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Изследване на плодоотделянето и повредите по плодовете при инерционно въздействие

Investigation of fruit detachment and fruit damage in inertial impact

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РЕЗЮМЕ: Анализирани са факторите оказващи влияние на процеса плодоотделяне при инерционни въздействия върху домати. Формулирани са критерии за качество, определени са параметрите на процеса и интервалите на вариране. Проведен е многофакторен експеримент. Получените резултати са обработени по методите на регресионния анализ и са получени математичните модели на процеса. Извършена е оптимизация и са дадени препоръки за практиката.

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ABSTRACT: The factors influencing the process of fruit separation in the case of inertial effects on tomatoes were analyzed. Quality criteria are formulated, process parameters and variation intervals are defined. A multifactorial experiment was conducted. The obtained results were processed according to the methods of regression analysis and the mathematical models of the process were obtained. Optimization is performed and recommendations for practice are given.

УВОД

Плодоотделянето е най-съществената част от механизираното прибиране на домати за преработка [1,2,3]. То влияе най-силно върху качеството на получаваната доматиена продукция. В периодът на прибиране плодовете са подложени на множество въздействия, които несъмнено оказват влияние на качеството им. При плодоотделянето е необходимо въздействията да бъдат достатъчни за преодоляване на силата на връзката между плода и стъблото и същевременно да бъдат по-малки от тези, при които ще настъпи разрушаване на обвивката на плода и ще доведе продукцията в категорията с по-ниско качество. Тези специфични изисквания, към плодоотделителните механизми, са довели до налагането на инерционния принцип на плодоотделяне като най-удачен. Силите, които предизвикват откъсването на плодовете не са приложени външно, а възникват в самите плодове, поради което те не могат да причинят повреди върху плода. Повреди биха се получили ако при откъсването плодът срещне елемент от плодоотделителния механизъм. Въпреки, че теоретично разгледано силата, откъсваща плода, независимо от стойността ѝ и влиянието ѝ върху плодоотделянето, сама по себе си не предизвиква повреди. Повредите, причинени от инерционната сила са вследствие на нейното влияние върху други сили, които от своя страна причиняват промените в структурата на плодовете.

Всички тези особености показват противоречивата същност на разглеждания принцип. Това налага необходимостта от задълбочено изясняване на всичките елементи на процеса плодоотделяне.

МЕТОДИКА НА ИЗСЛЕДВАНЕТО

При това изследване ще бъде приложен принципът на дедукцията т.е. ще бъде разгледан процеса като цяло и след това неговите съставни елементи.

Върху плодоотделянето влияние оказват множество фактори. Тези фактори според същността им и мястото на проявяване могат да бъдат разделени на две основни групи (вътрешни и външни). Външните фактори не зависят от параметрите на системата. Тяхното влияние може да се отчита, но не и да се регулира. Те са свързани с подавания в системата материал за обработка. В случая те са биологични, технологични и технически.

Към биологичните фактори се причисляват всички свързани с биологичните обекти. В случая това са доматените растения и техните параметри [9,10]. - височина, широчина, стъблестост, едрина на плодовете, разположение на плодовете по растението, зависимост между едрината на плодовете и разположението им в растението, дължина на разклоненията на

стъблата и плододържките и най-важния за изследването - силата на откъсване. Несъмнено съществуват и други, но те не са съществени за настоящото изследване.

Технологичните са свързани с технологията на отглеждане и прибиране [4,5]. Тук могат да се включат факторите: срок за прибиране, състояние на посева, заплевеленост и други.

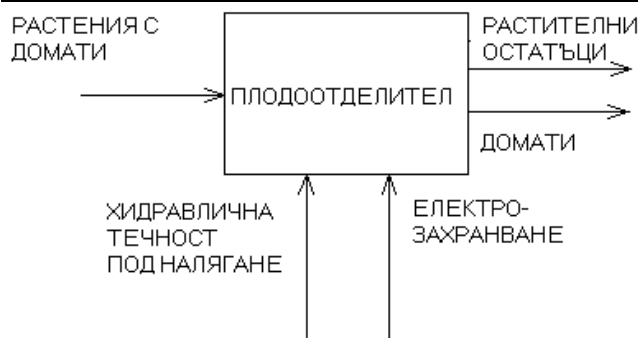
Технически са всички фактори, които свързват плодоотделителя с другите елементи на доματοкомбайна. Към тях спадат захранването с хидравлична течност, електрозахранването, окачването на плодоотделителя към рамата на машината, възможностите за промяна на разположението му и др.

За настоящото изследване интерес представлява втората група фактори. Те зависят от самата система на плодоотделяне и определят работата ѝ. Всички хидравлични елементи и техните характеристики са към хидравличните фактори, елементите на електронното табло и сигналите, които то генерира са електрически. И както при всяка система и тук са важни силовите взаимодействия, които определят силовите фактори.

Принципна схема на моделът на плодоотделянето

Разгледаното множество фактори, които оказват влияние върху процеса, създават значителни трудности при експерименталното изследване на всички възможни варианти. Тази трудност би могла да се избегне чрез построяване на модел на инерционния плодоотделител, който да обвързва всички съществени фактори. По този начин може да се изследва сравнително лесно как всеки фактор въздейства и неговата степен на значимост.

Плодоотделителният процес може да се разглежда по отношение на протичането на отделните съставни етапи във времето, но това е крайно недостатъчно за описание и изясняване на влиянието на всички елементи. Ползва се схемата на кибернетичния подход, при който процесът се нарича принцип на черната кутия и не се взема под внимание структурата и физическата същност на всички съставни етапи на плодоотделянето. Тук се взема предвид цялата налична информация за всички входни фактори и функциите на тяхната промяна. Това се нарича принцип на бялата кутия. Тук се съчетават предимствата на кибернетичния подход и теоретичния анализ. За целта се изхожда от цялостната схема на плодоотделянето, която се съставя по следния начин: плодоотделителят се поставя в центъра, като най-съществен елемент (фиг.1). Входни елементи са доматените растения, а изходни елементи са доматиите и растителните остатъци. Енергетични източници са хидравличната течност под налягане и електрозахранването.



фиг.1. Схема на взаимодействието: фактори и параметри - плодотделител

Тук са разгледани основно вътрешните за системата фактори и външните, които оказват влияние върху тях. Това са всички части на плодотделителя. В случая плодотделителят е разгледан в широк смисъл. Имат се предвид не само транспортните ленти, които предават вибрации на растенията, но и всички механизми, осъществяващи задвижването. Съществени са и характеристиките на движението на подаваната маса върху плодотделителния транспортър, подаването на хидравличната течност и режимът на работа на електронното устройство, генериращо импулсите за режима. Всички изброени съставни компоненти са подробно разгледани теоретично и анализиран за получаването на информация относно тяхното влияние.

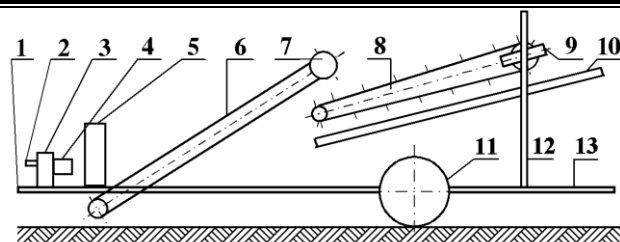
Изследването е проведено по опитна уредба, управляеми фактори и параметри на процеса описана в предходни публикации (Мортев, 2024). Опитите са проведени със сорт Топаз.

Опитна уредба за провеждане на изследването

Изследването на плодотделянето в процес на работа на доματοкомбайн води до недостатъчно точни резултати поради големия брой случайни фактори, оказващи влияние на изследването. За да се избегнат множеството от тях, в ИПАЗР „Н.Пушкаргов“ е изработен стенд с възможности за работа в лабораторни и в полски условия (фиг. 2). Основните елементи на стенда са: захранващ прътов транспортър 6 и плодотделител 8 – инерционен тип, монтирани върху полуприкачно двуколесно шаси, състоящо се от рама 13 и ходови колела 11. В предната част на рамата е монтиран теглич 1, за да може стендът да се придвижва до съответния опитен участък с помощта на трактор. В процеса на изследването стендът е стационарен.

При изследвания на полето е предвидена възможност задвижването да се осъществява чрез трактор. Хидравличните помпи 3 и 4 приемат въртливо движение от вала за отнемане на мощност от трактора. Вала за отнемане на мощност от трактора посредством карданен вал се прикрепва към входящия вал 2 на редуктора 3. Той задвижва сдвоената хидравлична помпа 4. Тя захранва хидромотора 7 и задвижващия блок на плодотделителя 9. Възвратно постъпателното движение на веригите се осъществява от блока 9, от хидроразпределител с електромагнитни превключватели и хидроаккумулятори. Режимите на работа се задават от електронен блок, чрез който могат да се променят честотите и амплитудите на колебанията. На рамата са монтирани резервоари за масло 5, филтри, изравнителни цилиндри и други помощни средства.

Електрическата управляваща система на стенда се захранва от акумулаторна батерия. При лабораторните експерименти е предвидено зареждане на акумулаторната батерия от токоизправител, което се налага от голямата консумация на електроенергия от електромагнитните превключватели.



Фиг. 2. Схема на стенд за изследване на инерционен плодотделителен процес:

1 – теглич; 2 – входящ вал на редуктора; 3, 4 – сдвоена хидравлична помпа; 5 – резервоари; 6 – захранващ прътов транспортър; 7 – хидромотор; 8 – плодотделител, 9 – задвижващ блок; 10 – секторна скара; 11 – ходови колела; 12 – регулиращ механизъм за ъгъла на наклона на плодотделителя; 8, 13 – рама.

Определяне на измерваните параметри

Смисълът на земеделското производство е получаването на максимални количества качествена продукция при минимални загуби. При производството на домати по механизирана технология е важно да се отделят плодовете от стъблата, за да се намалят загубите от неоткъснати плодове и същевременно да не се получават повреди, които влошават качеството. Във връзка с това са дефинирани два изследвани параметри:

Y_1 – степен на плодотделяне;

Y_2 – повреди по плодовете.

Стойността на параметъра степен на плодотделяне Y_1 се изчислява по формулата:

$$Y_1 = \frac{M_o}{M_p} \cdot 100[\%], \quad (1)$$

където: M_o – е масата на отделените от растението плодове, kg;

M_p – маса на всички плодове в растението, kg.

Стойността на параметъра повреди се изчислява по формулата:

$$Y_2 = \frac{M_{II}}{M_p} \cdot 100[\%],$$

(2)

където: M_{II} – е масата на повредените плодове, kg.

Определяне на управляемите фактори

Върху плодотделянето оказват влияние множество фактори – технически, биологични и технологични. Техническите са свързани с режимите на работа и конструктивните размери на плодотделителя. Биологичните характеризират състоянието на масата. Технологичните определят нивото на реализираната агротехника при производството.

На база на априорна информация [6, 7, 8] и предварителни изследвания за най-съществени са определени факторите:

- $X_1 (f)$ – честота на импулсите, Hz;

- $X_2 (k)$ – коефициент на запълване на импулсите;

- $X_3 (\beta)$ – ъгъл на наклона, под който се намира плодотделителя спрямо хоризонталната равнина, °.

Факторите $X_1 (f)$ и $X_2 (k)$ определят режима на плодотделителя 8 те се задават посредством електронен блок. Той генерира импулси за управление на електрическите превключватели на хидравличния разпределител. Фактора честота на импулсите (f) представлява реципрочната стойност на интервала от време, през който се подават импулсите за един цикъл. Фактора коефициент на запълване на импулсите

се определя като отношение между хода напред t_{II} и общата продължителност на цикъла t_{II} .

$$k = \frac{t_{II}}{t_{II}}$$

Това съотношение показва, през каква част от работния цикъл постъпилата за обработване растителна маса се придвижва върху транспортъра в посока напред.

Интервалите на изменение на управляемите фактори са определени с предварителни еднофакторни експерименти. Въз основа на тези експерименти са установени следните интервали:

- за X_1 – от 2,00 до 3,33 Hz;
- за X_2 – от 0,28 до 0,56;
- за X_3 – от 0 до 13°.

След определянето на параметрите, чието поведение се наблюдава, е необходимо задълбочено анализиране и избиране на факторите, оказващи влияние върху съответния параметър. Едно от основните изисквания към факторите на активния експеримент е да бъдат управляеми, т.е. да е възможно тяхното поддържане на дадено ниво с определена точност през цялото време на опита. Освен това е необходимо факторите да бъдат съвместими и независими.

Стойностите на факторите трябва да се изменят с колкото е възможно по голяма точност. Тази точност трябва да бъде съобразена с интервала на изменение на факторите, при малък интервал е необходима голяма точност и обратно.

Инерционният плодотделителен механизъм работи съобразно технологичните, техническите и режимните параметри, които му се подават или са предварително зададени. Най-съществени от тях са характеристиките на режима и ъгълът на наклона, под който се намира плодотделителя. От характеристиките на режима най-важните са честотата на импулсите и коефициентът на запълване на импулсите. Приети са следните означения:

Определяне на характеристиките на режима

Характеристиките на режима на плодотделителния транспортър се променят посредством електронно табло. То генерира импулси за командване на хидравличния разпределител. Импулсите командват два електрически превключвателя на разпределителя. Единият е за движение напред, а другия за движение назад. Върху предния панел на таблото са изведени два потенциометъра за промяна на характеристиките на подаваните импулси. Чрез единия се

променя честотата на подаваните импулси в интервала 1,25 – 3,33 Hz.

От стойността на тази величина зависи продължителността на един работен цикъл. Чрез вторият потенциометър се командва съотношението между хода напред и общата продължителност на цикъла. Това съотношение изразява каква част от работния цикъл постъпилата за обработване растителна маса се придвижва върху транспортъра в посока напред. От него в най-голяма степен зависи производителността на плодотделителя.

Тези два параметъра на режима са определени като регулатори на управляемите фактори в планирания трифакторен експеримент.

Планиране на експеримента

Опитите са проведени по план B_3 в еднократна повтораемост. Дисперсията на възпроизводимост е определена чрез петкратно повторение на опит в центъра на плана, при предпоставка за еднакво разсейване във всички точки от плана.

В резултат на предварителните опити и анализа на изследваните обекти, избрания брой фактори и нивата на тяхното вариране е съставена работна матрица на плана, в която са включени натуралните и кодираните стойности на факторите таблица 1.

РЕЗУЛТАТИ И АНАЛИЗ

За установяване нивата на вариране на управляемите фактори, преди провеждането на планирания многофакторен експеримент са проведени предварителни еднофакторни експерименти. От тях е установено, че процесът на плодотделянето при работа с доматокормбайн протича стабилно при f – честота на импулсите от 2,00 до 3,33 Hz; k – коефициент на запълване на импулсите от 0,28 до 0,56 и β – ъгъл на наклона от 0 до 13°.

За изследване на съвместното влияние на управляемите фактори върху параметрите Y_1 – Y_2 е проведен активен трифакторен експеримент по план B_3 , включващ 14 опита. Опитите са проведени по описаната методика, като получените резултати са показани в табл. 1.

Таблица 1. План на експеримента и получени резултати

№	План на Експеримента						Стойности на изследваните параметри	
	В кодиран			В натурален			Степен на плодо-отделяне	Повреди по плодовете
	вид			Вид				
	X_1	X_2	X_3	X_1 Hz	X_2	X_3 °	Y_1	Y_2
1	1	1	1	3,33	0,56	13	82.99	0,50
2	-1	1	1	2,00	0,56	13	80.05	0,50
3	1	-1	1	3,33	0,28	13	66.17	0,00
4	-1	-1	1	2,00	0,28	13	70.29	2,25
5	1	1	-1	3,33	0,56	0	82.50	2,12
6	-1	1	-1	2,00	0,56	0	54.05	1,93
7	1	-1	-1	3,33	0,28	0	63.90	0,50
8	-1	-1	-1	2,00	0,28	0	41.00	0,50
9	1	0	0	3,33	0,42	6	42.00	0,50
10	-1	0	0	2,00	0,42	6	88.92	0,50
11	0	1	0	2,66	0,56	6	75.46	0,50
12	0	-1	0	2,66	0,28	6	99.53	1,03
13	0	0	1	2,66	0,42	13	65.46	0,50
14	0	0	-1	2,66	0,42	0	79.22	1,03

Проверка на значимостта на факторите

Степента на влияние на управляемите фактори се определя с помощта на разработената за целта програма в среда на Microsoft Excel. Проверката е проведена като всеки от управляемите фактори се фиксира на основното ниво и се определя остатъчната дисперсия. Сравняват се получените

остатъчни дисперсии и факторът, показал най-ниски стойности се определя като най-слабо влияещ.

Установено е, че разликите в степента на влияние не е съществена (таблица 2). Този резултат определи нуждата да се анализират фиксирания нива на всички включени в изследването фактори.

Получените експериментални резултати са обработени по методите на регресионния анализ и са изведени регресионни уравнения, описващи взаимодействието на изучаваните управляеми фактори върху изследваните параметри. Извършената проверка за адекватност показва, че те описват с достатъчна точност изследвания процес.

за степента на плодоотделяне:

$$Y_{\text{ТОПАЗ}} = 78.84 + 0.33x_1 + 3.42x_2 + 4.43x_3 + 1.58x_1x_2 - 6.57x_1x_3 - 0.637x_2x_3 - 13.38x_1^2 + 8.66x_2^2 - 6.5x_3^2 \quad \text{за повреди по плодовете:}$$

$$Y_{1\text{ТОПАЗ}} = 0.5 - 0.21x_1 + 0.13x_2 - 0.23x_3 + 0.31x_1x_2 - 0.31x_1x_3 - 0.54x_2x_3 - 0.01x_1^2 + 0.27x_2^2 + 0.27x_3^2 \quad \text{където:}$$

X_1 – са кодираны стойности на честота на импулсите подавани към хидравличния разпределител;

X_2 – кодираны стойности на коефициента на запълване на импулсите;

X_3 – кодираны стойности на ъгъла на наклона на плодоотделителния транспортър.

Резултати от проверките за адекватност на регресионния модел.

