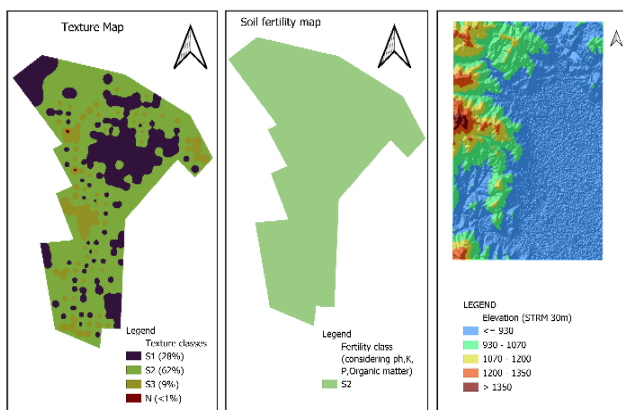
Classification	Index
Highly Suitable	S1
Moderate Suitable	S2
Not suitable	N

Fig.1 Land suitability map for *Nigella Sativa* in the Preza Commune of the Tirana District.



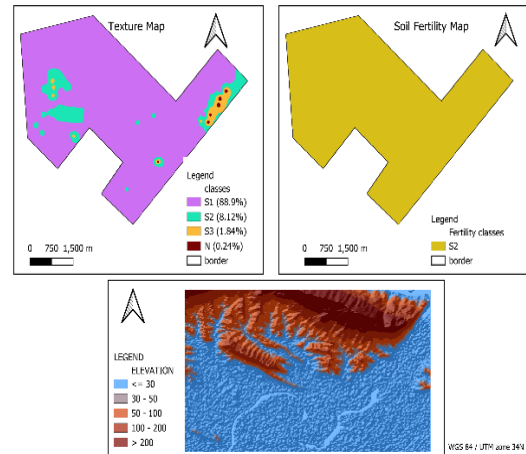
The GIS-based land suitability analysis for *Nigella sativa* L. in the Preza Commune of the Tirana District, focusing on soil texture and fertility, reveals promising potential for cultivation. The results indicate that 63% of the area falls under the highly suitable category (S1) based on soil texture loamy, fine-loamy, while 88% is classified as moderately suitable (S2). Regarding soil fertility, 12% of the area is highly suitable (S1), and 88% is moderately suitable (S2). These fertility evaluations were determined by considering critical parameters, including pH (H_2O), exchangeable potassium (Kex), assimilable phosphorus (Pas), and organic matter content. These findings suggest that while the majority of the area shows moderate suitability, targeted soil management practices could enhance the land's overall potential for cultivating *Nigella sativa* L.

Fig.2 Land suitability map for *Nigella Sativa* on Pirg Commune of the Korça District.



In the Pirg Commune of the Korça District, the GIS-based land suitability analysis for *Nigella sativa* L. highlights varying levels of suitability. Based on soil texture, 28% of the area is classified as highly suitable (S1), 62% as moderately suitable (S2), 9% as marginally suitable (S3), and less than 1% as not suitable (N). Regarding soil fertility, 12% is categorized as S1 and 88% as S2, considering pH (H_2O), exchangeable potassium (Kex), assimilable phosphorus (Pas), and organic matter. These results underline the potential for cultivation in the region, with moderate improvements recommended for maximizing productivity.

Fig.3 Land suitability map for Ana e Malit Commune of the Shkodra District.



In the Ana e Malit Commune of Shkodra District, the GIS-based land suitability analysis for *Nigella sativa* L. demonstrates a high level of suitability based on soil texture Coarse -loamy, loamy, with 88.9% of the area classified as highly suitable (S1), 8.12% as moderately suitable (S2), 1.84% as marginally suitable (S3), and less than 1% as not suitable (N). However, soil fertility analysis shows that 100% of the area falls under the moderately suitable category (S2), evaluated through pH (H_2O), exchangeable potassium (Kex), available phosphorus (Pas), and organic matter.

Considering the results from the three communes analyzed Preza in Tirana, Pirg in Korça, and Ana e Malit in Shkodra it is evident that land suitability for *Nigella sativa* L. cultivation varies significantly across regions. Preza demonstrates moderate to high suitability, characterized by favorable agro-climatic conditions, but with potential for improvement through enhanced soil fertility management. Pirg, on the other hand, exhibits a more balanced distribution across suitability classes, with highly suitable areas interspersed with zones requiring targeted intervention to address limitations such as soil texture and nutrient availability. Ana e Malit stands out for its predominantly highly suitable soil texture, yet its moderate fertility levels indicate that increasing organic matter and nutrient content is critical to fully realize its cultivation potential. Our study aligns with prior research such as [12], [13] [14] which highlight the subtle interaction between soil properties and regional agro-climatic conditions, emphasizing the need for tailored agronomic strategies. By addressing specific constraints in each commune, these results provide a roadmap for optimizing *N. Sativa* L. cultivation, contributing to more efficient land use and sustainable agricultural practices.

4. Discussion

This study represents a notable advancement in agricultural research in Albania, introducing GIS-based analysis for land suitability assessment an innovative and underexplored approach in the region. By incorporating spatial and environmental data, this methodology provides a comprehensive framework for evaluating agro-ecological conditions, enabling more precise and effective crop management strategies. In this context, the research focused on optimizing the cultivation of *Nigella sativa* L., a plant valued for its nutritional and medicinal properties, across varying agro-climatic zones. The results offer critical insights into the most suitable areas for its cultivation, highlighting its potential contribution to Albanian agriculture. Furthermore, the study establishes a precedent for integrating advanced geospatial tools into agricultural research, promoting sustainable land-use planning and encouraging future applications for other crops and regions.

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Low-input fertilization with organic and complex mineral fertilizers and their influence on the content of available and total forms of macroelements in haplic chernozems

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Abstract: The use of complex mineral, organo-mineral and organic fertilizers on Haplic Chernozems for 8 years lead to changes in the composition of soil organic matter. These fertilizers without the use of mineral N fertilization have a positive effect on the values of $^+NH_4-N$, available and total phosphorus in the soil, as well as cation exchangeable potassium.

Certainly organic fertilization as well as its combination with multicomponent mineral fertilizer has a positive impact on the agrochemical status of the soil. The potential nitrogen supplying capacity of the soil determined on the 28th and 56th days of incubation significantly increased the amount of mineralized nitrogen. The same was highest in the use of the organic fertilizer Excel^{Orga}, where the excess over the control in the values of net mineralizing capacity was 24.20%.

Keywords: ORGANIC, ORGANO-MINERAL, COMPLEX MINERAL FERTILIZERS, pH, AVAILABLE AND TOTAL FORMS OF MACROELEMENTS, POTENTIAL NITROGEN SUPPLYING ABILITY OF SOIL IN DYNAMICS (14, 28 AND 56 DAYS OF INCUBATION)

Introduction

The high productivity and quality of crops is an impossible task without ensuring the plants' need for nutrients and optimal soil status in terms of its water-physical and agrochemical properties. Nutrient deficiency not only reduces plant tolerance to adverse environmental conditions and damages yield, but also lowers soil fertility [1, 2]. This forms the main task of applying nutrients to the soil - to restore the soil regime, to influence the soil-forming process and the genesis of the soil, because with the export of manufactured agricultural products, significant transformations occur in a negative direction [3].

In the region of slightly leached chernozems in South Dobrudzha, studies on the influence of various agrotechnical practices on the fertility of these soils have been summarized in a series of publications [4, 5, 6].

The aim of the present study is to investigate the influence of different origin and content fertilizers for basic soil fertilization, excluding the introduction of nitrogen fertilizers during the growing season of long-term monoculture wheat cultivation, on the changes in the content of absorbable and common forms of the main macroelements, as well as on the potential nitrogen-supplying ability of the soil.

Material and Methods

At Dobrudzha Agricultural Institute - General Toshevo on Haplic Chernozem [7], the influence of main soil fertilization with the combined mineral fertilizer Suprefos (12% N; 24% P₂O₅; 0.5% Mg; 14% Ca; 25% S) and the organic fertilizer Excell^{Orga} (50% organic matter, org. N - 4 %, P-2%, K-6%, Mg-3%) produced by Angibaud & Specialites (France) was followed for 8 years. Four variants of the created nutrient regime in the soil were studied: 1. Control, reflecting the natural fertility of the site; 2. Superfos (350 kg/ha) – Mineral fertilization (MF); 3. Superfos + Excell^{Orga} (175+175 kg/ha) – Organo-Mineral Fertilization (OMF) and 4. Excell^{Orga} (350 kg/ha) – Organic fertilization (OF). Agrochemical characterization was done in 0-20 cm, 20-40 cm and 40-60 cm layers which included soil reaction, mineral nitrogen forms, potential nitrogen supplying capacity of soil - mineralization ability (MA), available phosphorus, cation exchangeable potassium and total nitrogen (TN) and phosphorus (TPh) forms.

After grinding and drying to an air-dry state, the soil samples were sieved through a 2-mm sieve. Agrochemical analyzes include determination of: potentiometric determination of soil acidity in 1N KCl; forms of mineral nitrogen in 1 % K₂SO₄ by using spectrophotometric methods (NO₃-N – its ability to form an intense yellow coloration in an alkaline medium upon interaction with disulfophenolic acid [C₆H₃OH(HSO₃)₂], and NH₄-N was determined by the phenolic method [8] available phosphorus was determined spectrophotometrically by the AL-method (by the modification of Ivanov [9], and cation exchange potassium - flame photometrically.