При заместване на опитните резултати в описаните от методиката формули са получени следните стойности на критерия на Фишер:

- адекватност на модела на плодоотделянето

$$F_{\text{изч}} = 8.36 < F_{0.05; k_1; k_2} = 19.35$$

- адекватност на модела повредите на плодовете

$$F_{\text{изч}} = 0.09 < F_{0.05; k_1; k_2} = 19.35$$

За изследвания сорт получената изчислена стойност за F -критерия е по-малка от табличната при определеното равнище на значимост и съответния брой на степените на свобода. Следователно може да се констатира адекватност на регресионните модели.

След проверка на значимостта на коефициентите и изключване на незначимите по описаната в методиката схема се получават следните уравнения:

• степен на плодотоделяне

$$Y_{\text{ТОПАЗ}} = 78.84 + 4.43x_3 - 0.63x_2x_3 - 13.38x_1^2 + 8.66x_2^2 - 6.5x_3^2$$

• степен на повреди по плодовете

$$Y_{1\text{ТОПАЗ}} = 0.5 + 0.01x_1^2 + 0.27x_2^2 + 0.27x_3^2$$

Резултати от оптимизацията на регресионните модели

Оптимизацията е извършена с помощта на разработена за целта програма в среда на Mathcad 2001 Professional. Получените оптимални стойности на кодираните и натурални стойности на факторите са представени в таблица 3.

Таблица 2. Стойности на остатъчните дисперсии при фиксирани фактори на основните нива

СОРТ	Остатъчни дисперсии $S_{\text{ост}}^2$		
	X_1	X_2	X_3
Плодоотделяне	69018	66997	68383
Повреди	19.67	19.14	19.14

Таблица 3 Кодирани и натурални стойности на оптимизирани фактори

Целеви параметри Y_i	Екстремална стойност на целевите параметър	Оптимални стойности на факторите					
		В кодиран вид			В натурален вид		
		X_1	X_2	X_3	X_1 Hz	X_2	X_3 °
$Y_1 - \max$	91.47	0	1	0.29	2.66	0.56	8.35
$Y_2 - \min$	0,01	1	0.197	1	3.33	0.49	12.95

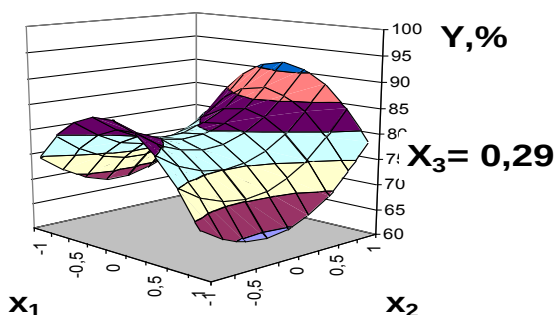
Графична интерпретация и анализ на резултатите на плодоотделянето.

За графичната интерпретация на опитните данни е фиксиран един фактор и са построени повърхнините на отклика при изменение на другите два.

Резултати, получени при фиксирането на фактора X_3

Получените графични зависимости показват значителни различия в повърхнините и характера на влияние на управляемите фактори.

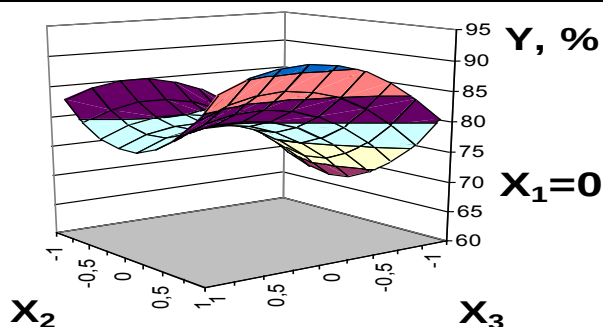
Изследваният сорт Топаз (фиг. 3) проявява различно поведение спрямо предходни изследвания [8]. При него повърхнината на отклика се характеризира с голям размах, което предполага, по-голямата чувствителност на плодоотделянето от стойностите на управляемите фактори. Това определя сорта Топаз като по-малко пригоден за механизано прибиране. Препоръчва се ограничено приложение при механизана технология на прибиране, тъй като са възможни повече загуби от неотделени плодове.



Фиг. 3. Плодоотделяне при сорта Топаз при ъгъл на наклона на плодоотделителя $\beta = 13^\circ$ в зависимост от честотата на импулсите X_1 и коефициента на запълване на импулсите X_2

Резултати, получени при фиксиране на фактора X_1

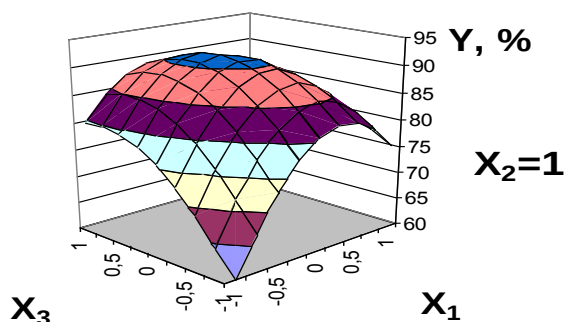
Факторът X_3 оказва точно противоположните характеристики на повърхнината в сравнение с фактора X_2 (Фиг. 4).



Фиг. 4. Плодоотделяне при сорта Топаз при честотата на импулсите $f = 2.66\text{Hz}$ в зависимост от ъгъла на наклона на плодоотделителя X_3 и коефициента на запълване на импулсите X_2

Това съвместно влияние на двата фактора определя седловидни повърхнини, които могат да се опишат на хиперboloиди по фактора X_2 . Седловината е сравнително симетрична по отношение на координатните оси. Изместването се дължи на разликите в екстремалните точки спрямо двата фактора. При долното ниво на фактора X_3 повърхнината се спуска с увеличаване на X_2 , а след основното ниво – обратно.

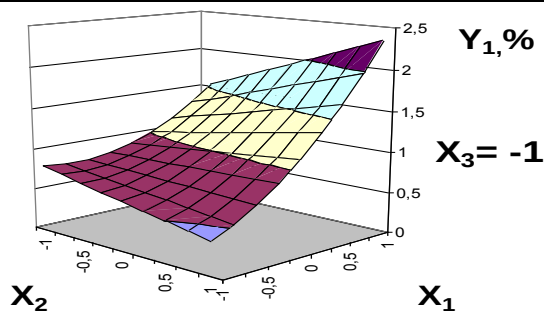
Резултати получени при фиксиране на фактора X_2



Фиг. 5. Плодоотделяне при сорта Топаз при коефициента на запълване на импулсите $k = 0.56$ в зависимост от честотата на импулсите X_1 и ъгъла на наклона на плодоотделителя X_3

При фиксирано ниво на фактора X_2 седловидния характер на повърхнината вече се измества в изпъкнала. При това тази изпъкналост е силно изразена спрямо двата фактора. (фиг. 5) Това се дължи на големия толеранс в силите на задържане на плода, а от там и голямата зависимост от параметрите на режима. При неправилен режим на работа на доматокосача изследваният сорт Топаз показва незадоволителни резултати, процентът на толеранса достига 60.

Графична интерпретация и анализ на резултатите от повредите по плодовете при фиксирането на фактора X_3

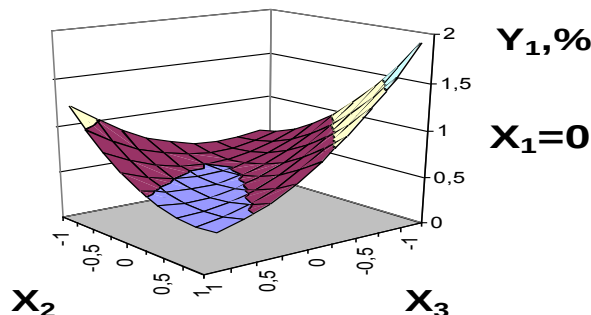


Фиг. 6. Повреди при ъгъл на наклона на плодоотделителя $\beta=0^\circ$, в зависимост от честотата на импулсите X_1 и коефициента на запълване на импулсите X_2

В долното ниво на X_3 , повредите се увеличават при увеличаването на фактора X_1 при всички нива на X_2 . Фиксираното средно ниво представя запазване на тази тенденция при горното ниво на X_2 , а в долното се променя противоположно. При фиксирано горно ниво на X_3 се получават обратните характеристики или при всички нива на X_2 с увеличаването на фактора X_1 повредите намаляват.

Резултати от повредите по плодовете получени след фиксиране на фактора X_1

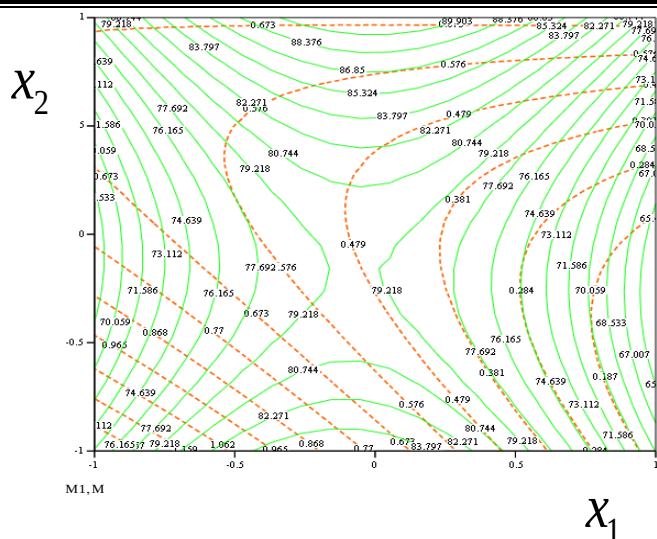
Повредите са минимални при горните нива на ъгъла на наклона на плодоотделителя X_3 (фиг. 7) и на коефициента на запълване на импулсите X_2



Фиг. 7. Повреди върху плодовете при честотата на импулсите $f = 2.66\text{Hz}$, в зависимост от ъгъла на наклона на плодоотделителя X_3 и коефициента на запълване на импулсите X_2

Линии на еднакъв отклик на плодоотделянето и повредите

Сортът Топаз бе определен като не най-подходящ за механизизирано прибиране, но при подбор на подходящи режими на работа избрани от фиг. 6. могат да се получат добри резултати. Фиг. 8 дава нагледна информация за тенденциите на двата оптимизационни параметъра за сорта Топаз. Значимостта на увеличените повреди е несъществена и може да се счита, че оптималната зона на плодоотделянето е оптимална за процеса.



фиг. 8 Линии на еднакъв отклик за параметрите плодотделяне Y_1 - и степен на повреждане на плодовете Y_1 - за сорта Топаз при фиксирано ниво на ъгъла на наклона на плодотделителя на ниво 0,29 при изменение на честотата на импулсите X_1 и коефициента на запълване на импулсите X_2

Изследванията на плодотделянето и повредите по плодовете показват, че повредите като числени стойности са незначителни и не се влияят толкова съществено от режима на работа, както плодотделянето. Едно обобщено представяне дава възможност да се проследи тенденцията на плодотделянето и същевременно промените в повредите по плодовете. За постигане на тази цел е представена графична интерпретация в среда на Mathcad. Съвместно представяне в равнина е възможно да бъде осъществено чрез установяване на един от факторите на фиксирано ниво и построяване на линиите на еднакъв отклик. За определянето на фактора с фиксирано ниво са анализирани оптималните стойности на всички фактори за двата изследвани параметъра и е определен факторът, който и при двата параметъра на оптимизация получава еднакви или близки стойности. След това той се фиксира на така определеното ниво и се съставя регресионното уравнение. Изчертават се линиите на еднакъв отклик в една и съща равнинна координатна система.

На фиг. 8 са показани линиите на еднакъв отклик. Тези линии имат важно практическо значение, защото спомагат за избор на различни стойности на управляемите фактори X_1 и X_2 за постигане на определени резултати.

Например, при икономическия анализ на производството може да се окаже, че е по-изгодно да се повреди малка част от продукцията отколкото да остане неприбрана на полето. Когато се налага вземане на такова управленско решение може да се изберат варианти от линиите на еднакъв отклик (фиг. 8) и да се избере режим на работа на доματοкомбайна.

ИЗВОДИ

1. Сортовите особености влияят съществено върху плодотделителния процес. Това се определя както от големите различия в стойностите на откъсващата сила, така и от другите свойства на доматените растения, характерни за дадения сорт. Изследвания сорт не показва добри резултати но при правилно подбран режим на работа на механизмите може да се прилага.
2. Оптималните стойности на плодотделянето Y_1 е 91.47 % и се постига при честотата на импулсите в долните нива на

вариране 2.66 Hz, коефициент на запълване на импулсите 0.56, и ъгъл на наклона на плодотделителния транспортър 8.35°.

3. При плодотделителния процес сортовите особености не влияят съществено върху повредите по плодовете, могат да бъдат сведени до практически незначими стойности. Това се определя от въздействията, прилагани върху растителната маса, които са едни и същи, независимо свойствата на доматените растения, характерни за дадения сорт. Оптималните стойности на повредите Y_1 0.01 % се получават при честотата на импулсите в горните нива на вариране 3.33 Hz, коефициентът на запълване на импулсите - между основното и горното ниво 0.49, и ъгъл на наклона на плодотделителния транспортър 12.95°.

4. Линиите на еднакъв отклик (фиг. 8) дават възможност да се изберат варианти за режим на работа на доματοкомбайна. Тези линии имат важно практическо значение, защото спомагат за избор на различни стойности на управляемите фактори X_1 и X_2 за постигане на определени резултати.

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Differential equations of motion of table beet root crop of round shape on the surface of a spiral separator

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Abstract. An actual problem in the technological process of table beet production is the cleaning of root crops from adhered soil, soil impurities and plant residues after digging them out of the soil. In this paper we have constructed a mathematical model of table beet root crop movement along the working channel of the new construction of the spiral separator developed by us, because at such movement just the cleaning of root crops from these impurities takes place. On the basis of the equivalent scheme developed in this article, a system of differential equations of motion of table beet root crop along the surface of the working channel of the spiral separator is drawn up. The solution of the obtained system of differential equations on the PC makes it possible to investigate the influence of constructive and kinematic parameters of the separator on the speed of movement of the root crop in the working channel before its descent from the spirals. Thus determined constructive and kinematic parameters will provide improvement of the quality of cleaning of table beet root crops from soil impurities and plant residues.

KEYWORDS: TABLE BEET, ROOT CROP, SPIRAL SEPARATOR, EQUIVALENT SCHEME, DIFFERENTIAL EQUATIONS, MATHEMATICAL MODEL, DESIGN AND KINEMATIC PARAMETERS.

1. Introduction

At the time of table beet harvesting, its haulm is in a lodged state. Therefore, the harvesting technology is a continuous cutting of the haulm and further digging of root crops, which requires their cleaning from loose and sticky soil, as well as plant residues. It should be noted that a number of works [1-6] are devoted to the cleaning of potato roots and tubers immediately after digging them out of the soil. This stage should ensure high quality of harvesting with minimal damage to root crops, which makes it possible to store them for a long time.

The most suitable cleaner of table beet root crops from the specified impurities can be a spiral separator. For this purpose, a spiral separator can be used as a prototype [7, 8]. Experimental studies have shown that this separator provides a sufficiently high level of cleaning with minimal damage to root crops, which are within the agrotechnical requirements. However, table beet harvesting takes place in conditions different from potato harvesting. In addition, there is a difference and technological material. Therefore, there is a need to change the technical and technological characteristics of the above-mentioned separator [9].

For this purpose, we have developed a new construction of spiral separator of table beet root crops, which has significant advantages over existing separators.

However, to determine the rational construction and kinematic parameters of our proposed construction of the separator it is necessary to conduct a number of theoretical and experimental studies of the interaction of table beet roots with the working bodies of the separator. Such studies of the spiral separator for potato peeling are presented in [10, 11]. For this purpose, we will make differential equations of motion of table beet root crop along the working bodies (spiral springs) of the mentioned separator. In this regard, it should be noted that the most common form of table beet root is round, i.e. in the form of a ball or slightly flattened along the vertical axis of the ellipsoid. Therefore, in the mathematical model, we will consider the movement of a spherical-shaped root crop.

The developed mathematical model will give an opportunity to carry out numerical modeling with the use of PC, i.e. machine experiment, as a result of which the considered process will be comprehensively studied and rational constructive and kinematic parameters of the separator will be theoretically determined taking into account the non-damage of table beet roots in the process of their cleaning.

2. Results and discussions

To build the mentioned mathematical model, let us consider one of the most probable variants of the root crop location in the working channel of the spiral separator. This is the case when the table beet root crop is located on the lower spiral 1, and its lower part is between two neighboring turns of the mentioned spiral, thus contacting its surface at two points K_1 and K_2 (Fig. 1). The rotation

of the spiral 1 causes the root crop to move in said working channel in a longitudinal axial direction before descending from said spiral.

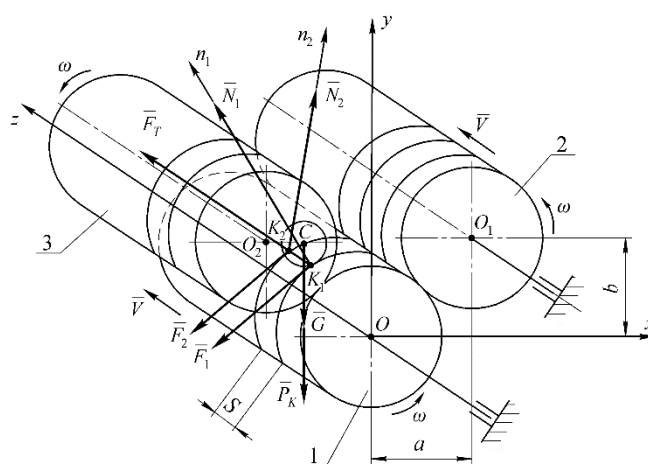


Figure 1. Equivalent scheme of interaction of table beet root crop with turns of the separator cleaning spirals

More precisely, turns of spiral 1 at the points of contact K_1 and K_2 with the root crop at rotation of spirals will slip on its surface, thus involving the root crop in translational motion along the working channel before coming off this channel at the free end of the spiral. In this case, the cleaning of root crops from free soil and plant residues will be carried out by separating impurities through the interscroll space of spiral springs, due to transverse oscillations of cantilever springs in the vertical plane. However, the main movement of the root crop will be its translational movement along the longitudinal axes of the spirals, due to which the pile will be transported along the working surface of the separator. Therefore, it is necessary to theoretically investigate the process of root crop movement along the longitudinal axis of the spiral.