The general forms were determined according to the classic methods of Kjeldahl and Bonnet, and the mineralizing ability of the soil - in dynamics at 14, 28 and 56 days of incubation. It aims to provide optimal conditions for nitrification and takes place at constant temperature levels (30° C) and 60% humidity from its total moisture absorption capacity. Its determination is identical to the method of determination of NO₃-N.

The obtained results were subjected to statistical analysis - analysis of variances (ANOVA). Multivariate statistical analysis includes analysis of variance, F test and LSD (Least Significant Difference) test, after which the mean values for each variant were compared by applying the Duncan Multiple Range Test. Pearson correlation coefficients ("R coefficients") were also determined, which were also tested for significance.

Results and Discussions

Based on ANOVA, the results of the multifactorial analysis of variances of the studied agrochemical indicators by depth of the studied layers show high levels of statistical significance (Table 1). Changes in profile depth are unproven only in terms of NO₃-N content and exch. K₂O. The introduction of fertilizers of different origin and content lead to the formation of a similar trend, although with a different degree of statistical significance in relation to some indicators. The established differences in the Pure MA 14-56 and Pure MA 0-56 indicators remain unreliable.

The interaction between the factors affects with the maximum degree of credibility in the absorbable P₂O₅, MA-14, Pure-to14 and Pure14-28. The same is significant, but with a lower level of statistical confidence in Min-N and MA-28. For all other indicators, this interaction is unreliable.

Table 1. Varians analysis of the agrochemical indices

Dependent Variable	Depth (1)			Fert. Var (2)			1 x 2		
	df	F	Sig.	df	F	Sig.	df	F	Sig.
pHKCl	2	25,279	,000***	3	4,608	,006**	6	2,184	,057 ^{NS}
$^+NH_4-N$	2	112,014	,000***	3	12,539	,000***	6	1,683	,141 ^{NS}
$^-NO_3-N$	2	,714	,494 ^{NS}	3	2,773	,049*	6	2,063	,071 ^{NS}
Min. N	2	64,434	,000***	3	3,568	,019*	6	2,760	,020*
P ₂ O ₅ - available	2	193,210	,000***	3	39,694	,000***	6	5,763	,000***
K ₂ O - exchangeable	2	2,822	,067 ^{NS}	3	12,385	,000***	6	1,968	,084 ^{NS}

Total N	2	73,492	,000***	3	8,035	,000***	6	1,885	,098 ^{NS}
Total P	2	9,929	,000***	3	12,048	,000***	6	,872	,521 ^{NS}
MA - 14	2	506,799	,000***	3	11,411	,000***	6	7,881	,000***
MA - 28	2	84,585	,000***	3	5,511	,002***	6	3,139	,010**
MA - 56	2	61,440	,000***	3	2,836	,046*	6	,878	,517 ^{NS}
Pure MA- to14	2	262,721	,000***	3	8,373	,000***	6	6,536	,000***
Pure MA -14-28	2	8,250	,001***	3	4,062	,011**	6	3,913	,002***
Pure MA - 28-56	2	3,522	,036*	3	1,218	,311 ^{NS}	6	1,489	,197 ^{NS}
Pure MA - total	2	43,890	,000***	3	2,068	,114 ^{NS}	6	1,038	,410 ^{NS}

The soil reaction is an important characteristic of the quality of the soil and an indicator of the processes taking place in it, because affects the microbiological activity, the mobility and solubility of nutrients, the mobilization of soil organic matter and, in general, the biogeochemical cycle of the planet [10, 11, 12]. From the surface layer to the layers lying below, the values of this indicator increase (Fig.1). Nankova [13] reported that, depending on the amount of macronutrient fertilization rates and especially with nitrogen fertilization at high rates for 50 years, exchangeable Al^{3+} appeared in the surface layer of Naplic Chernozems. In this experiment, the variant with MF (5.20) stands out with the lowest pH value. Certainly OMF and OF have an ameliorating effect and increase the values of the indicator by 4.8%.

Phosphorus available to plants quite naturally decreases with depth of the profile, but in general the experimental section is poorly stocked. The applied fertilizers and especially MF and OMF the amount of available phosphorus. The influence of the tested fertilizers on the content of total phosphorus is particularly strong.

For the study period, no statistically significant differences were found between them. However, they contributed to an increase in the phosphate status of the soil by about 8% compared to the control. The strength of the influence of the depth factor on plant-available phosphorus is 71.55%***, while for TPh, the influence of the fertilization factor is stronger. The experimental site is very well stocked in terms of cation-exchanged potassium. Its content very smoothly decreases along the depth of the profile from 23.79 to 22.93 mg $K_2O/100$ g of soil, which is a characteristic feature of this soil type. A strong positive influence of MF and OMF was found compared to the control variant and that with OF.

The content of TN in the soil maintains a tendency to decrease along the depth of the profile - from 169.84 (0-20 cm) to 146.74 mg N/100 g of soil (40-60 cm). Of the tested fertilizers, only MF (167.44 mg N/100 g) had a reliable contribution to increasing the content of TPh in the soil.

From the changes in basic agrochemical characteristics of soil fertility discussed so far, it is necessary to pay attention to the changes in the forms of mineral nitrogen and the potential ability of the soil to supply this nutrient during the growing season. Of the forms of Min. N most significant and the differentiation in profile depth for NH_4-N , while for NO_3-N the differences are insignificant (Table 2). Regardless of this fact, at the end of the wheat growing season, the concentration of Min. N is low, but well differentiated by layers, which also determines its high power of impact (82.54%***). The fertilizers used also affect the values of the indicator, but with a strength of 6.86%*. Again, the differentiation is best marked with NH_4-N .

The mineralizing ability of the soil at all incubation periods shows that the 0-20 cm layer has the greatest potential N-supplying ability of the soil. It decreases gradually with the depth of the studied layer.

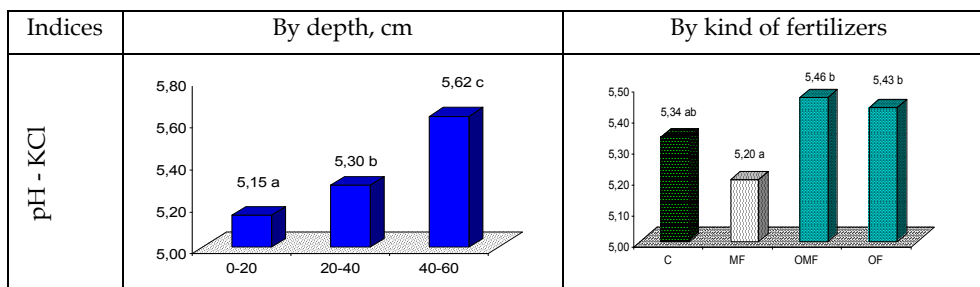
Different types of fertilizers also affect mineralization processes, but the differentiation in values is much less pronounced. In all three incubation periods, the lowest amounts of mineralized nitrogen were found after fertilization with Excel^{Orga}. As with the forms of Min. N, the influence of the depth factor is decisive - over 80%***. The influence of the fertilization factor is also credible, but its influence reaches only 8.08%**.

The Pure/net amounts of mineralized nitrogen (when Min. N was eliminated before incubation) showed increasing values with increasing duration of incubation. Again, the surface layer 0-20 cm has the greatest potential for nitrogen supply. The differences between individual fertilizer products are small, and in the case of incubation between the 28th and 56th day, they are insignificant. As for the influence of the tested factors, the depth of the layer is decisive. On average for Pure MA 0-56, the same is determined at 87.60%, and the fertilization factor, as well as the interaction between the two factors, has an unreliable power of influence. The latter only reliably influence Pure MA 0-14 and Pure MA 14-28.

Numerous correlative dependencies between the studied indicators have been established, which indicate the main interrelationships and their direction (Fig. 2). The results of the analysis show that the soil reaction is in a negative relationship with all the investigated indicators. The same is most pronounced with MA at the early incubation periods, Min. N, available phosphorus and Total N. The ammonium form of nitrogen is in strong correlative relations with all the studied indicators except for NO_3-N and Total P. They are particularly strongly manifested with Min. N (0.854**) MA-14 (0.828**), P_2O_5 (0.796**). NO_3-N is in proven correlation only with Min. N. For available phosphorus, the best correlations are with MA-14 (0.842**), PMA-14 (0.807**) and Total N (0.743**).

Cation exchange potassium is characterized by less pronounced interrelationships, the most significant being the one with the content of available phosphorus.

Pure soil MA at the beginning of incubation (14 days) is distinguished by high levels of correlation coefficients with almost all indicators. For the 2nd and 3rd terms, in most cases, they are insignificant. The interrelationships of PMA 0-56 with all terms of determination of the potential nitrogen supplying ability of soil, with NH_4-N , Total N and available phosphorus in the soil are markedly high values.