To make differential equations of root crop motion along the longitudinal axis of the spiral, it is necessary to develop an equivalent scheme of its interaction with the surfaces of the spiral turns at the contact points K_1 and K_2 (Fig. 1). As shown in the scheme, the lower part of the root crop is located in the depression between two neighboring turns of the spiral 1. Moreover, the first coil in the direction of movement of the root crop will be pushing and the second coil will be supporting.

As shown in the equivalent diagram, at each point of contact K_1 and K_2 act normal reactions and respectively.

The normal reactions $\bar{N}_1$ and $\bar{N}_2$ are directed along the normals to the surface of the corresponding turns at the contact points K_1 and K_2 . The direction of action of the normal reactions is formed by the turns of the helix, the geometrical properties of which are described by the equations of the helical line of the said helix. The mentioned equations of the helical line of the spiral serve as coupling equations, which specify geometrical properties of the

trajectory of movement of the contact points K_1 and K_2 as they move along the turns of the spiral.

At the center of mass of the root crop (point C) is applied its gravity. In addition to the already mentioned forces, the equivalent diagram shows friction forces $\bar{F}_1$ and $\bar{F}_2$, applied at the corresponding contact points K_1 and K_2 . These forces arise from the slippage of the turns of the spiral 1 on the surface of the root crop. They are directed in the direction of rotation of the spiral along the tangents to the surface of the coils at the points of contact with the surface of the root crop.

In addition, to ensure the movement of the root crop in the direction of the longitudinal axis of the spiral 1 there is a driving force $\bar{F}_T$, applied at the point of contact K_1 . This force is directed parallel to the longitudinal axis of the spiral in the direction of movement of the root crop in the working channel.

The equivalent diagram also shows the active force of the crop fed to the spiral separator, which causes the spirals to bend and, because of its variable value due to the change in the mass of the crop fed, causes transverse oscillations of the spirals. It is directed vertically downwards.

To compose the differential equations of motion of table beet root crop in the working channel, we choose a fixed spatial Cartesian coordinate system $xOyz$, the origin of which (point O) is located on the longitudinal axis of the spiral 1, axis Oz coincides with the longitudinal axis of spiral 1, axis Oy is directed vertically upwards, axis Ox is directed to the right, perpendicular to the plane Oyz , and axes Ox and Oy are located in the plane of the cross-section of spiral 1 (Fig. 1).

Taking into account the scheme of forces shown in the equivalent diagram, using the basic law of dynamics of a material point, let us write down the equation of motion of the table beet root in vector form:

$$m \cdot \bar{a} = \bar{G} + \bar{N}_1 + \bar{N}_2 + \bar{F}_1 + \bar{F}_2 + \bar{F}_T + \bar{P}_K, \quad (1)$$

where $\bar{a}$ – is the acceleration of the table beet root along the working channel under the action of the forces indicated in the diagram.

Let's write further vector equation (1) in projections on axes of Cartesian coordinate system $xOyz$:

$$\left. \begin{aligned} m \cdot \ddot{x} &= N_1 \cdot \cos(x, \bar{n}_1) + N_2 \cdot \cos(x, \bar{n}_2) - \\ &- F_1 \cdot \cos(x, \bar{V}_1) - F_2 \cdot \cos(x, \bar{V}_2), \\ m \cdot \ddot{y} &= N_1 \cdot \cos(y, \bar{n}_1) + N_2 \cdot \cos(y, \bar{n}_2) - \\ &- F_1 \cdot \cos(y, \bar{V}_1) - F_2 \cdot \cos(y, \bar{V}_2) - G - P_K, \\ m \cdot \ddot{z} &= N_1 \cdot \cos(z, \bar{n}_1) + N_2 \cdot \cos(z, \bar{n}_2) - \\ &- F_1 \cdot \cos(z, \bar{V}_1) - F_2 \cdot \cos(z, \bar{V}_2) + F_T, \end{aligned} \right\} \quad (2)$$

where $\bar{n}_1$ and $\bar{n}_2$ – normal to the surface of the spiral turns at the contact points K_1 and K_2 , respectively; $\bar{V}_1$ and $\bar{V}_2$ – velocity vectors of relative movement of the table beet root along the spiral turns at the contact points K_1 and K_2 , which are directed along the tangent to the spiral surface in the direction opposite to the circumferential velocity of the turn at the contact points K_1 and K_2 , respectively.

Further, we define the directional cosines of the angles included in the system of differential equations (2).

The directional cosines of the angles between the axes of the $xOyz$ coordinate system and the direction of the normals to the surface of the coils at the contact points K_1 and K_2 are determined according to [12], which are conveniently represented in parametric form. For this purpose, the parametric equations of the helical line [13] are used.

As a result, we obtain the values of the directional cosines of the angles between the coordinate axes Ox , Oy and Oz and the normal reactions of the spiral turns at the contact points K_1 and K_2 in parametric form:

$$\begin{aligned} \cos(x, \bar{n}_1) &= \cos(x, \bar{n}_2) = \\ &= (L \cdot \sin \omega t + M \cdot \cos \omega t \cdot \sin 2\omega t) \times \\ &\times \left(\sqrt{L^2 + (2ML + M^2) \cdot \sin^2 2\omega t + Q^2 \cos^2 2\omega t} \right)^{-1}, \end{aligned} \quad (3)$$

$$\begin{aligned} \cos(y, \bar{n}_1) &= \cos(y, \bar{n}_2) = \\ &= (L \cdot \cos \omega t + M \cdot \sin \omega t \cdot \sin 2\omega t) \times \\ &\times \left(\sqrt{L^2 + (2ML + M^2) \cdot \sin^2 2\omega t + Q^2 \cos^2 2\omega t} \right)^{-1}, \end{aligned} \quad (4)$$

$$\begin{aligned} \cos(z, \bar{n}_1) &= -\cos(z, \bar{n}_2) = \\ &= Q \cos 2\omega t \cdot \left(\sqrt{L^2 + (2ML + M^2) \cdot \sin^2 2\omega t + Q^2 \cos^2 2\omega t} \right)^{-1}. \end{aligned} \quad (5)$$

Where

$$L = -\frac{S^2}{4\pi^2 R} \cdot \cos\left(\frac{S}{2\pi R}\right), \quad (6)$$

$$M = \frac{S^2}{4\pi^2 R} \cdot \cos\left(\frac{S}{2\pi R}\right) - \frac{S^3}{8\pi^3 R^2} \cdot \sin\left(\frac{S}{2\pi R}\right), \quad (7)$$

$$Q = \frac{S}{2\pi} \cdot \cos\left(\frac{S}{2\pi R}\right), \quad (8)$$

where R – is the radius of the helix, S is the pitch of the helical line, ω is the angular velocity of the helix.

Let us further determine the directional cosines of the friction forces.

This is reduced to the determination of the cosines of the angles between the vectors of relative velocities of movement of the root crop along the turns of the spirals at the contact points K_1 and K_2 , and the coordinate axes Ox , Oy and Oz , i. e. $\cos(x, \bar{V}_1)$, $\cos(y, \bar{V}_1)$ and $\cos(z, \bar{V}_1)$, ($i = 1, 2$).

It should be taken into account that vectors $\bar{V}_1$ and $\bar{V}_2$ are collinear. Therefore, the following equations hold:

$$\begin{aligned} \cos(x, \bar{V}_2) &= \cos(x, \bar{V}_1), \\ \cos(y, \bar{V}_2) &= \cos(y, \bar{V}_1), \\ \cos(z, \bar{V}_2) &= \cos(z, \bar{V}_1). \end{aligned} \quad (9)$$

The directional cosines $\cos(x, \bar{V}_i)$, $\cos(y, \bar{V}_i)$ and $\cos(z, \bar{V}_i)$, ($i = 1, 2$), in the Cartesian coordinate system can be found according to [12] and represented parametrically using the parametric equations of the helical line [13]. As a result, we obtain:

$$\cos(x, \bar{V}_2) = \cos(x, \bar{V}_1) = \frac{2\pi R \cdot \sin \omega t}{\sqrt{4\pi^2 R^2 + S^2}}, \quad (10)$$

$$\cos(y, \bar{V}_2) = \cos(y, \bar{V}_1) = -\frac{2\pi R \cdot \cos \omega t}{\sqrt{4\pi^2 R^2 + S^2}}, \quad (11)$$

$$\cos(z, \bar{V}_2) = \cos(z, \bar{V}_1) = \frac{S}{\sqrt{4\pi^2 R^2 + S^2}}. \quad (12)$$

Substituting expressions (3) – (5) and (10) – (12) into the system of differential equations (2), after a number of transformations we obtain the following system of differential equations in parametric form:

$$\left. \begin{aligned}
 m \cdot \ddot{x} &= (N_1 + N_2) \cdot (L \cdot \sin \omega t + M \cdot \cos \omega t \cdot \sin 2\omega t) \times \\
 &\times \left(\sqrt{L^2 + (2ML + M^2) \cdot \sin^2 2\omega t + Q^2 \cos^2 2\omega t} \right)^{-1} - \\
 &- (F_1 + F_2) \cdot \frac{2\pi R \cdot \sin \omega t}{\sqrt{4\pi^2 R^2 + S^2}}, \\
 m \cdot \ddot{y} &= (N_1 + N_2) \cdot (L \cdot \cos \omega t + M \cdot \sin \omega t \cdot \sin 2\omega t) \times \\
 &\times \left(\sqrt{L^2 + (2ML + M^2) \cdot \sin^2 2\omega t + Q^2 \cos^2 2\omega t} \right)^{-1} + \\
 &+ (F_1 + F_2) \cdot \frac{2\pi R \cdot \cos \omega t}{\sqrt{4\pi^2 R^2 + S^2}} - mg - P_k, \\
 m \cdot \ddot{z} &= (N_1 - N_2) \cdot Q \cos 2\omega t \times \\
 &\times \left(\sqrt{L^2 + (2ML + M^2) \cdot \sin^2 2\omega t + Q^2 \cos^2 2\omega t} \right)^{-1} - \\
 &- (F_1 + F_2) \cdot \frac{S}{\sqrt{4\pi^2 R^2 + S^2}} + F_r.
 \end{aligned} \right\} \quad (13)$$

The system of differential equations (13) is a system of differential equations of motion of table beet root crop under the action of rotating spirals along the working channel formed by cantilever spiral springs, where the root crop is cleaned from soil impurities and plant residues.

As a result of twofold integration of the system (13) taking into account the initial conditions, it is possible to obtain the laws of movement of table beet root crop along the working channel of the spiral separator as functions of time t and values of its parameters.

3. Conclusion

1. The system of differential equations of motion of table beet root crop along the working channel of spiral separator is obtained, on the basis of which it is possible to determine rational design parameters and kinematic modes of operation of the mentioned separator by means of PC.

2. As a result of solving the system of differential equations on the PC will be obtained graphical dependencies of the influence of kinematic parameters of the separator on the speed of movement of root crops along its working channel.

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Determination of dynamic loads during operation of a flexible screw sectional working body

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Abstract. *The article presents the design of a flexible screw sectional working body that will improve the functional and operational characteristics of screw conveyors during the utilization of the removed contaminated soil layer. A mathematical model of the dynamic system of a flexible screw conveyor was created, and dynamic starting torques were calculated at the rated load of the loaded screw and when the system was braked. The analysis of the results shows that with significant damping coefficients, the startup transient process is smooth and the load reaches its nominal value without fluctuations in torque and speed.*

KEYWORDS: AGRICULTURAL SOILS, CONTAMINATION, FLEXIBLE SCREW CONVEYOR, SCREW.

1. Introduction

As a result of the military actions, Ukraine's soil resources are being significantly destroyed, their quality is deteriorating, and degradation processes are intensifying, with a number of mechanical, physical, and chemical impacts on the soil cover. Such impacts lead to the destruction of the structure and functions of the soil ecosystem and deterioration of physical and geochemical properties.

Enemy aircraft and artillery have the greatest impact on agricultural land and soil cover, accounting for about 80% of the impact. As a result of missile and artillery shelling, the fields are covered with craters (craters) from the explosions of shells, mines, and missiles. The craters are of different diameters and depths [1].

The depth of the craters in the fields ranges from 30 cm (82 mm mortar) to 5 m (cruise missiles), and the soil remaining at the impact site is turbulized, subject to dynamic compaction, and contains numerous metal fragments with residues of explosive toxic substances, i.e., deterioration of physical properties of soils, changes in particle size distribution, compaction and disintegration due to a decrease in the content of agronomically valuable fractions, etc.

Other important impacts on the soil cover are the consequences of explosions, detonations, or burning of heavy machinery on agricultural land. The results of the analysis of the soil particle size distribution showed that the content of physical clay decreased in places where heavy machinery burned and fuel and lubricants leaked [2].

Therefore, restoring and ensuring the conditions for preserving the fertility of agricultural soils in Ukraine that have been destroyed by military operations is a very acute, global and urgent problem for the entire agricultural sector, which has a state priority.

In order to restore areas damaged by explosions, it is necessary to remove or clean the surface layer of soil, since in addition to chemical contamination with heavy metals, the fertile soil layer also burns out, dehydration and "sterilization" occur, killing both pathogenic microorganisms and beneficial biota [1].

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

To dispose of 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.

Screw conveyors are used for transportation of various types of bulk agricultural materials, including: cereals, granular seed materials, clay, sand, loose soil, mixed fodder, mineral fertilizer granules, etc. From the analysis of the literature, it can be concluded that the least resource-intensive technology for moving bulk and lumpy agricultural materials along curved routes is the use of flexible screw conveyors, which are made on the basis of individual screw sections that are hinged to each other [3]. Works [4, 5] substantiate the structural, kinematic, and technological parameters of screw working bodies in terms of their functional purpose.

However, the existing flexible screw impellers cannot fully meet the operational requirements for these types of conveyors. The use of shaftless flexible screw spirals leads to their rapid destruction when conveyors operate on curved routes due to the occurrence of alternating cyclic loads. The design of the working body in the form of a solid or sectional shaft, on which individual elements of screw ribs are located, leads to a significant complication of the design of the technological body, an increase in its material consumption, which, accordingly, causes an increase in energy consumption, as well as damage to the transported materials.

Therefore, the task of developing new designs and substantiating the parameters of flexible screw conveyor working bodies that will improve the functional and operational performance of the process of utilizing the removed contaminated soil layer is relevant.

2. Results and discussions

To improve the performance of flexible screw conveyors, a design of a screw sectional working body was developed, which is shown in Fig. 1. It contains sections 1 of equal diameters and lengths, which are made in the form of welded structures of tubular blanks 2, to one conditional inner end of which a cylindrical sleeve 3 is rigidly fixed. The latter is made with a system of axial parallel grooves 4, which are placed evenly around the circumference, for example, four, and are parallel to the axis of the tubular blank and which are in interaction with rolling elements 5. On the other side, the rolling elements 5 are in contact with the spherical recess 6 of the spherical body 7 with the possibility of axial and angular rotation of the spherical rod 8. In addition, from above, the cylindrical sleeve 3 is in rigid interaction with the spherical body 7, in which the inner sphere 6 is in interaction with the outer surfaces of the rolling elements 5, and at the free inner end of the spherical body 7 there is a cylindrical ring with an outer triangular profile 9, which is in rigid interaction with a similar recess 10 of the cylindrical sleeve 3, which is made at its free end outside. From the other end of the welded cylindrical section, a connecting sleeve 11 with an internal square or shaped hole 12 is rigidly installed in the inner hole perpendicular to the axis, which is in interaction with the corresponding end of the spherical rod of the neighboring section and rigidly fixed in a known way. Four jumpers 13, for example, are welded to the outer diameter of the connecting sleeve 11 evenly around the circumference at one end, and at the other end the jumpers are welded to the outer diameter of the cylindrical sleeve 3. A screw section 13 is rigidly welded to the outer diameter of the cylindrical section 2, which is actually a continuation of the helical spirals of the neighboring sections, a recess 14 is made in the center of the spherical rod 8, which is in contact with the lubricant, which in turn is connected to the rolling elements 8 by a system of holes, and a central hole is made at the free end of the rod, which is connected to the recess 15 and an oiler is screwed at its end.

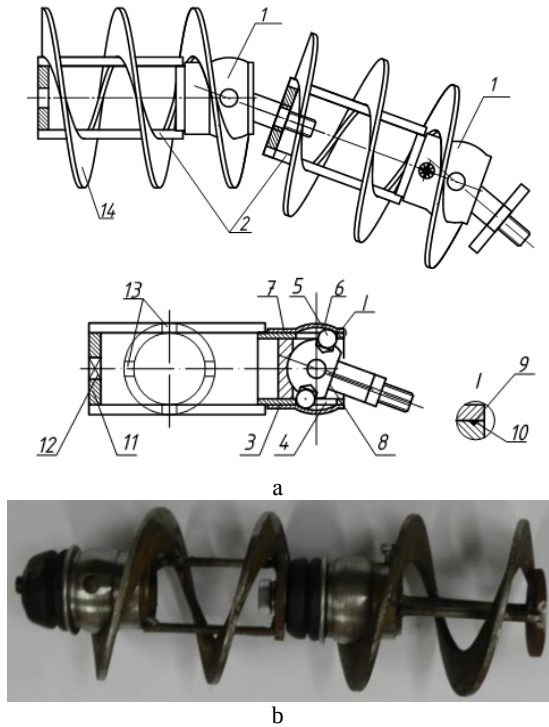


Figure 1. Constructional diagram (a) and general view (b) of the screw sectional working body

The operation of the screw working body is as follows. During the rotation of the spiral section 14, the rotational motion is transmitted through the rolling elements 5 to the spherical linkage 7 and the adjacent sections of the screw working body.