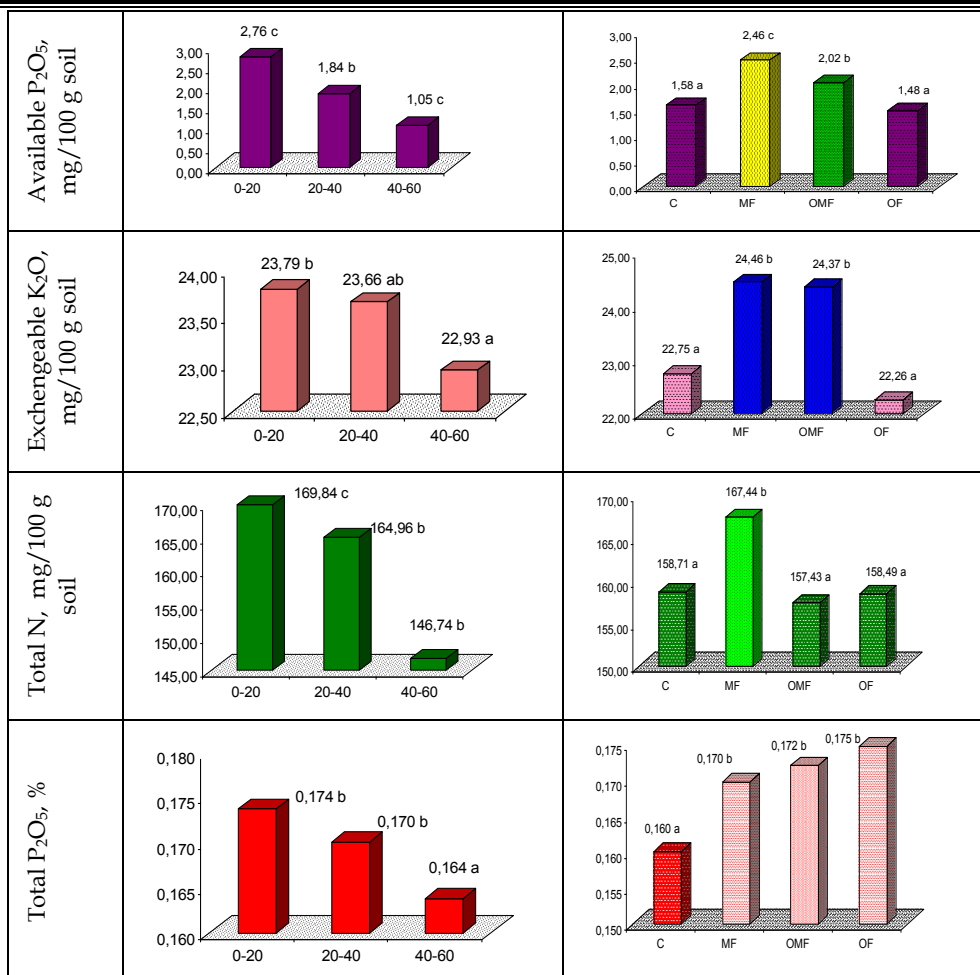


Figure 1. Changes in soil acidity values, available forms of phosphorus and potassium, and total nitrogen and phosphorus in the soil

Table 2. Changes in the composition of the forms of mineral nitrogen and the mineralizing ability of the soil by profile depth and depending on the type of applied fertilizers

Nitrogen mineral forms, mg /1000 g soil							
Depth, cm	NH_4-N	NO_3-N	Min. N	Fertilizer variants	NH_4-N	NO_3-N	Min. N
0-20	3,73 c	5,24 a	8,97 c	Control	3,09 c	5,06 ab	8,16 b
20-40	2,76 b	5,07 a	7,84 b	Superfos	3,02 c	4,89 a	7,91 ab
40-60	1,87 a	5,10 a	6,97 a	Superfos+Excel ^{Orga}	2,73 b	5,35 b	8,08 b
				Excel ^{Orga}	2,30 a	5,24 ab	7,54 a
Mineralization ability according to days of incubation, mg NO_3-N /1000 g soil							
Depth, cm	14	28	56	Fertilizer variants	14	28	56
0-20	16,761 c	26,58 b	40,39 c	Control	11,69 a	22,73 b	35,42 b
20-40	13,37 b	24,95 b	35,64 b	Superfos	13,20 b	22,71 b	35,55 b
40-60	7,14 a	15,27 a	26,92 a	Superfos+Excel ^{Orga}	13,11 b	23,92 b	34,40 ab
				Excel ^{Orga}	11,69 a	19,70 a	31,89 a
Pure mineralization ability between days of incubation , mg NO_3-N /1000 g soil							
Depth, cm	to14 th day	14 th - 28 th day	28 th - 56 th day	Fertilizer variants	to14 th day	14 th - 28 th day	28 th - 56 th day
0-20	7,79 c	9,82 a	13,81 b	Control	3,54 a	11,03 b	12,70 a
20-40	5,54 b	11,57 b	10,70 a	Superfos	5,29 b	9,51 ab	12,84 a
40-60	,17 a	8,13 a	11,64 ab	Superfos+Excel ^{Orga}	5,03 b	10,81 b	10,48 a
				Excel ^{Orga}	4,15 a	8,01 a	12,19 a