In order to estimate the maximum loads that occur in the elements of a flexible screw conveyor during the transient processes of starting and braking, we will create its dynamic model and analyze the resulting solution.

The simplified dynamic model will be written in the form of an elastic three-mass rotating system subject to external torques from the motor and the transported material. The dynamic model is shown in Fig. 2.

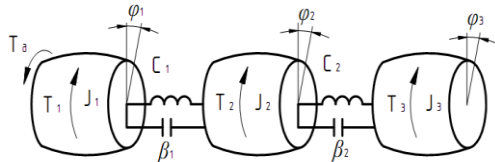


Figure 2. Scheme of the dynamic model

The first rotating mass J_1 represents the combined mass of the drive mechanism (motor, gearbox, coupling). It is affected by the torque of the motor's electromagnetic forces T_d , reduced to the screw's axis of rotation, and the force T_1 of friction in the drive mechanism. The second rotating mass J_2 – is the combined mass of the first link of the flexible screw conveyor together with the mass of the transported material. It is subjected to a moment of resistance, which can be represented as the sum of two components – a constant dry friction moment T_2 and a viscous friction moment that depends on the speed of movement. Similarly, J_3 the following corresponds to the combined mass of the next link of a flexible screw conveyor.

Obviously, if there are several conveyor links, the number of rotating masses should correspond to their number. However, in models that study transient processes, due to the presence of significant friction forces of bulk material, which causes damping of oscillations of subsequent links, it is possible to replace a long chain of links with a reduced torque of resistance T_3 , applied to the link by mass J_3 , as well as a certain viscous friction moment. This

assumption significantly reduces the complexity of the system analysis, with virtually no effect on the determination of the maximum dynamic loads that occur in the drive mechanism and the first link of the screw. Therefore, for the purpose of the study, we will limit ourselves to a dynamic system consisting of three characteristic rotating masses.

Each link is connected to the next elastic element, the combined stiffness of which is determined by the elastic properties of the screw link and the hinge mechanism.

The dynamic model shown in Fig. 2, the dynamic model is described by a system of three differential equations of motion. Each equation describes the motion of the corresponding rotating mass:

$$\left. \begin{aligned} J_1 \ddot{\varphi}_1 &= T_d - c_1(\varphi_1 - \varphi_2) - \beta_1 \dot{\varphi}_1 - T_1 \operatorname{sgn}(\dot{\varphi}_1); \\ J_2 \ddot{\varphi}_2 &= c_1(\varphi_1 - \varphi_2) - c_2(\varphi_2 - \varphi_3) - \beta_2 \dot{\varphi}_2 - T_2 \operatorname{sgn}(\dot{\varphi}_2); \\ J_3 \ddot{\varphi}_3 &= c_2(\varphi_2 - \varphi_3) - \beta_3 \dot{\varphi}_3 - T_3 \operatorname{sgn}(\dot{\varphi}_3); \end{aligned} \right\} \quad (1)$$

where $\varphi_1, \varphi_2, \varphi_3$ – rotation angles of rotating masses J_1, J_2, J_3 accordingly; c_1, c_2 – rigidity of the connecting elements; $\beta_1, \beta_2, \beta_3$ – coefficients of viscous damping forces acting on the respective masses.

The torque of a motor is described by its mechanical characteristic, which relates rotational speed and torque. The simplest is the static mechanical characteristic of an electric motor, which does not take into account electromagnetic processes in the motor. As a drive motor, an asynchronous electric motor with a squirrel-cage rotor is most often used without a starting current and speed control circuit, i.e., the motor is directly connected to the mains. In this case, its mechanical characteristic can be written as:

$$T_d = \frac{2T_k}{\frac{s}{s_k} + \frac{s_k}{s}}. \quad (2)$$

The values in expression (2) are determined by the following formulas:

$$s_k = \frac{\omega_0 - \omega_k}{\omega_0} \quad \text{– critical slip of the electric motor;}$$

$$s = \frac{\omega_0 - \dot{\varphi}_1}{\omega_0} \quad \text{– running sliding of the electric motor,}$$

where ω_0 – synchronous rotor speed of the electric motor;

ω_k – critical rotor speed of the electric motor;

T_k – critical torque of the electric motor.

The last three values are determined from the motor's tabulated parameters and must be reduced to the screw's axis of rotation.

The system of differential equations (1) is nonlinear, so its analytical solution is difficult, and therefore we will use a numerical method based on transforming the system of second-order differential equations into a system of first-order differential equations with twice as many of them. To do this, we will make the appropriate substitutions and replacements. As a result, we get the following system of equations:

$$\left. \begin{aligned} \varphi_1 &= u; \\ \dot{u} &= \frac{T_d - c_1(\varphi_1 - \varphi_2) - \beta_1 \dot{\varphi}_1 - T_1 \operatorname{sgn}(\dot{\varphi}_1)}{J_1}; \\ \varphi_2 &= v; \\ \dot{v} &= \frac{c_1(\varphi_1 - \varphi_2) - c_2(\varphi_2 - \varphi_3) - \beta_2 \dot{\varphi}_2 - T_2 \operatorname{sgn}(\dot{\varphi}_2)}{J_2}; \\ \varphi_3 &= w; \\ \dot{w} &= \frac{c_2(\varphi_2 - \varphi_3) - \beta_3 \dot{\varphi}_3 - T_3 \operatorname{sgn}(\dot{\varphi}_3)}{J_3} \end{aligned} \right\} \quad (3)$$

To solve system (3), it is advisable to apply the Runge-Kutta numerical method, which has proven to be convenient and reliable for solving systems of equations describing dynamic models of oscillating mechanical systems.

During the startup, the system of masses was at rest at the beginning of the movement, so the initial conditions are written in the form:

$$\left. \begin{aligned} \varphi_1(0) &= 0; \\ \varphi_2(0) &= 0; \\ \varphi_3(0) &= 0; \\ u(0) &= \dot{\varphi}_1(0) = 0; \\ v(0) &= \dot{\varphi}_2(0) = 0; \\ w(0) &= \dot{\varphi}_3(0) = 0 \end{aligned} \right\} \quad (4)$$

In order to analyze the influence of certain system parameters on the magnitude of dynamic loads during the startup period, we will perform the calculation by assuming the following numerical values of mass, power, and elastic coefficients:

- Rotating mass of the drive $J_1 = 2 \text{ kg m}^2$;
- Rotating masses of 1 and 2 screw links $J_2 = J_3 = 0.01 \text{ kg m}^2$;
- Rigidity of drive elements $c_1 = 2000 \text{ N m}$;
- Rigidity of the 1st link elements $c_2 = 1000 \text{ N m}$;
- Coefficient of viscous friction of the drive mass $\beta_1 = 0.5 \text{ N m s}$;
- Coefficients of viscous friction of 1 and 2 links $\beta_2 = \beta_3 = 5 \text{ N m s}$;
- Torque of the drive elements $T_1 = 10 \text{ N m}$;
- Moment of resistance of 1 link $T_2 = 20 \text{ N m}$;
- Resistance torque 2 links $T_3 = 200 \text{ N m}$;
- Rated speed of the drive $\omega_0 = 10 \text{ s}^{-1}$;
- Critical sliding $s_k = 0.25$;
- The critical torque $T_k = 500 \text{ N m}$.

The values of friction moments and critical torque are selected for the calculated rated power of the electric motor of 2.2 kW. In order to increase the starting torque, which is necessary when starting the screw conveyor under load, we choose an asynchronous motor with increased slip. The second, particularly loaded case of flexible screw conveyor movement is its sudden braking due to material jamming or accidental entry of a certain object into the transportation zone. At this point, the system, which has been rotating at a constant speed, begins to brake, increasing the braking torque until the drive comes to a complete stop. Mathematically, applying certain assumptions, this can be written as a linear increase in torque T_3 in time t from the initial value T_{30} to the maximum value when the movement of the rotating mass J_3 is stopped:

$$T_3 = T_{30} + Mt, \quad (5)$$

where M – braking torque growth factor.

The value M determines the braking speed of the drive. In real systems, the braking time can last from 0.1 s to 5 s. A short time is typical for incompressible bulk materials (sand, dry grain materials), and a long braking time is typical for the transportation of compressible media (soft grain materials, feed, seeds, chaff). The conveyor movement during braking can be divided into 2 stages. The first is braking until the rotating mass J_3 stops. At this stage of motion, the system is described by the same equations (1-3), but with different initial conditions that correspond to the final values of the angles and their velocities in steady-state motion before the start of braking at time t_1 , and the braking torque is determined from expression (5):

$$\left. \begin{aligned} \varphi_1(0) &= \varphi_1(t_1); \\ \varphi_2(0) &= \varphi_2(t_1); \\ \varphi_3(0) &= \varphi_3(t_1); \\ u(0) &= \dot{\varphi}_1(t_1) = \omega_1; \\ v(0) &= \dot{\varphi}_2(t_1) = \omega_2; \\ w(0) &= \dot{\varphi}_3(t_1) = \omega_3 \end{aligned} \right\} \quad (6)$$

The second stage of motion is the oscillation of masses J_1 and J_2 , connected through elastic elements c_1 and c_2 to the stopped

mass J_3 . At the second stage, the elastic system is described by a system of two differential equations:

$$\left. \begin{aligned} J_1 \ddot{\varphi}_1 &= T_d - c_1(\varphi_1 - \varphi_2) - \beta_1 \dot{\varphi}_1 - T_1 \operatorname{sgn}(\dot{\varphi}_1); \\ J_2 \ddot{\varphi}_2 &= c_1(\varphi_1 - \varphi_2) - c_2(\varphi_2 - \varphi_3) - \beta_2 \dot{\varphi}_2 - T_2 \operatorname{sgn}(\dot{\varphi}_2) \end{aligned} \right\} \quad (7)$$

Accordingly, after substitution, we obtain a system of four first-order differential equations:

$$\left. \begin{aligned} \dot{\varphi}_1 &= u; \\ \dot{u} &= \frac{T_d - c_1(\varphi_1 - \varphi_2) - \beta_1 \dot{\varphi}_1 - T_1 \operatorname{sgn}(\dot{\varphi}_1)}{J_1}; \\ \dot{\varphi}_2 &= v; \\ \dot{v} &= \frac{c_1(\varphi_1 - \varphi_2) - c_2(\varphi_2 - \varphi_3) - \beta_2 \dot{\varphi}_2 - T_2 \operatorname{sgn}(\dot{\varphi}_2)}{J_2} \end{aligned} \right\} \quad (8)$$

with the corresponding initial conditions, which are final for the moment of time t_2 of the mass J_3 stopping:

$$\left. \begin{aligned} \varphi_1(0) &= \varphi_1(t_2); \\ \varphi_2(0) &= \varphi_2(t_2); \\ u(0) &= \dot{\varphi}_1(t_2) = \omega_2; \\ v(0) &= \dot{\varphi}_2(t_2) = \omega_2; \end{aligned} \right\} \quad (9)$$

Thus, a mathematical model of the dynamic system of a flexible screw conveyor was obtained, and dynamic starting torques were calculated at the rated load of the loaded screw and when the system was braked.

On the basis of the created mathematical model of the dynamic system of a flexible screw conveyor, we calculated the dynamic starting torques at the rated load of the loaded screw. The calculation results are shown in Fig. 3 – 6. The graphical results of calculating the dynamic loads during braking of the system described by Fig. 5–9 are shown in Fig. 7 – 10.

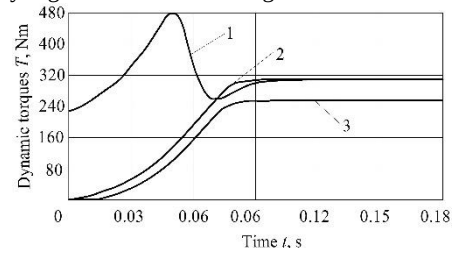


Figure 3. A change of the dynamic torques of the drive and in the elastic sections of the conveyor with significant external damping $\beta_2 = \beta_3 = 5$: 1 – T_d ; 2 – $c_1(\varphi_1 - \varphi_2)$; 3 – $c_2(\varphi_2 - \varphi_3)$

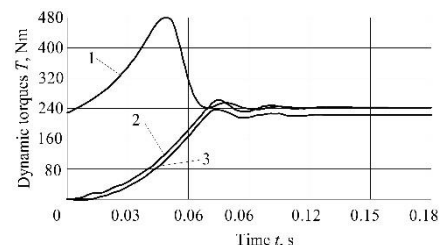


Figure 4. A change of the dynamic torques of the drive and in the elastic sections of the conveyor with small external damping $\beta_2 = \beta_3 = 1$: 1 – T_d ; 2 – $c_1(\varphi_1 - \varphi_2)$; 3 – $c_2(\varphi_2 - \varphi_3)$

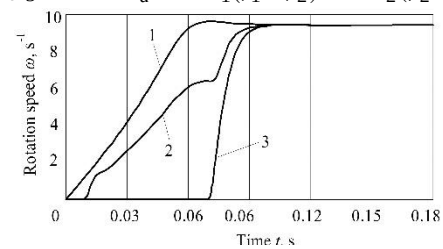


Figure 5. The rotation speeds of masses with significant external damping $\beta_2 = \beta_3 = 5$: 1 – ω_1 ; 2 – ω_2 ; 3 – ω_3

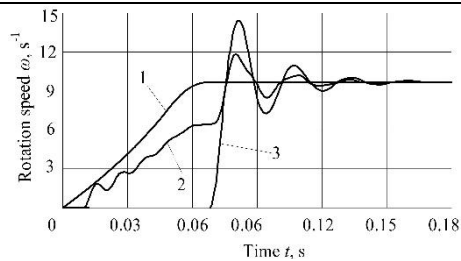


Figure 6. The rotation speeds of masses with small external damping $\beta_2 = \beta_3 = 1$: 1 – ω_1 ; 2 – ω_2 ; 3 – ω_3

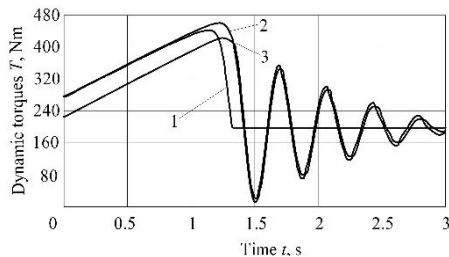


Figure 7. Dynamic torques in the sections of the conveyor during slow braking (1 s): 1 – T_d ; 2 – $c_1(\phi_1 - \phi_2)$; 3 – $c_2(\phi_2 - \phi_3)$

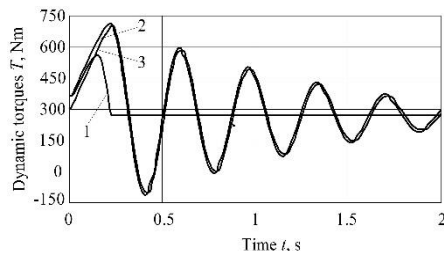


Figure 8. Dynamic torques in the conveyor sections during fast braking (0.2 s): 1 – T_d ; 2 – $c_1(\phi_1 - \phi_2)$; 3 – $c_2(\phi_2 - \phi_3)$

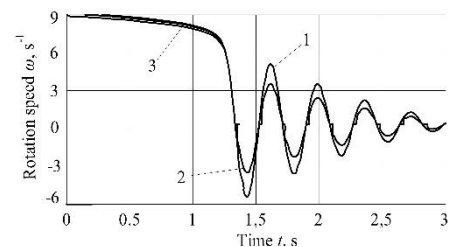


Figure 9. The speeds of the conveyor sections during slow braking: 1 – ω_1 ; 2 – ω_2 ; 3 – ω_3

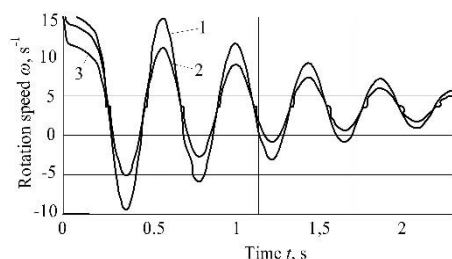


Figure 10. The speeds of the conveyor sections during fast braking (0.2 s): 1 – ω_1 ; 2 – ω_2 ; 3 – ω_3

The analysis of the results shows that with significant damping coefficients, the start-up transient process is smooth and the load reaches its rated value without fluctuations in torque and speed. At low damping, a certain transient oscillatory process is observed, but the dynamic loads do not exceed 20% of the nominal value.

The cases of slow and fast braking are considered. The analysis of the graphs shows that fast braking significantly increases dynamic loads, which can significantly exceed the maximum critical torque of the electric motor (on average by 50-70%) and

the rated load torque (by 2.5-3 times). To ensure the strength of the screw links during braking, it is necessary to provide safety elements (clutches) with an actuation torque not exceeding 1.5 times the nominal torque.

The analysis showed that the dynamic loads during system startup are not critical, and in case of jamming, they significantly exceed the permissible values.

3. Conclusion

Based on the analysis of literature sources and patent search, a flexible screw sectional working body has been developed and manufactured, which will improve the functional and operational characteristics of screw conveyors. On the basis of the created mathematical model of the dynamic system of a flexible screw conveyor, the dynamic starting torques were calculated at the rated load of the loaded screw. The analysis of the results shows that at significant damping coefficients, the startup transient process is smooth and the load reaches its nominal value without fluctuations in torque and speed. At low damping, a certain transient oscillation process is observed, but the dynamic loads do not exceed 20% of the nominal value.

The analysis of the results of calculating the dynamic loads during braking of the system shows that rapid braking significantly increases the dynamic loads, which can significantly exceed the maximum critical torque of the electric motor (on average by 50-70%) and the rated load torque (by 2.5-3 times). To ensure the strength of the screw links during braking, it is necessary to provide safety elements (clutches) with an actuation torque not exceeding 1.5 times the rated torque.

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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.

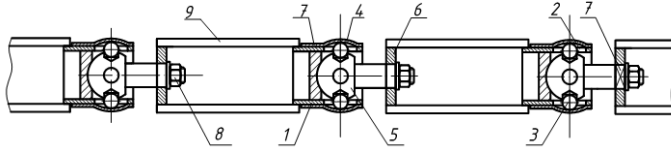


Figure 1. Structural diagram (a) of a flexible screw sectional articulated working body

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.

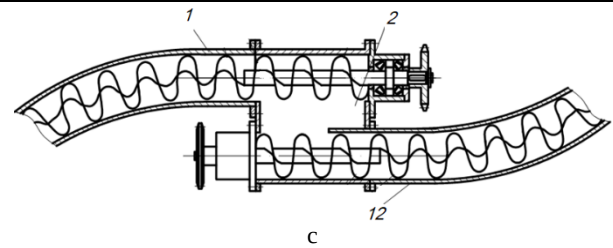
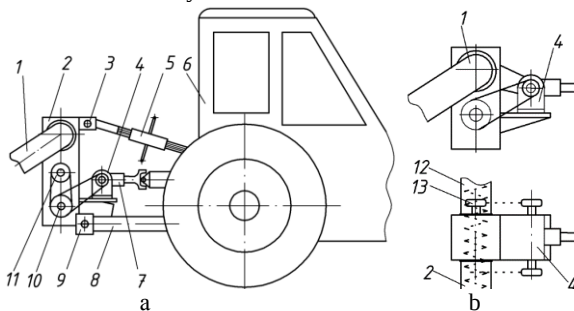


Figure 2. Structural diagram of the experimental setup with a tractor-machine hitch system (a, b) and a flexible screw conveyor (c)

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.

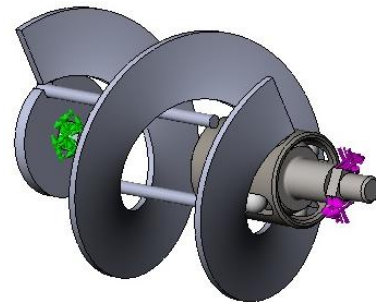


Figure 3. Model of the assembled section with the load applied to it

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.

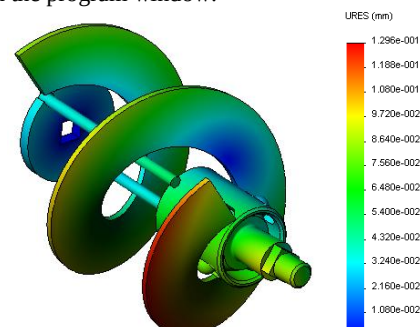


Figure 4. Movement of working body components under the influence of torque

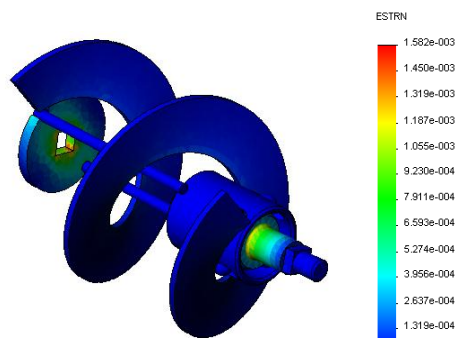


Figure 5. Deformation of working body components under the influence of torque

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.

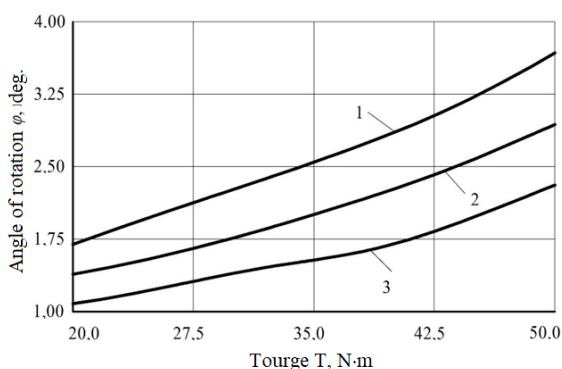


Figure 6. Graphical dependence of the section twist angle φ on the number of rods: 1 – $n = 2$; 2 – $n = 3$; 3 – $n = 4$

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.

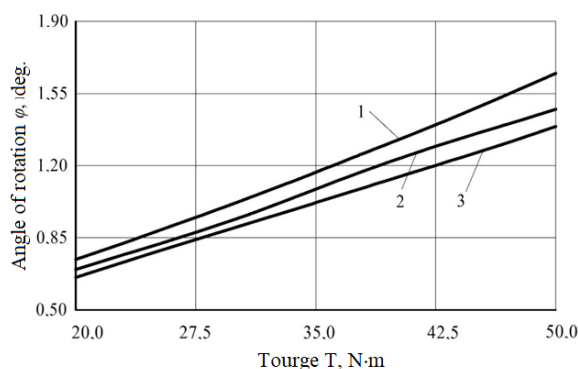


Figure 7. Graphic dependences of the twisting angle of the section φ on the change in the thickness of the helical spiral: 1 – $\delta = 2$ mm; 2 – $\delta = 3$ mm; 3 – $\delta = 4$ mm

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.

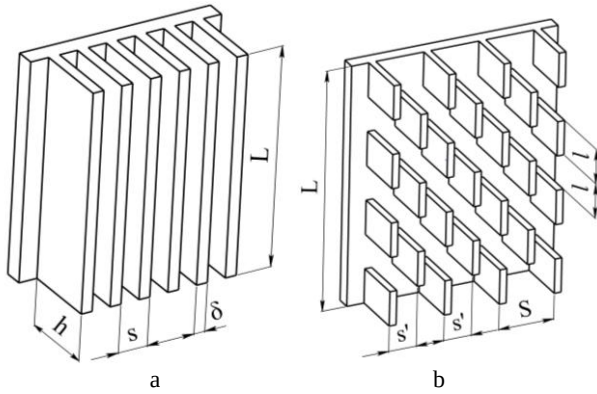


Figure 1. Diagram of vertical surfaces with continuous (a) and discrete (b) finning

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%.

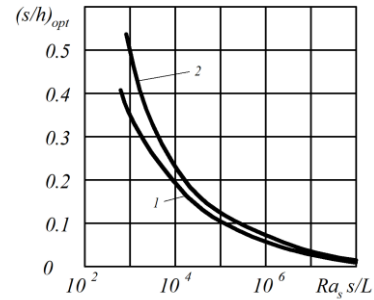


Figure 2. Dependence of s_{opt} on the parameter $Ra_s \cdot h \cdot L^{-1}$ for continuous finning: 1 – calculated curve; 2 – calculation for an isothermal surface [6]

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.

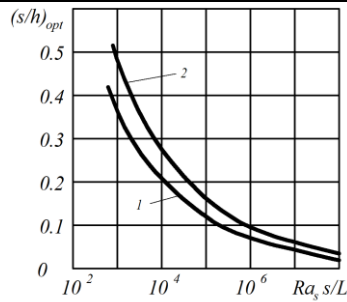


Figure 2. Dependence of s_{opt} on the parameter $Ra_s h L^{-1}$:
1 – continuous finning; 2 – discrete finning

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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Development of experimental setup, program and methods experimental research of carrot heads cleaning from root haulm residues

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Abstract. Mechanized carrot growing technologies involve the use of various operations, in particular, digging by pulling the root and removing it inside the combine, as well as by pre-cutting the green mass of the root and subsequent cleaning of the heads from the remains of the root before digging. Due to the fact that there are high requirements for cleaning carrot root heads from residues, the development of new, more improved cleaners is an important and urgent task. The solution to this problem was implemented by developing a new design of the purifier, which is able to perform the specified cleaning process with high quality. The cleaner consists of two shafts that cover each row of carrots on both sides and rotate in opposite directions. Cleaning shafts are located in a horizontal plane at an angle to each other. As cleaning elements, pairs of rubber blades are used, which are installed on hubs on each shaft, which are fixed on the shafts with the appropriate step. The rubber blades are mounted on hubs hinged and the ends of the blades of one shaft are located between the pairs of blades of the second shaft. By simultaneously hitting the heads of the carrot root crops with flexible blades from both sides, the process of cleaning them from residues is carried out. In order to study the process of cleaning carrot heads from the remains of ghee on the root, an experimental installation was made and a program of experimental studies of this technological process was developed.

KEYWORDS: CARROTS, PUMP COLLECTION, REMAINS, EXPERIMENTAL RESEARCH, INSTALLATION, PROGRAM.

1. Introduction

Among the modern technologies for harvesting root crops, in particular carrots, which are grown industrially, the most common is the technology of separate harvesting, that is, when a separate unit is used to collect the ghee on the root, and then the root crops are dug out of the soil with a root harvester.

Previously, the technology of harvesting the gorse involved its previous continuous cut at an elevated height and the subsequent mechanical cutting of the upper parts of the heads together with the remains. At the same time, the cut parts of the heads were not collected, but, on the contrary, were scattered over the surface of the field, and later, as fertilizers, they were plowed into the soil. However, recently it has been thoroughly investigated and found that along with the cut parts of the heads, the useful parts of root crops are irreversibly lost. Yes, this is especially noticeable when harvesting sugar beets, when up to 14% of sugar can be lost together with the cut root heads. In addition, due to the mechanical cutting of the heads of root crops, juice is almost immediately lost from their bodies, the cut part becomes a place through which microbes and viruses begin to penetrate into the body, causing their subsequent decay and loss. In general, it is impossible to store such root crops, even for a small period of time, and they urgently need to be processed. In addition, even with short-term storage, their marketability is intensively lost. Modern gorse harvesting machines of foreign production provided not only for cutting, but also for grinding the entire massif of cut green gorse and spreading it on the field, also as a plant fertilizer.

In this regard, in the future, the technology of collecting gorse was improved and provided for a preliminary continuous section of the green array of gorse, and then a separate operation was performed to clean the carrot heads from the remains of gorse on the root without damage and to knock out the bodies of root crops from the soil. Recently, carrot husks have been collected, taken from the fields and effectively used in the production of biogas.

The technological process of harvesting scallions and cleaning carrot heads from residues on the roots must meet agrotechnical requirements. Thus, the appropriate operation related to the final cleaning of the heads of carrot root crops from residues involves the waste of parts of the heads of no more than 5% by mass, and contamination by residues should be no more than 0.5% [1].

Thus, careful cutting and harvesting of a solid mass of carrot tops, high-quality cleaning of their heads from residues on the root, ensuring the quality of the root heads, in which they do not have plant remains on their surface, nor their damage, nor the roots themselves being knocked out of the soil, are a very important and urgent problem in the field of vegetable growing.

Research was devoted to the solution of the problem of cleaning the heads of root crops, including carrots, from the remains of ghee on the root, which were reflected in numerous scientific works [2, 3]. In particular, the works of L. V. Pohorily [4, 5] are devoted to the fundamental basis of creating various designs of cleaners and the development of the theory of cleaning

the root heads of sugar beet root crops. The works of V.Ya. Martynenko [6, 7] and V.M. Bulgakov [8, 9] are devoted to the creation of the theoretical foundations of mechanical combing and removal of chaff residues from the root heads of sugar beet root crops. The development of various designs of cleaners for the heads of root crops from the remains of ghee on the root and the theoretical and experimental substantiation of their parameters were reflected in the works of M. M. Helemendik [10], B. P. Shabelnyk [11], M. M. Borys [12] and others.

However, a thorough analysis of both the design of the existing cleaners (with horizontal and vertical drive shafts on which the cleaning elements are installed) and studies of their performance indicators, obtained from the results of testing and field experimental studies, shows that the quality of their work is largely depends on the type of root crops and the condition of their crops at the time of harvesting. Thus, even the OGD-6 root head cleaner, which was industrially manufactured and used as a separate cleaning unit, was not under all conditions able to effectively separate all the residue from root heads from 6 rows of crops with a continuous drive shaft with a horizontal axis of rotation and hingedly mounted on it flexible cleaning blades. The more advanced cleaner OGD-6A, which was also manufactured industrially and is still used, already had two successively installed same cleaning shafts, but it was also unable to effectively separate the remains of ghee on the heads of sugar beet root crops, especially their short and strong stems, which remained after the main continuous section of the massif of the haulm.

This is due to the fact that when moving in a straight line along the rows of cut root heads, the flexible cleaning blades have planes of rotation that are parallel to the specified rows. As a result, the ends of the cleaning blades may not touch the rear and side parts of the heads of root crops located above the field surface. Taking into account the increase in the speed of translational movements of modern harvesting units, this drawback is not only insurmountable, but also has the ability to strengthen.

The development of new designs of cleaners, which have individual cleaning working bodies for each row of crops, is also not without the indicated drawback, since the application of cleaning efforts to each head of the root crop can be more directed to the spherical surfaces of the heads of different sizes and shapes, however, with progressive rectilinear movement with at a considerable speed, they are also unable to clear the front and back of the heads located in the row of crops along which they move. In addition, those root crops that have an offset from the center line of the row of crops (this is due to the agricultural techniques of cultivation and the peculiarities of cultivation) may generally be uncleaned by such types of cleaners. This type of cleaners has increased energy costs for this process.

The use of harder materials as cleaning elements also has a negative effect on the quality of cleaning, as the heads and bodies of root crops can be significantly damaged and lost.

Increasing the effort of pressing even flexible cleaning elements to the heads of root crops also negatively affects the quality of the execution of this technological process, as it leads not only to their damage, but most importantly to the intensive knocking out of the bodies of root crops from the soil. Clamping forces must be applied simultaneously from several sides of the heads, but this is not always possible.

Thus, the search for the most effective constructive solutions for cleaning the heads of root crops from residues on the root should take into account the noted features and shortcomings, and their justified kinematic, constructive and operational indicators should ensure high-quality performance of this technological process.

2. Results and discussions

An experimental setup was developed and manufactured for experimental research. In fact, a new carrot head cleaner was developed, which is at once two cleaning shafts, on which working cleaning elements in the form of pairs of rubber blades are hinged. The cleaning shafts in this design cover each row of root crop crops on both sides and, due to counter-rotating movements, they hit the carrot heads with the ends of their working cleaning elements simultaneously from both sides, combing the remaining husks from them. Undoubtedly, the main mass of green gorse from the carrot heads has already been pre-cut by a gorse harvester, but there are remnants left on them, in the form of uncut green tips, as well as dry and fallen thin stems of considerable length, which actually lie on the surface of the soil. At the same time, the carrot roots themselves are in the soil and are firmly connected to it. After cleaning the carrot heads from the remains of goo on the roots, the next operation is to directly dig out the root crops from the soil.

To simulate the functioning of this cleaner in real field conditions and, accordingly, study the quality of its work under different parameters and regimes, a construction of a field experimental installation, inside which this cleaner was installed, was developed and manufactured. The experimental setup provides for the study of the quality of cleaning the heads of root crops from one row of crops, it is aggregated by a class 1.4 wheeled tractor, which sets the cleaner, during field experimental studies, different speeds of translational movement along the row of crops of root crops, and different angular speeds of rotational movements of its cleaning workers bodies.

In Fig. 1 shows the scheme of the experimental setup for researching the quality of cleaning yorlike heads from the remains of burdock on the root. The experimental setup is a carrot head cleaner on the root installed on frame 3, which is single-row. The frame 3, with the help of the attachment device 2, is installed behind the wheeled aggregate tractor 1. At the same time, the frame 3 in its front part rests on two support-copying wheels 5 with mechanisms for changing the distances of the frame 3 to the soil surface. In the rear part of the frame 3, there is a cleaner, which consists of two horizontal cleaning shafts 6. The drive of the shafts 6 in counter-rotating movements is carried out with the help of drive elements 4 from the rear power take-off shaft of the tractor 1. The cleaning shafts 6 are installed in the transverse plane horizontally, and their longitudinal axes in this plane are located at an angle α .

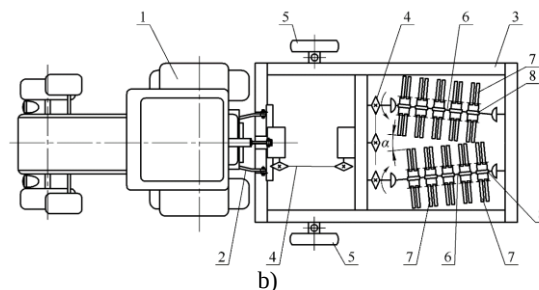
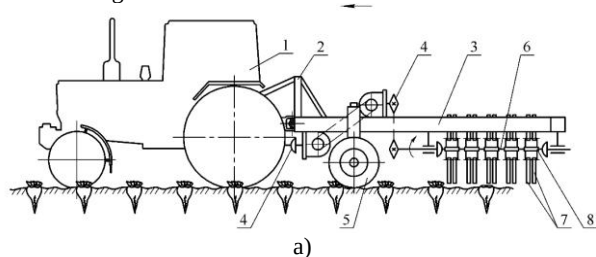


Figure 1. Structural and technological diagram of a field experimental installation for researching the quality of cleaning carrot heads from the remains of the root rot:

a) side view; b) top view:

1 – tractor; 2 – attachment device; 3 – frame; 4 – elements for driving the cleaning shafts into a counter-rotating motion; 5 – supporting and copying wheels; 6 – drive cleaning shafts; 7 – pairs of rubber cleaning blades; 8 – hubs with articulated cleaning blades

At the same time, five hubs 8 are installed on each cleaning shaft 6 with the corresponding step by means of a key connection 9. Each hub 8 contains a pair of rubber blades 7 on the outer surfaces, mounted with the help of leashes, hinged on the axes of a pair of rubber blades 7, of which it contains four (located at the ends of mutually perpendicular axes). At the same time, the ends of the rubber blades of one cleaning shaft are located in the gaps between the blades of the second cleaning shaft. The angle α , under which the cleaning shafts are installed, provides a suitable area for root crops in the front part of the cleaner and is of little importance.

The directions of translational movement of the experimental setup and rotational movements of its component elements are shown in the diagram with arrows.

In this cleaner, ordinary rubber blades are used, which have standard dimensions: length 25...33 cm; width 6...8 cm, thickness 1.5...2.0 cm. At the outer ends of each blade, along their entire width, rubber protrusions with a height of 0.3...0.5 cm and a hemispherical shape were arranged in a checkerboard pattern. The place of hinged installation of each blade was reinforced with a thin metal - tin. All blades are made of solid molded rubber.