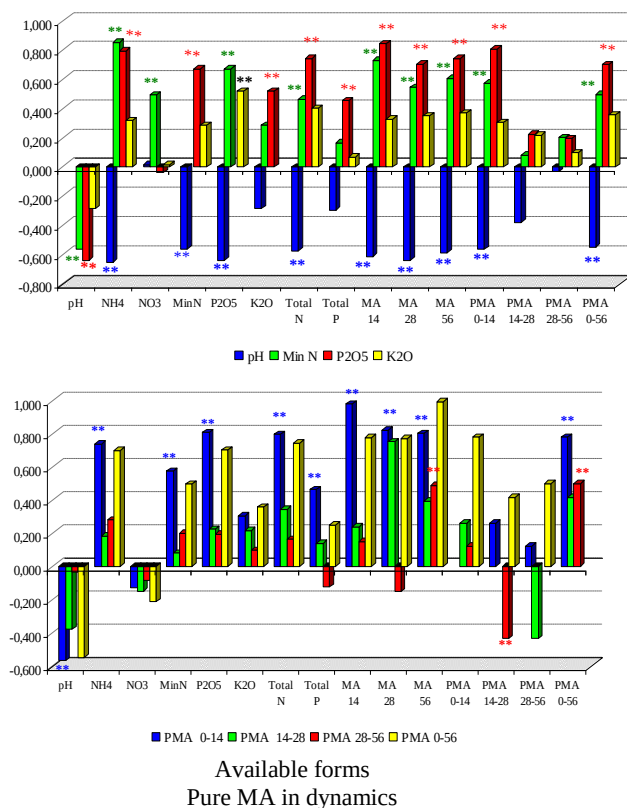


Figure 2. Strong correlative relationships between investigated agrochemical indices of soil fertility (Pearson Correlation)

Conclusions

In general, the results show that with prolonged discomfort in relation to the predecessor and without the application of nitrogen fertilization during the growing season, the tested technological solutions in terms of optimizing wheat nutrition by selecting different origin fertilizers for main fertilization have a positive effect on the agrochemical status of Haplic Chernozems.

The investigated layers by depth of the profile influence the values of a number of the studied indicators. A high level of statistical reliability of this influence was found in the changes in soil reaction (pH_{KCl}), the content of mineral forms of nitrogen, referring mainly to the ammonium form. In this regard, the potential nitrogen supplying capacity of the soil determined on the 28th and 56th days of incubation significantly increased the amount of mineralized nitrogen. The same was highest in the use of the organic fertilizer Excel^{Orga}, where the excess over the control in the values of net mineralizing capacity was 24.20%. There was also a significant effect on the plant available phosphorus content, as well as an increase in total nitrogen values in the soil.

Tested fertilizers of different composition and origin without the use of mineral nitrogen fertilizers have a positive effect on the values of ammonium form of nitrogen, available and total phosphorus in the soil, as well as cation exchangeable potassium. Certainly organic fertilization as well as its combination with multicomponent mineral fertilizer has a positive impact on the agrochemical status of the soil. Numerous clear correlations between soil acidity, digestible and total forms of macronutrients have been established.

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Study of the seasonal dynamics of microcystins and nutrients in Kokalyane bent

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Abstract: This article presents a summary of data derived from studies conducted on the seasonal dynamics of microcystins and nutrients in the water of Kokalyane bent in 2023 and 2024. The chromatographic analytical method (HPLC) was employed for the determination of microcystins in water samples from Kokalyane bent. Ten water samples were examined, and traces of microcystins were identified in two samples from 2023 (equivalent concentration of MYC-LR approximately $0,2 \mu\text{g L}^{-1}$). The measured concentrations of total nitrogen ranged from $0,58$ to $1,75 \text{ mg L}^{-1}$, while those of total phosphorus ranged from $0,02$ to $0,04 \text{ mg L}^{-1}$.

Keywords: MICROCYSTINS, HPLC, DRINKING WATER

Introduction

Kokalyane bent is located at 600 m height above mean sea level in the eastern part of the Sofia field, in the valley of the Iskar river, at 12 km southeast of the capital [1]. Kokalyane bent delivers water in the high parts of Kokalyane and Pancharevo villages.

In 1956, the construction of the second level of the Iskar Hydroelectric Station, part of the Iskar cascade on the Iskar river, was completed. This very large construction is part of the national plan for electrification of Bulgaria. The main facilities of the hydroelectric junction are the massive concrete wall of the Iskar dam with which the water catchment of the Iskar river is carried out and a multi-year equalization of the river's outflow is ensured. This dam solves the capital's water supply, irrigation of the Sofia field and is also used for silage extraction. The hydroelectric complex includes the Kokalyane bent, the Pasarel hydroelectric power plant, the Pasarel dam, the Pancharevo lower leveling dam and the designed and partially constructed Sofia navigation canal and the Sofia hydroelectric power plant.