In Fig. 2 shows the general view of the experimental setup attached to the wheeled aggregate tractor during field experimental research.



Figure 2. View of the experimental setup

The method of conducting field experimental studies to determine the quality of cleaning carrot heads from the remains of burdock on the root in some issues was consistent with modern requirements and was as follows [13, 14].

From the very beginning, the area of the field with carrot crops was carefully prepared (for this, the area with crops was most suitable), which was (according to the terms and according to the indicators of agrophysical assessment of the crop) suitable for harvesting. Measurements and a comprehensive analysis of the physical and mechanical properties of the soil with crops were carried out, as well as indicators of the biological state of the root crops themselves. Next, they performed an operation to cut the gorse from the heads of root crops with a regular machine for harvesting gorse. At the same time, the string harvesting machine

itself did not have a head cleaner from residues in its composition. After the passage of the gorse harvesting machine, an assessment of the state of the plantation was carried out based on the results of the first main continuous cut of the green mass of gorse. Here, the main indicator in the evaluation of the work of the gorse harvesting machine was the quality of the cut of the carrot heads itself (the presence of highly cut root bodies, chips, cracks, knocking out of the root bodies themselves from the soil) and the assessment of the presence of those remains of gorse, which the gorse harvester was unable to cut and collect qualitatively. Such a thorough assessment of the quality of the work of the gorse harvester gave every reason to conduct further comparisons and reliably evaluate the quality of cleaning the heads of root crops from residues on the roots by the most improved cleaner, that is, to actually "divide" the quality of cleaning during the first and during the second cleaning.

In the future, the process of cleaning the carrot heads with this cleaner took place, while two adjacent rows were immediately selected and similar conditions were determined with the help of a frame that had the contours of one linear meter. Next, manual cutting of all the remains was carried out, both after passing through only the ginseng machine and after simultaneous passage of the ginseng machine and the cleaner. All remains, in both cases, were carefully collected and weighed on electronic scales with an accuracy of ± 0.1 g. The obtained weighing results in both cases, that is, before and after the passage of the cleaner, made it possible to evaluate the quality of cleaning the heads of root crops from residues.

The very degree of cleaning of carrot heads from residues on the root was then calculated using the following formula:

$$\delta = \frac{M - M_{cl}}{M} \times 100, \quad (1)$$

where δ is the degree of cleaning of carrot heads, %; M is the mass of the remaining scum before the cleaner passes, g; M_{cl} is the mass of the residue after passing through the cleaner, g.

The conditions for conducting field experimental studies of the improved purifier were as follows: soil type and name according to mechanical composition – chernozem, low-humus, medium loam; average soil hardness – 2.0...2.8 MPa; average soil moisture – 12.1...14.5%; the relief of the surface is flat; yield of root crops – 53.4 t·ha⁻¹; yield of buckwheat – 13.3 t·ha⁻¹; plant density – 82.9 thousands pcs·ha⁻¹; the average distance between carrot roots is 8.8 cm.

The following devices and equipment were used during field experimental research: measuring and recording the angular speed of the rotational movements of the driven cleaning shafts was carried out using a strain gauge, the speed of the translational movement of the experimental installation was measured using a travel measuring wheel.

At the same time, the strain gauge was installed on the rear pick-up shaft capacity of the aggregate tractor, which made it possible, with the help of a developed program and connection to a PC using an electronic converter, to immediately fix and measure the angular velocity of its shank. This was followed by recalculation into the angular velocity of the drive shafts of the cleaner and with the help of variable sprockets in its drive to set the required variable angular velocities of the rotational movements of the cleaning shafts themselves. The construction of the drive of the cleaning shafts in the experimental setup was carried out with the help of cardan shafts, a reducer and chain gears, which ensured their counter-rotation in the direction of the axis of the row of root crops. The distance-measuring wheel, which was connected to the frame of the cleaner, also with the help of a developed program and connection through a converter to a PC, gave accurate values of the translational movement of the cleaner during field experimental studies in different modes of its operation. Setting the exact location of the ends of the rubber blades relative to the field surface was carried out each time with the help of a metal ruler, which made it possible to accurately set different values of the height of the location using the screw mechanisms of the copying wheels of the cleaner frame. These measurements were made with an accuracy of 1 mm.

In order to establish the influence of independent factors on the

performance indicators of the investigated carrot head cleaner from the remains of burdock on the root, a comparative multifactorial experiment of the FFE P^k type was planned and carried out, where P is the number of levels of variation of the factor; k is the number of factors present in the experiment [15]. The indicator that characterizes the quality of the cleaner is the residue on the running meter (g·m⁻¹) that occurs after it passes through the line section. This parameter in the model of the multivariate experiment was chosen as an optimization function, that is, a dependent variable that can be taken in the form of a functional: $Y = f(x_1; x_2; x_3)$, where Y is the residuals of the hook from the 1-st to the i -th case; $x_1, x_2, \dots, x_i$ – are natural independent variable factors.

The indicated natural independent factors were selected according to the corresponding conditional plan of the multivariate experiment, the implementation of which was carried out in the following sequence.

In order to determine the value of the remaining Y hooks on each linear meter, independent variable factors were adopted:

- speed of translational movement V , which was coded with the index X_1 ;
- the angular speed of rotation ω of the cleaning shafts, which was coded with the index X_2 ;
- height of installation of the ends of the rubber blades relative to the horizontal surface of the soil h , which was coded with the index X_3 .

When coding the factors, the factor space will be linearly transformed – the origin of the coordinates is moved to the center of the experiment, the scale along the axes is selected in units of factor variation. Coding of factors was carried out using such a dependence:

$$X_i = \frac{2 \cdot (x_i - x_{i0})}{x_{\max} - x_{\min}}, \quad (2)$$

where X_i is the coded value of the factor (dimensionless quantity); x_i – value of the factor in named (natural) units; x_{i0} – the natural value of the factor at the zero level; $x_{\max}, x_{\min}$ – the maximum and minimum value of the factor, respectively.

When constructing the plan-matrix of the multifactorial experiment, coded designations of the upper, lower and zero levels of variation by each factor were entered, which were respectively marked as (+1), (–1), (0). The results of the coding of variable factors and the levels of their variation are given in the table. 1.

Table 1. Results of factor coding and levels of their variation FFE 3³

Factors	Marking		Levels of variation, natural / coded		
	coded	natural			
The speed of translational movement V , m·s ⁻¹	X_1	x_1	0.9/–1	1.6/0	2.1/+1
Angular speed of rotary movements of cleaning shafts ω , rad·s ⁻¹	X_2	x_2	36.6/–1	56.5/0	76.6/+1
The height of the blade ends relative to the soil surface h , cm	X_3	x_3	0/–1	2/0	4/+1

The coding of natural variables based on the data in Table 1 has the following values:

$$\begin{aligned} X_1 &= 1.67 \cdot V - 2.67, \\ X_2 &= 0.05 \cdot \omega - 2.81, \\ X_3 &= 0.5 \cdot h - 1. \end{aligned} \quad (3)$$

After coding the factors, a plan-matrix of the appropriate multifactorial experiment of the FFE 3³ type was drawn up for the total number of experiments $N = 3^3$.

In order to reliably assess the quality of the cleaner of carrot heads from the remains of burdock on the root during field experimental studies, the required number of measurements of controlled indicators (repeatability of experiments) was determined according to the methodology outlined in [16]. In our case, the experiments were carried out in six replicates.

In the implementation of composite plan-matrices, in order to eliminate the influence on the obtained results of the value of the residual amount of the hemlock on the running meter from

uncontrolled and unregulated factors, the randomization of the plan-matrix was carried out using the method of random balance, which was implemented by the method of arbitrarily extracting the serial numbers of experiments, that is, it is carried out randomly.

Statistical processing of the results of experimental studies, which were obtained after the implementation of the multifactorial experiment, was carried out in the following sequence.

Thus, the response function (i.e., the optimization parameter) was adopted in the form of an approximate mathematical model of a full quadratic polynomial [16], which describes a real experimental process:

$$Y = b_0 + b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_{12} \cdot x_1 \cdot x_2 + b_{13} \cdot x_1 \cdot x_3 + b_{23} \cdot x_2 \cdot x_3 + b_{123} \cdot x_1 \cdot x_2 \cdot x_3 + b_{11} \cdot x_1^2 + b_{22} \cdot x_2^2 + b_{33} \cdot x_3^2, \quad (4)$$

where Y – is the value obtained experimentally; $b_0, b_1, b_2, b_3, b_{12}, b_{13}, b_{23}, b_{123}, b_{11}, b_{22}, b_{33}$ – regression coefficients of the corresponding values of input factors x_i ; x_1, x_2, x_3 – are input coded factors.

The coefficients of the approximating polynomial, presented in the form of a complete quadratic equation, under the condition of orthogonality and symmetry, were determined by the corresponding general formulas [16].

The statistical significance of the coefficients of the regression equation $b_{i(jk)}$ were conducted according to the Student t -criterion. If the condition of significance was not fulfilled, then such coefficient $b_{i(jk)}$ of the regression equation was taken as insignificant (equal to zero), and the corresponding member x_i of the regression equation was excluded.

Thus, the following regression equation was obtained:

$$Y = 48.6309 + 10.1185 \cdot x_1 - 17.1025 \cdot x_2 + 20.4086 \cdot x_3 + 4.0951 \cdot x_1 \cdot x_2 - 6.5278 \cdot x_2 \cdot x_3 + 6.1716 \cdot x_1 \cdot x_3 + 1.6531 \cdot x_1 \cdot x_2 \cdot x_3 - 2.207 \cdot x_3^2. \quad (5)$$

Accordingly, in natural coordinates, the regression equation after transformation and simplification of the expressions will have the following form:

$$Y = 63.498 - 4.9527 \cdot V - 0.8498 \cdot \omega + 19.5504 \cdot h - 0.2723 \cdot \omega \cdot h + 1.2733 \cdot V \cdot h + 0.2026 \cdot V \cdot \omega + 0.0688 \cdot V \cdot \omega \cdot h - 0.5518 \cdot h^2. \quad (6)$$

Thus, the obtained regression equation (20) describes the dependence of the residue Y on the heads of root crops when they are cleaned by the improved design of the cleaner on its speed V of translational movement, the angular speed ω of the rotational movement of its two cleaning shafts when they move in the opposite direction and the height h of the location of the ends rubber blades relative to the soil surface, which separate the remains from the heads of root crops.

3. Conclusion

1. Designed and developed an improved design of a carrot root head cleaner from residues on the root, and developed a program and methodology for conducting experimental field studies.

2. According to the results of the field experimental study of the cleaner of carrot heads from the residues on the root, equipped with pairs of rubber cleaning blades, installed on the drive horizontal shafts with appropriate steps along the length, which cover the row on both sides, it will be established that the use of the improved cleaner will make it possible to significantly improve the quality cleaning.

3. When carrying out regression analysis and numerical calculations using statistical methods with the help of a PC, it will be possible to establish the optimal structural, kinematic and operational parameters of the improved purifier, which will provide the highest quality of cleaning (the least amount of residue on the heads of carrot root crops per linear meter of its crops).

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Establishment of training of specialists in agricultural engineering at the kyiv polytechnic institute

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Abstract. Together with the foundation of Kyiv Polytechnic Institute in 1898, it was introduced at its Agricultural Department to teach the academic discipline "Mechanics in Adaptation to Agriculture", which will be called "Agricultural Mechanics" in the future. Three years later, that is, in 1902, students of this department began to study this subject, having previously studied the subject "Elementary Mechanics" at the beginning of the III year. Soon, after a period of time, the students of the Mechanical Department began to study a subject called "Agricultural Mechanical Engineering". It was from 1906–1908 that students of both departments began to carry out so-called "Special projects" in agricultural engineering during their studies, and in the following years to carry out diploma projects dedicated to this area of science and study. The teaching of the specified subjects, as well as the students' careful study of real agricultural machines and tools that worked in the field at the Kyiv Machine Testing Station at the Polytechnic Institute (the students even took part in the tests themselves) and gives grounds for the assertion that the organization of training specialists in the field of agricultural engineering began at the Kyiv Polytechnic Institute at the indicated times.

KEYWORDS: MECHANICAL ENGINEERING, AGRICULTURAL ENGINEERING, TRAINING, SPECIALISTS, KYIV POLYTECHNIC INSTITUTE.

In many previous numerous publications, it was claimed that from the moment of the foundation of the Kyiv Polytechnic Institute in 1898, the Department of "Agricultural Machines" immediately existed (under the conditions of that time, a position that was filled by a professor). It was also indicated that students were immediately taught the academic discipline called "...mechanics as applied to agriculture..." (original language of the document) at the Agricultural Department. However, this is not at all true and it is proved in detail in [1]. It is also obvious that the specified subject, which had to be studied only by the students of the "Agricultural Department" of Kyiv Polytechnic Institute (KPI), could not be taught to them earlier than these students will already be studying in the 3rd year. And this was to happen only 3 years after the establishment of this institute, i.e. no earlier than 1901–1902. And of course, for students of other departments of higher education, who had to study according to their own, previously declared and approved programs, this subject was completely unnecessary and it is here was not. It should also be taken into account, and this is generally known, that in the year of the foundation of the Kyiv Polytechnic Institute in 1898, it was originally located in the building of the Kyiv Commercial College, namely, as was reliably stated in the historical documents of that time [2]. By the way, the funds for the construction of the "First Commercial School" in Kyiv (then it had such an initial name) back in 1896 were allocated by rich merchants Lev and Lazar Brodsky, who were the owners of a large number of sugar factories in Ukraine. It is also known that the project of the school building was developed by the well-known Kyiv architect of German origin Shleifer H. P., and the construction of the school, which was originally two-story, was carried out by the Kyiv builder-contractor Ginzburg L. B. So, after its foundation, the Kyiv Polytechnic Institute began its work and the first full academic year was temporarily housed (of course, on lease) in the building of this Commercial School. Although, according to preliminary calculations, the premises of the school building were not enough even for giving lectures and conducting some practical classes for the first full set of students (for the 1st year of study) in the number of 360 people. But, despite such limited conditions, the Kyiv Polytechnic Institute started its work right here, since there were no other necessary premises in Kyiv at that time. Several separate free buildings, but located not far from each other, were also not found at that time, although such a possibility was considered. It was here in the assembly hall of the Commercial School that the ceremonial opening of this university took place. Not about any teaching of subjects related to the systematic study by students of the methods of experimental research of materials and machines, according to the statement of the rector of the higher education professor V. L. Kirpychov, as well as the methods of experimental mechanics in special mechanical laboratories, which must first be studied by students for at least two years, it was out of the question, since the location

of the university in this area was temporary and it did not have any laboratory or other equipment at that time [2, c. 16]. Therefore, there were not and could not be here, in the first year of KPI's existence, neither subject laboratories, nor classrooms for the relevant academic disciplines, nor halls for drawing with models, nor pavilions, nor workshops, nor test stations, nor museums, nor any workshops, not even a library.

It is known that after the first academic year, in the fall of 1899, the Polytechnic Institute was forced to vacate the premises of the Commercial School (although the admission of students to the new 1st year of study this year took place within the walls of the school) and the relocation of the institute and its property to the building of the chemical building, which had already been built, was owned by the institute, although at that time it was not yet fully suitable for direct use (mainly the interior work and numerous arrangements, including furniture, etc., were not finished). And although the building of the chemical building of KPI was designed and rebuilt in full accordance with its name and purpose and did not have significant dimensions, the institute was forced to move there.

And so it continued until 1902, since the construction of all the premises of the Kyiv Polytechnic Institute was mostly completed only then, and the commission headed by the rector of the university, Professor V. L. Kyrpychov, accepted them for use and signed the corresponding act. Another period in the life of KPI has begun, associated with the relocation and reconfiguration of its educational units in the new building. Therefore, only in the summer of 1902, all the educational and scientific departments of the institute were finally distributed in the corresponding buildings and buildings that belonged to it. By the way, by this act, in addition to the main buildings on the territory allocated for the institute, in accordance with paragraph 3, Research Field No. 2 was also accepted for use: «...3) On the territory located near the dacha village "Karavaevskie dachi", allocated for the use of the Institute by the Kiev city public administration and indicated on the drawings under the name of experimental field No. 2» (original language of the document), namely:

- 1) A stone building for testing agricultural implements with a wooden extension for a riding arena and living quarters for workers with a volume of 384 cubic fathoms and an area of 125 square fathoms;
- 2) A wooden barn for storing agricultural implements with a stone cellar;
- 3) A wooden shed for agricultural machinery;
- 4) A wooden cellar;
- 5) ...a place (for sanitary use), a cesspool and a well (original language of the document) [2, c. 141].

Such were the historical events that took place at that time during the organization and the first steps in the foundation and work of the Kyiv Polytechnic Institute. Therefore, there are grounds for confidently asserting that permanent relocations,

construction, reconstruction, furnishing, equipment, etc., had a significant impact both on the implementation of the educational process at the institute and on its quality.

So, taking into account such incredibly complex organizational difficulties that arose from the beginning of the work of the Kyiv Polytechnic Institute, as well as the complete lack of conditions for testing agricultural machines and tools at its own Machine Testing Station (which was organized and built for this purpose) until 1902, there is every reason to believe that that, most likely, it was only after that that the subject, which began to be called "Agricultural Machines", began to be taught to students, and then only at the Agricultural Department. That is, there are no solid grounds to believe that the training of specialists in agricultural engineering began here in 1902. Teaching at the Agricultural Department to students of the last year of study (that is, future agronomists, veterinarians and economists) only one academic discipline "Agricultural machines" does not mean preparing "Agroengineers". This was the case with the training of engineers at the Mechanical Department and the reading of the "Agricultural Machines" discipline to students in the last course of study, which also did not give the right to consider it as the training of "Technological engineers for the field of agriculture". At that time, the Mechanical and Agricultural Department of KPI trained technological engineers and agronomist scientists, according to the training programs according to the Charter of KPI. So, the first graduates of specialists with higher education, i.e. technologists and agronomists at the Kyiv Polytechnic Institute were in no way connected with agricultural engineering. These graduate engineers and agronomists were only familiar with agricultural machinery and implements by taking very short descriptive courses on agricultural machinery in their final training courses. At that time, even the term "agricultural engineering" was not yet used. By the way, in these first years of the institute's work, the name "Machine Testing Station at KPI" was not yet used, pointing to its then name: "Experimental Field No. 2". To conduct tests of some agricultural machines and tools outside the Experimental Field No. 2, for example, on farms that belonged to private landowners (which were located even at a small distance from Kyiv) is another matter, since it is precisely in these very difficult times related to the organization of training in the newly created higher education institution, attracting students for this and taking them to trials to demonstrate and teach this subject directly in the field, most likely, was simply impossible. And testing "on the side" of agricultural machines or tools without appropriate measuring devices, fixing equipment, the necessary adjustment, and most importantly without specialists in the field of testing and technical workers, of which there must be a lot, was unlikely.

As for the theoretical study of the subject "Mechanics in Adaptation to Agriculture", for the students of the Department of Agriculture, its teaching began, most likely, in 1902 or even later. Without a doubt, from the beginning, it was necessary for the students of this department to study the academic discipline "Elementary Mechanics", which was foreseen by the "Regulations" and "Statute" of the university, precisely in the III year, and this was carried out by the acting extraordinary professor of the Department of Mechanics, mechanical engineer Schindler K. G., who was employed at the Kyiv Polytechnic Institute since September 1, 1899. It was during this period that Kyiv Polytechnic Institute was forced to vacate the premises of the Commercial School and relocate to the building of its own chemical building.

In this connection, a completely logical and fundamental question arises: "Since the educational subject, i.e.: mechanics in adaptation to agriculture, was intended only for students of the Agricultural Department (as defined in the "Regulations" and "Statutes" of KPI, i.e. official documents of that time), but higher mathematics, descriptive geometry, theoretical mechanics, applied mechanics (theory of mechanisms and machines, resistance of materials, machine parts, etc.) and mechanical engineering (fundamentals of design and construction, machine mechanics, production technology, etc.) they will not study (also according to

these official documents), then what kind of "mechanics in agriculture" can we talk about when training agronomist scientists? And therefore, only an elementary study of the basics of mechanics, only familiarization with the designs of existing agricultural machines, only a possible demonstration of the operation of these machines in the field! This situation still exists in agricultural universities of Ukraine during the training of agronomic specialists (they very briefly study the descriptive course of agricultural machines), but now only without demonstrating their work in the field.

On the other hand, the subject "Mechanics in Adaptation to Agriculture" was not at all intended to be studied according to the "Regulations" and "Statute" of KPI by the students of the Mechanical Department who studied according to their program. But after some time, it was introduced and began to be taught in this department in the IV year, as a subject called "Agricultural mechanical engineering" or "Agricultural mechanical engineering". However, the Kyiv Polytechnic Institute did not train mechanical engineers specifically for agriculture, but only technological engineers for other various branches of industry and transport.

So, it turns out that for the students of one of the departments of KPI, the subject "Agricultural mechanical engineering" or "Agricultural mechanical engineering" (as they were later called) was almost superfluous, actually unnecessary during education (what is the benefit of studying this subject for agronomists, soil scientists, animal breeders, veterinarians and economists?), and for students of another department, i.e. Mechanical, these subjects may be useful for general familiarization with the designs and technologies of industrial production of agricultural machines and tools, but to train mechanical engineers for this branch of production (especially engineers, who would work directly in agriculture) was not foreseen according to the existing training programs.

In addition, it should be clearly understood that the content of the academic disciplines "Mechanics in adaptation to agriculture" (or agricultural mechanics) and "Technology of the production of agricultural machines themselves", or "Agricultural engineering" are essentially different subjects. And therefore these subjects for teaching at a polytechnic institute had to be distinguished in the training of different specialists. In the first case, it is the study of technological processes carried out with the help of agricultural machines or tools and their working bodies and the study of their interaction with the soil, plants or other agricultural environment, and these processes take place in the field, on the farm, on the farm, etc. And that is why it is necessary to study the technological regularities of the interaction of working bodies with processing objects, that is, what will be the properties and what will be the condition of the soil, plants, and animals. In the second case, it is a study of the basics of design, construction and industrial production of the same machines and tools at a machine-building plant or at some industrial enterprise. Here it is already necessary to study the basics, based on which preliminary calculations of machines and tools (as well as their constituent elements) can be carried out during construction for strength, wear, questions regarding the selection of materials for working bodies, as well as to know the machines and equipment that will be used in the manufacture. That is, it is necessary to study the technology of manufacturing the components of machines, as well as their subsequent assembly, debugging, and regulation, which should be used in the mass industrial production of this or that agricultural machine.

If we look at such an obvious contradiction, then it is most likely to assume that something similar to the "average" was initially chosen within the walls of the Kyiv Polytechnic Institute: in the main building (and that is where the Agricultural Department was located) students studied "pure" mechanics (or as defined in the Charter for the Agricultural Department – elementary mechanics), and at the Machine Testing Station real designs of existing agricultural machines and tools were studied during practical classes and were shown working in the field,

although the educational subjects had different names. All the more so since the specified official documents of that time "Regulations" and "Statutes" of KPI state that ["Teaching is accompanied by exercises and practical classes in educational and auxiliary institutions." (the original language of the document)], to which since 1902 ["Station for testing agricultural machinery and tools." (original language of the document)] and it was there that practical classes in this academic discipline were to be held. Therefore, to say that within the walls of the Kyiv Polytechnic Institute from the beginning of its establishment, as it were, trained agricultural engineering engineers is, unfortunately, a regrettable mistake of modern historians.

On the basis of a thorough study of the teaching staff of KPI for each academic year, it was established that K. G. Schindler, acting extraordinary professor of the Department of Mechanics, began to teach students of the Department of Agriculture a course on elementary mechanics and did so until the end of the 1900–1901 academic year.

However, it should be assumed that the mechanical engineer K. G. Schindler, acting as an extraordinary professor of the Department of Mechanics even at that time and not yet an adjunct at KPI, began to feel the above-mentioned contradiction, since already in the 1903–1904 academic year he began to teach for students who have just become students of the III and IV courses, the following educational disciplines, namely: agricultural machines for students of the III and IV years of the Agricultural Department and agricultural machines for students of the IV year of the Mechanical Department. This is the same training course for two different departments, since it is not known how "agricultural machines" differ from "agricultural machines", and therefore, obviously, such a different name for essentially the same courses was artificial. At the same time, since 1903–1904, he has been in charge of drawing up special projects (most likely, we are talking about course projects) at the Agricultural Department. It was also noted that the mechanical engineer Schindler K. G. leads practical classes on agricultural mechanical engineering in the III and IV courses of the agricultural department. It should be noted that in this academic year and beyond, he is no longer listed as a lecturer (or teacher) of elementary mechanics at the Agricultural Department. In addition, there were no educational disciplines with the name "Agricultural Mechanical Engineering" at that time.

Therefore, during the first five years from the day of the foundation of KPI, the appropriate adjustment of the educational programs took place, due to which in the last courses of study, students of two departments, Agricultural and Mechanical, began to study at once several educational disciplines in the field of agricultural machinery with different names (but the same in essence). It should be assumed that the students of the Agricultural Department studied only the structure of most agricultural machines, most likely using the Atlas developed for this purpose and published in 1902 by K. G. Schindler. This assumption is the most reliable, since for future agronomists, soil scientists and veterinarians in the form of sketches and schemes of agricultural machines and tools, which were manufactured at that time in the world, it was the most simple and convenient to study them. In addition, in the practical classes that Schindler K. G. conducts with students of the last years of the Department of Agriculture on the subject called "Agricultural Machine Science", he tries to involve future agronomists in some initial elementary foundations of their theory and calculation. Most likely, during practical classes, students at that time gained knowledge of soil tillage machines and learned to draw plow bodies, made drawings on the rotation of soil strips during plowing, etc. The students of this department did not need more in-depth knowledge of agricultural mechanics. Special projects, which were carried out by students most likely and were devoted to drawing the shelves of plows, probably the working bodies of planters and potato diggers, etc. As for the students of the last years of the Mechanical Department, when studying agricultural machines, they most likely received the same knowledge of the initial

foundations of the theory and construction of plowing tools, since K. G. Schindler had already written and almost finished his own monograph on this topic. It was at this time that he performed the duties of the dean of the agricultural department, where he was appointed on August 1, 1904, and definitely had the right to adjust the educational programs with his own hands.

In the following 1904–1905 academic year, the dean of the Agricultural Department and acting extraordinary professor of the Department of Mechanics, mechanical engineer Schindler K. G. performs the same pedagogical work in two departments and manages the station for testing agricultural machines and tools. In addition, he prepares and on October 14, 1905, at the meeting of the Institute's Academic Council, he defends his own scientific work "Theory and Construction of Plowing Tools" and receives the title of adjunct of the Kyiv Polytechnic Institute.

In the following years, in particular in the academic year 1906–1907, Schindler K. G. was no longer the dean of the agricultural department, but left the position of extraordinary professor at the department of mechanics. Protected scientific work and receiving the title of associate professor of KPI gave him such an opportunity. As before, he gives lectures for students of the two departments mentioned earlier, but at the same time, he introduces new courses to the students of the Agricultural Department, in addition to the existing ones, in particular, "Mechanical Science" and "Theory of Agricultural Machines and Tools", "Fundamentals of Mechanical Science", "Machines-tools", "Machines-engines". That's when a new subject called "Mechanical Engineering" is introduced in the Mechanical Department. As we can see, the range of subjects for study by students in the field of agricultural mechanics and agricultural engineering at KPI is gradually expanding, which indicates a significant increase in the knowledge and competencies of graduates of the Kyiv Polytechnic Institute. In addition, it is during this period that Schindler K.G. leads practical classes at the station for testing agricultural machines, and also begins to manage the diploma theses of students of the Department of Agriculture. Therefore, it should be assumed that during the management of the Department of Agriculture, as a dean, Schindler K.G. proposed the completion of diploma theses for a certain group of future scientists-agronomists, in accordance with their desire to more broadly and confidently possess knowledge in the engineering field of agriculture. Although even then future agronomist scientists needed only initial, actually familiar knowledge of agricultural machines, for which their descriptive course was suitable.

In the following academic years, in particular in the 1908–1909 academic year, K. G. Schindler already works as a full professor in the Department of Mechanics, which he received on November 14, 1906, continues to teach all the previously listed academic disciplines, manages special and diploma projects. In addition, studying the designs of various agricultural machines at the Machine Testing Station, which was managed by K.G. Schindler, was very useful for the students of the Mechanical and Agricultural Departments, since not only the visual perception of their real designs, but also the visual demonstration of work in the field gave incomparable advantages in the students' acquisition of knowledge and acquisition of the necessary competencies. At the same time, students of both departments were involved in the tests themselves, performing work on the adjustment of various agricultural machines during their preparation for the tests, participating in various adjustments, setting up devices, obtaining the results of the tests themselves, during measurements, etc. In 1908, the appointment of K. G. Schindler as the dean of the Mechanical Department gave him the opportunity to introduce here in larger volumes educational disciplines and the implementation of special and diploma projects in the field of agricultural engineering. It should be assumed that it was at that time that the work of this scientist in the field of education was very fruitful and, most likely, the time could not be far off when a new separate department (or a new faculty) should be opened at the Kyiv Polytechnic Institute, which would exclusively prepare engineers-designers of agricultural machines, or mechanical

engineers of agricultural production. But the unexpected and forced dismissal of K. G. Schindler from the position of dean of the Mechanical Department of the Kyiv Polytechnic Institute in early February 1911 most likely prevented this.

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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).

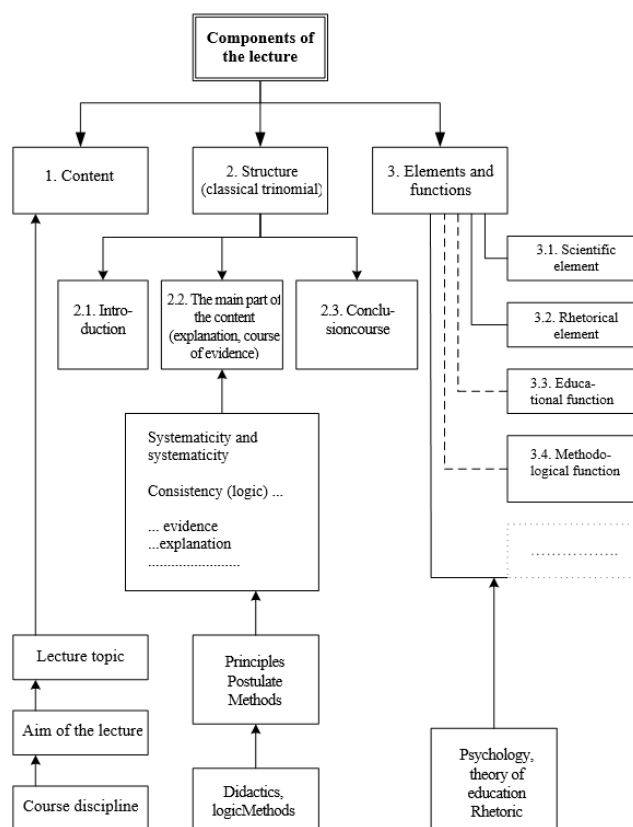


Figure 1. Lecture construction scheme

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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Low intensity fertilization with organic and complex mineral fertilizers and their influence on the organic matter content of haplic chernozems

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Abstract: The use of complex mineral, organo-mineral and organic fertilizers on Haplic Chernozems for 8 years leads to changes in the composition of soil organic matter. Certainly the organic fertilizer Excell^{Orga} and its combination with the complex mineral fertilizer Suprefos increase the content of soil organic carbon, and humic acids, related with calcium. A positive trend is also the increase of carbon in insoluble residue. A statistically reliable positive influence of organic and organo-mineral fertilization on individual groups and fractions compared to those in the control variant was established. The trend is especially well expressed on the carbon values of humic acids and those related to calcium. This leads to a sustainable level of humification and an increase in the share of agronomically valuable groups and fractions in the organic carbon of the soil.

KEYWORDS: ORGANIC, ORGANIC-MINERAL AND MINERAL FERTILIZATION WITH COMPLEX FERTILIZERS, ORGANIC CARBON, GROUP AND FRACTIONAL COMPOSITION OF SOIL ORGANIC MATTER

Introduction

Soil is one of the most important natural resources and is the basis of life on the planet. In addition to productivity and quality requirements, modern managed ecosystems face a number of challenges - regulating and conserving water flow, protecting its physico-chemical properties, soil organic matter and its genetic potential.

The main component of soil organic matter is the general hemes substances, which are characterized by high biological activity. From a chemical point of view, they are heteropoly (oligo)mers having different molecular weights. They are a very important structure former of the individual fragments of organic macromolecules [1]. The application of modern agrotechnical practices, regardless of the method of agricultural production - conventional or biological, require not only maintaining, but also increasing the content of organic C in the soil [2].

For decades, research at the DAI-G. Toshevo has included this topic in its scientific program, including the influence of the ways of utilizing the plant remains of the predecessor on the state of soil fertility [3-12].

The purpose of the present study is to characterize the changes in the concentration of organic carbon in the soil, as well as the changes occurring in the composition of the soil organic matter as a result of the application of complex mineral, organo-mineral and organic fertilizers.

Materials and Methods

In the experimental field of Dobrudzha Agricultural Institute - General Toshevo on Haplic Chernozem, in a long-term study, the influence of fertilizers for basic soil fertilization - Suprefos and ExcellOrga - was studied. The experiment is a continuous wheat monoculture and does not include the application of nitrogen fertilizers during the growing season. Suprefos is a combined mineral fertilizer containing: 12% N; 24% P₂O₅; 0.5% Mg; 14% Ca; 25% S. The all-organic fertilizer ExcellOrga is manufactured by Angibaud & Specialites (France). It represents composted waste from the fishing industry and guano, and its composition is 50% organic matter, org.N-4%, P-2%, K-6%, Mg-3%. It is produced in the form of pellets - 6 mm. Fertilizers were applied before the last pre-sowing treatment of wheat at the rate of 350 kg/ha (physical). The experimental setup consists of 4 backgrounds of soil fertilization: 1. Control; 2. Mineral Fertilization (Suprefos -350 kg/ha)-MF; 3. Organo-Mineral Fertilization (Suprefos + Excel^{Orga} (175+175 kg/ha)-OMF and 4. Organic Fertilization (Excel^{Orga} 350 kg/ha)-OF.

At the end of the study, the changes in the group and fractional composition of the organic matter were tracked. From the tested variants, soil samples were taken in three replicates from the layers 0-20 cm, 20-40 cm and 40-60 cm.

To determine the composition of soil organic matter, we used the method of Kononova-Belchikova [13;14]. The carbon content (C%) was determined by the modified Tyurin method (oxidizing with K₂Cr₂O₇/H₂SO₄ solution in thermostate at 125° C, 45 min, in the presence of Ag₂SO₄ and titration with (NH₄)₂SO₄.FeSO₄.6 H₂O [13; 15]. The methods of Konnova [14] and Filcheva & Tsadilas [16] were used to determine the composition of soil organic matter by groups.

Results and Discussions

Before discussing the obtained results, it is necessary to recall some of the characteristic features of the soils in the area. Southern Dobrudja, according to its geomorphological zoning, refers to the Danube epiplatform plain. It is distinguished by a low layer-denudation and accumulation relief. The Southern Dobrudja Plateau is formed by Sarmatian limestones. According to Ismail & Dimov [17] the emergence of the modern black soil dates back to the middle of the Bronze Age (III millennium BC). Medium-thick leached and weakly leached chernozems, developed on loess-like, sandy clays and loess, layered on highly fractured Sarmatian and Lower Cretaceous limestones, prevail. Their characteristic feature is their more pronounced washing regime and more powerful profile compared to carbonate and typical chernozems. In some areas, the humus-accumulative horizon can reach 80 or more than 80 cm.