The water resources from Kokalyane bent serve as a reserve for supplying the Pancharevo water treatment plant [2].

Cyanobacteria, or blue-green algae, are pervasive microorganisms in freshwater ecosystems [3]. The proliferation of cyanobacteria in surface waters is accelerated by global warming and human-induced eutrophication, which create optimal conditions for their development [4]. Furthermore, they are frequently linked to toxic blooms, which emerge when a confluence of environmental elements, including elevated temperatures and the presence of nitrogen and phosphorus compounds, stimulate the proliferation of these microorganisms, potentially resulting in their extensive blooms [5].

Cyanotoxins occur naturally, although high concentrations are typical of eutrophicated freshwater bodies. For example, contamination of nutrients and acceleration of cyanobacteria growth can occur from sewage or agricultural runoff. The most probable route of exposure is through drinking water. Additionally, cyanotoxins can accumulate in certain food products. Furthermore, recreational activities in lakes with cyanobacterial blooms can also periodically expose individuals to elevated concentrations of cyanotoxins.

The current requirements for the quality of drinking water in Europe are reflected in the recently adopted Directive (EU) 2020/2184 of 16 December 2020 on the quality of water intended for human consumption. The directive was incorporated into Bulgarian legislation as an amendment to Ordinance No. 9/2001 on the quality of water intended for drinking and domestic purposes (promulgated SG No. 30 of 2001, last amended SG No. 43 of 16 May 2023). Among the newly identified pollutants that will be subject to mandatory monitoring from 2026 onwards is microcystin-LR, for which an assessment of the potential risk of water pollution is also required. It is a representative of microcystins, which are a group of cyanotoxins produced by blue-green algae. The directive establishes a maximum permissible concentration of $1 \mu\text{g L}^{-1}$ [6] for microcystin-LR in drinking water.

Microcystins (MYCs) are secondary metabolites that are produced by cyanobacterial genera, including *Microcystis*, *Anabaena*, and *Planktothrix* [7]. They are comprised of seven amino acids, and due to substitutions and structural modifications, over 240 variants are currently known, each with a distinct degree of toxicity [8, 9]. MYC are classified as hepatotoxins. Individuals who have been exposed to microcystins have also reported experiencing neurological symptoms, which has led to the hypothesis that microcystins may have adverse effects on the nervous system [10].

Their cyclic structure endows them with resistance to extreme pH values, high temperatures, and sunlight. The isomer with the highest toxicity is the known hepatotoxin microcystin-LR (MYC-LR). Similarly, microcystin-LA exhibits comparable toxicity, followed by microcystin-RR (MYC-RR) and microcystin-YR (MYC-YR) [11]. Adverse effects on human health may result from direct physical contact, inhalation, or ingestion of contaminated food or water. The World Health Organization (WHO) has set a maximum allowable concentration of microcystins in drinking water at $1 \mu\text{g L}^{-1}$ [12], a guideline that is reflected in the recently introduced drinking water directive.

The study of cyanobacterial blooms around the world has been a topic of research for decades. In Bulgaria, the initial investigation into the presence of microcystins in Bulgarian water bodies designated for drinking water and recreational use was conducted by a research team from the National Center for Public Health and Analyses (NCPHA) between 2004 and 2005 [13, 14].

The aim of the present study is to investigate microcystins monthly during the warm seasons of 2023 and 2024, as well as the nutrients in samples from Kokalyane bent.

Experimental

The Kokalyane bent water samples considered in this paper were taken during the summer and autumn months of 2023 and 2024. A total of ten samples were taken during the considered periods, which were intended for the analysis of microcystins, and nutrients (total nitrogen and total phosphorus).

Determination of microcystins by liquid chromatography (HPLC)

Water samples for the determination of microcystins are stored frozen in plastic bottles of 1,5 L. Before processing, they were thawed and frozen three times to ensure lysis of the cyanobacterial cell walls, then filtered with a glass microfiber filter (glass microfiber filter GF/A, 47 mm-Cytiva).

Filtered samples were extracted by solid phase extraction with cartridges (Oasis HLB $60 \mu\text{m}$ (LP) 6 mL, Waters Corporation, USA). Elution was performed with methanol (HPLC grade) and evaporated to dryness using a gentle stream of nitrogen. Add $0,5 \text{ ml}$ of 50 % (v/v) methanol. The final extracts were filtered with PTFE filters ($0,45 \mu\text{m}$, Alltech).

Chromatographic determination was performed with a liquid chromatograph with an Agilent 1200 diode array detector. The

analytical column was a Supelcosil ABZ+Plus column (150 mm x 4,6 mm, 5 µm, Supelco), thermostated at 25 °C. A gradient of acetonitrile (HPLC purity) and ultrapure water (0,055 µS) was used with the addition of 0,1 % trifluoroacetic acid (spectroscopically pure) to both solvents: 20 % acetonitrile at 0 min to 46 % at 20 min, chromatography time - 25 min at a flow rate of 1 mL min⁻¹, wavelength - 238 nm. Certified reference materials for MYC-LR and MYC-RR and reference material for MYC-YR (Cifga Laboratorio S.A, Spain) were used for calibration.

Determination of nutrients

The determination of total nitrogen is carried out after mineralization of the sample with concentrated sulfuric acid in a thermoblock (Digestor unit DS6, type 2006, FOSS TECATOR, Sweden). The ammonium sulfate obtained in this process is decomposed with sodium hydroxide to ammonia, which is captured in a boric acid solution in a distillation apparatus Kjeltac 2100, FOSS TECATOR, Sweden). Ammonium borate is determined by back titration with 0,01 mol L⁻¹ (0,01 N HCL) solution Hydrochloric acid 10 cm³ burette, tolerance ± 0,02 cm³, ISOLAB, Germany is used to calculate the total nitrogen, with a limit of quantification of 0,5 mg L⁻¹.

The determination of total phosphorus was carried out according to the procedure described in BDS EN ISO 6878:2005 "Water quality. Determination of phosphorus. Ammonium molybdate spectrometric method [15] using Specol 11 spectrophotometer, Carl Zeiss Jena. The limit of quantification is 0,02 mg L⁻¹.

Results and discussion

The results of the analyzes of water samples from Kokalyane bent taken monthly during the warm seasons of 2023 for the presence of microcystins and presence of nutrients (total nitrogen and total phosphorus) are summarized in Table 1.

Table 1: Kokalyane bent 2023. Results of analyzes for microcystins content and nutrients.

Sampling site/ Date of sampling	MYC-RR, YR, LR, µg L ⁻¹ LOD 0,1 µg L ⁻¹ LOQ 0,2 µg L ⁻¹	Total N, mg L ⁻¹ LOQ 0,5 mg L ⁻¹	Total P, mg L ⁻¹ LOQ 0,02 mg L ⁻¹
Kokalyane Bent 14.06.2023	< LOQ	0,86	0,04
Kokalyane Bent 19.07.2023	LR eqv ~ 0,2	1,62	0,04
Kokalyane Bent 22.08.2023	LR eqv ~ 0,2	1,75	0,05
Kokalyane Bent 12.09.2023	< LOQ	1,46	0,02
Kokalyane Bent 13.10.2023	< LOQ	0,73	0,02

In two of the five samples taken in 2023, trace amounts of MYC-LR equivalent (a compound with a spectrum similar to LR, but with a different retention time in the chromatogram than that of the three investigated MYC-RR, MYC-YR and MYC-LR). The described samples were taken in July and August 2023, and these samples are characterized by the highest concentration of total phosphorus among all the samples of the study.

The results of the analyzes of water samples from Kokalyane bent taken monthly during the warm seasons of 2024 for the presence of microcystins and presence of nutrients (total nitrogen and total phosphorus) are summarized in Table 2.

Table 2: Kokalyane bent 2024. Results of analyzes for microcystins content and nutrients.

Sampling site/ Date of sampling	MYC-RR, YR, LR, µg L ⁻¹ LOD 0,1 µg L ⁻¹ LOQ 0,2 µg L ⁻¹	Total N, mg L ⁻¹ LOQ 0,5 mg L ⁻¹	Total P, mg L ⁻¹ LOQ 0,02 mg L ⁻¹
Kokalyane Bent 25.06.2024	< LOQ	1,20	0,02
Kokalyane Bent 25.07.2024	< LOQ	1,01	0,02
Kokalyane Bent 23.08.2024	< LOQ	1,02	0,04
Kokalyane Bent 12.09.2024	< LOQ	0,58	0,04
Kokalyane Bent 18.10.2024	< LOQ	0,66	0,04

The results obtained for microcystin content (MYC-RR, MYC-YR and MYC-LR) from the present study show that no presence of microcystins was observed in the samples taken during the summer season of 2024.

Trace amounts of toxins correspond to the highest values found for total nitrogen (1,75 mg L⁻¹ and 1,62 mg L⁻¹ respectively).

Regarding total nitrogen content, the results obtained ranged from 0,73 to 1,75 mg L⁻¹. The total phosphorus concentrations obtained ranged from 0,02 to 0,05 mg L⁻¹.

Conclusions

The results of the studies on the presence of microcystins in the water of Kokalyane bent of the dynamics of toxins in 2023 and 2024 showed the presence of traces in two samples in 2023. Given the use of the water from the reservoir for drinking domestic purposes and the rapidly occurring changes in the climate and eutrophication, it is necessary to periodically examine the waters of Kokalyane bent in terms of the presence of cyanobacteria and toxins produced by them in the seasons and conditions suitable for blooming.

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