The results of the analyzes of the variances of the composition of the soil organic matter (SOM) along the depth of the humus-accumulative horizon up to 60 cm show the strong influence of the nutrient regime of the soil created by fertilization (Table 1). Both tested factors influence the values of the tested indicators, and the types of fertilizers included in the study for basic soil fertilization with maximum statistical reliability influence all the tested indicators characterizing the composition of the SOM. Depth as a factor in the study has a strong impact on some of its main characteristics - C_{org}, THS, FA, HA_{R2O3}, HA_{Ca} and C_{residue}. This, in turn, affects the credibility of the interaction between the two factors. The same is most clearly expressed for fulvic acids at an early stage of formation, free and associated with - R₂O₃, as well as their share relative to C_{org}. The proven influence of the interaction between the factors on THS, HA, HA_{Ca}, HA/C_{org}, C_{residue}/C_{org} also deserves significant attention.

The eight-year application of the tested fertilizers reflects not only the absolute values of carbon in individual groups and fractions, but also their share relative to the organic C of the soil, respectively humus. For the most part, the tested indicators are subjected to statistically reliable changes, which are preserved according to the depth of the root-inhabited horizon.

The used fertilizer products have a significant influence on the values of Sorg compared to the control variant (Table 2). In the surface layer 0-20 cm OMT and OT definitely lead to its increase compared to the variant with MT. Fertilization with the tested fertilizer products has a positive effect on Sorg values in the 40-60 cm layer as well.

Table 1. Analysis of the variances of the indicators characterizing the composition of SOM by depth and depending on the type of fertilizers used

Dependent Variable	Depth (1)			Fert. variants (2)			1 x 2		
	df	F	Sig.	df	F	Sig.	df	F	Sig.
C _{org} (Organic Carbon)	2	69,809	,000***	3	12,293	,000***	6	,881	,515 ^{NS}
FA _{agr} (Agressive Fulvic Acids)	2	3,412	,039*	3	72,101	,000***	6	4,041	,002**
THS (Total humic substances)	2	15,074	,000***	3	7,737	,000***	6	2,767	,019*
HA (Humic acids)	2	1,982	,147 ^{NS}	3	9,445	,000***	6	2,338	,043*
FA (Fulvic acids)	2	9,917	,000***	3	29,977	,000***	6	,179	,982 ^{NS}
HA/FA ratio	2	2,973	,059 ^{NS}	3	16,088	,000***	6	,466	,830 ^{NS}
HA _{R2O3} (connected with sesqui oxides)	2	106,439	,000***	3	11,198	,000***	6	1,243	,297 ^{NS}
HA _{Ca} (connected with calcium)	2	5,937	,004**	3	15,719	,000***	6	2,597	,026*
C _{residue} (insoluble residue)	2	11,787	,000***	3	21,574	,000***	6	1,978	,083 ^{NS}
FA _{agr} /C _{org}	2	3,933	,025*	3	54,956	,000***	6	4,973	,000***
THS/C _{org}	2	,154	,857 ^{NS}	3	16,455	,000***	6	2,644	,024*
HA/THS	2	2,894	,063 ^{NS}	3	26,814	,000***	6	,381	,888 ^{NS}
FA/THS	2	2,894	,063 ^{NS}	3	26,814	,000***	6	,381	,888 ^{NS}
HA/C _{org}	2	1,816	,171 ^{NS}	3	6,427	,001***	6	2,622	,025*
FA/C _{org}	2	3,523	,036*	3	34,304	,000***	6	,186	,980 ^{NS}
HA _{R2O3} /HA	2	43,713	,000***	3	19,322	,000***	6	1,581	,168 ^{NS}
HA _{Ca} /HA	2	43,713	,000***	3	19,322	,000***	6	1,581	,168 ^{NS}
C _{residue} /C _{org}	2	,154	,857 ^{NS}	3	16,455	,000***	6	2,644	,024*

Table 2. Content of organic C in individual groups and fractions of POV by soil layers depending on the type of fertilizers used

Fert. variants	Depth, cm	C _{org}	FA _{agr}	THS	HA	FA	HA/FA	HA _{R2O3}	HA _{Ca}	C _{residue}
Control	0-20	1,7785 a	,0353 a	,9549 b	,6061 a	,3488 b	1,83 a	,3205 b	,2856 a	,8236 a
	20-40	1,7473 a	,0353 a	,9383 b	,6061 a	,3322 b	1,90 a	,2657 b	,3404 a	,8090 b
	40-60	1,5951 a	,0311 a	,7844 ab	,5148 a	,2696 b	2,13 a	,1777 a	,3371 a	,8106 ab
MF	0-20	1,8305 a	,0398 b	1,0144 c	,6958 b	,3186 b	2,34 ab	,3152 b	,3806 b	,8161 a
	20-40	1,7606 a	,0377 a	,9892 b	,6539 ab	,3353 b	1,97 a	,2649 b	,3890 ab	,7714 a
	40-60	1,6104 a	,0377 b	,8970 b	,6371 ab	,2599 b	2,49 a	,1760 a	,4611 a	,7134 a
OMF	0-20	1,9283 b	,0563 d	,9345 ab	,7259 b	,2086 a	3,82 b	,2720 a	,4539 b	,9939 b
	20-40	1,8200 a	,0459 b	,8635 a	,6841 b	,1794 a	3,90 b	,2186 a	,4655 b	,9565 c
	40-60	1,6349 a	,0542 d	,7424 a	,6091 a	,1333 a	5,40 b	,1769 a	,4322 a	,8925 b
OF	0-20	1,9353 b	,0501 c	,8927 a	,6858 b	,2069 a	4,20 b	,2770 a	,4089 b	1,0426 b
	20-40	1,8375 a	,0528 c	,8886 a	,6842 b	,2044 a	4,00 b	,2002 a	,4839 c	,9489 c
	40-60	1,7190 a	,0459 c	,9119 b	,7692 b	,1427 a	5,48 b	,1352 a	,6340 b	,8072 ab

As a result of fertilization, changes also occur in the values of total humic substances (THS), with their absolute values being the highest in the 0-20 cm layer in the variant with MF application. Their certain reduction was found when using OT. At the same time, in comparison with the control variant and the one with MT, an increase in CHA and a decrease in SFC were observed in the variants with the use of organo-mineral and organic fertilizers. This fact applies to all three studied layers by profile depth. Ultimately, there is a change in the HC/FC ratio. From the fulvate-humate type in the control variant (0-20 and 20-40 cm) the values increased more than 2 times and in the variants with the use of OMF and OF the type of humus is already markedly humate.

Changes were found in both main fractions of HC - free and sesquioxide-bound oxides and those with calcium. In the variants with OMF and OF, C of HA_{R2O3} decreases along the profile depth compared to those found in the control variant. At the same time, a positive trend was expressed for the increase of those related to calcium. Positive changes in the direction of increasing C_{residue} were also found when using OMF and OF in the 0-20 and 20-40 cm layers.

Soil organic carbon in the 0-20 cm layer is in very strong positive correlations with C_{residue} and HA_{Ca} carbon (Table 3). A clear correlative relationship with the most dynamic and low molecular fraction of organic matter, called the fraction of "aggressive" fulvic acids" (0.807**) was also established. In the 20-40 cm layer, the correlations keep their direction, but the correlation values slightly decrease. In the layer below, a large part of the correlations between C_{org} and the index characterizing the composition of the POV are statistically unreliable. However, at this depth, the correlation between C_{org} and HA and between C_{org} and HA_{Ca} still remains very well pronounced. Correlative dependencies between C_{residue} and other indicators characterizing the composition of the POV are also clearly expressed.

Throughout the studied depth, carbon of the insoluble residue is strongly negatively correlated with THS, FA HA_{R2O3}.

One of the main characteristics of SOM - C_{org}, THS and C_{residue} clearly show that their values gradually decrease with depth of the investigated layers (Fig. 1). The constituent components of THS - HA and FA also show a tendency to decrease along the depth of the profile. The established changes in HA are unreliable. However, FA carbon has higher values in the surface layers and at a depth of 40-60 cm it reliably decreases. On average for the tested factors in the experiment over the entire studied depth, the type of humus is markedly "humate".

The obtained results show that the slightly leached Chernozem in this section retains a high degree of humification of the organic matter - from 36.31% (0-20 cm) to 38.58% (40-60 cm). The presented results give us an opportunity to obtain information about the behavior of the HC fractions. With depth, the sesque-related HA oxides decrease, and the differentiation by layers is very well expressed. The fraction bound to calcium inversely increases. In the surface layer 0-20 cm their level is defined as "average" (56.34%), while in the following layers according to Orlov and Grishina [18] is defined as "high" and reaches 73.68% of the THS.

The tested types of fertilizers for the period of their application also influence the studied indicators (Fig. 2). Application of complex mineral fertilizer does not lead to proven changes in C_{org}. The application of OMF and OF increased the values of the indicator by 5.1% (1.794%) and 7.2% (1.831%) compared to the control (1.707%), respectively. Regarding THS, the differences are insignificant, only the variant using MT stands out, where the increase is credible. The carbon of the insoluble residue (humus, or also called the "guard" of the humus) shows a tendency towards a reliable increase in the variants with the introduction of OMF and OF.

Against this background, the used fertilizer products lead to changes in the carbon values of HA and FA. The most significant increase was found in the use of OF, where the increase was 23.8% compared to the control variant. In the case of FA carbon, the differentiation in the average values for the study period is less pronounced.

The variants using OMF and OF were distinguished by lower levels of FA carbon compared to the control and MF. This, in turn, leads to the formation of a fulvate-humate type of humus in the control variant and a gradual increase in the values of the HA/FA ratio. This fact leads to consolidation of the "humic" type of humus of this soil type.

Table 3. Correlations between C_{org} and some indices, characterizing soil organic matter composition in depth layers (Pearson Correlation)

Indices	OrgC			THS			$C_{residue}$		
	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
C_{org}	1	1	1	-,579(**)	-,0285	,504(*)	,919(**)	,757(**)	0,335
FA_{agr}	,807(**)	,462(*)	0,335	-,0364	-,590(**)	0,031	,692(**)	,662(**)	0,263
THS	-,579(**)	-,0285	,504(*)	1	1	1	-,854(**)	-,842(**)	-,645(**)
HA	,586(**)	,616(**)	,646(**)	-,0098	-,0008	,833(**)	,422(*)	0,352	-,0337
FA	-,786(**)	-,637(**)	-,0323	,726(**)	,702(**)	0,159	-,853(**)	-,837(**)	-,460(*)
HA/FA	,737(**)	,597(**)	0,276	-,795(**)	-,547(**)	0,073	,855(**)	,709(**)	0,164
HA_{R2O3}	-,591(**)	-,406(*)	0,153	,522(**)	,699(**)	0,085	-,630(**)	-,705(**)	0,042
HA_{Ca}	,644(**)	,617(**)	,578(**)	-,0261	-,0328	,774(**)	,538(**)	,571(**)	-,0333
$C_{residue}$	,919(**)	,757(**)	0,335	-,854(**)	-,842(**)	-,645(**)	1	1	1

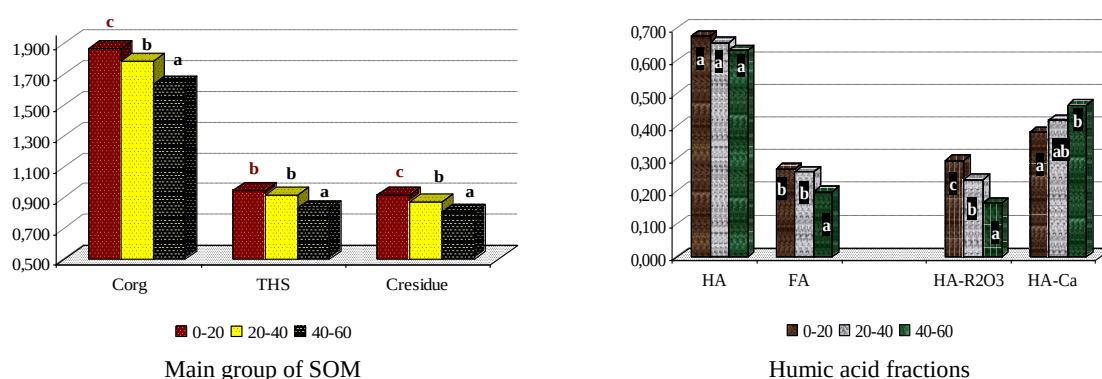


Figure 1. Composition of SOM depending on the depth of the studied layer, C%

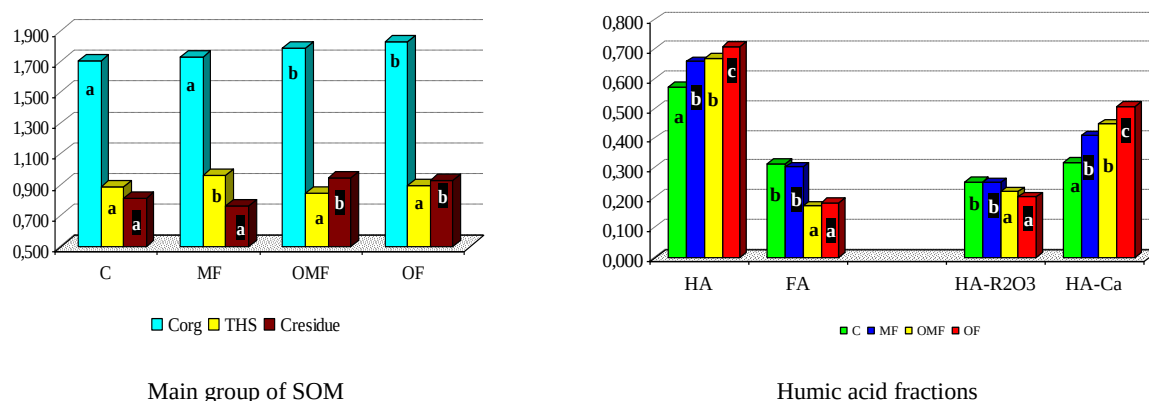


Figure 2. Composition of SOM depending on the type of fertilizers used for main fertilization, C%

The degree of humification of SOM is between 30 and 40% and is defined as "high". However, the differences between the tested fertilizer variants compared to the control are very well expressed, with the use of OF approaching a "very high" rating. Another positive trend is observed, expressed in an increase in the carbon of calcium-related HA, as well as their share of total HA and that in soil organic carbon.

Of the many correlative dependencies between the complex of tested indicators, we present the most clearly and reliably standing out (Fig. 3).

A well-expressed negative correlation was established between the "aggressive" FA and the group of FA, as well as between the fractions of HA associated with sesquioxides and those associated with Ca. The highest positive correlation was found between the HA group and the fraction of the same related to Ca. The correlative dependence of the latter with the HA/FA ratio is also high. A strong positive correlation between $C_{org} - C_{residue}$ was also found.

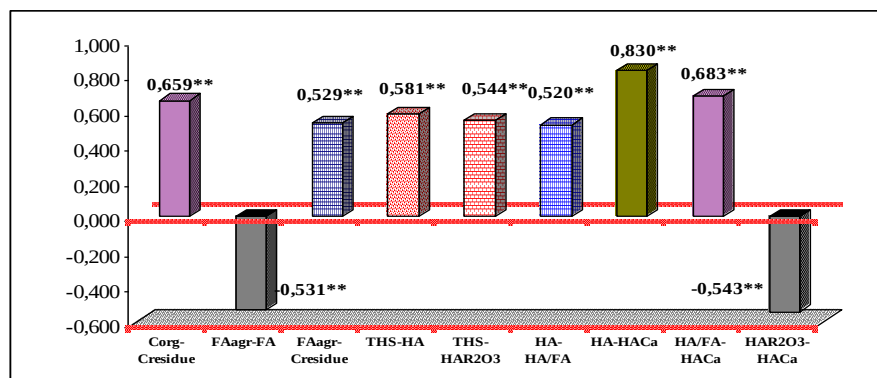


Figure 3. Strong correlative relationships between some of the components characterizing the composition of the SOM (Pearson Correlation)

Conclusions

The long-term application of different types of fertilizer products leads to changes in the organic carbon of the soil at the depth of the root layer. The upper soil layers 0-20 cm and 20-40 cm are richer in organic carbon, in total humic substances and in insoluble residue compared to the 40-60 cm layer.

In addition to the depth of the studied profile, differences were found depending on the type of tested fertilizer products. Certainly the organic fertilizer Excell^{Orga} and its combination with the complex mineral fertilizer Suprefos increase the content of soil organic carbon, and humic acids, related with calcium. A positive trend is also the increase of carbon in insoluble residue. A statistically reliable positive influence of organic and organo-mineral fertilization on individual groups and fractions compared to those in the control variant was established. This trend is especially well expressed on the carbon values of humic acids and those related to calcium. This leads to a sustainable level of humification and an increase in the share of agronomically valuable groups and fractions in the organic carbon of the soil.

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Обща характеристика на почвите в градските зелени площи на Кърджали и здравословно състояние на растителността

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Резюме: Градските зелени пространства предоставят редица екосистемни услуги за местните общности, но тези екосистеми са засегнати от комплекс от въздействия – както естествени, така и антропогенни. Продуктивният потенциал на почвите се определя от почвените характеристики и климатичните условия на регионално ниво. Междувременно антропогенното въздействие може да предизвика промени и да улесни процесите на деградация и ерозия в почвите. Следователно анализите на общите характеристики на почвите в градските зелени площи ще позволят прилагането на подходящи практики за управление на почвата и за възстановяване на здравословното състояние на парковата растителност. Очертани са трансекти в два градски лесопарк „Арпезос“ и „Простор“ в Кърджали и са взети проби от повърхностния 0-10 см почвен слой в пет точки /прикопки/ на трансект в период от 5 години (2019-2024). Общите характеристики на почвата са анализирани по стандартните методи. Получените резултати показват влошено структурно състояние на изследваните почви и протичащи процеси на алкализирание. Установена е силна вариация в съдържанието на органично вещество в почвата, което е в пряка връзка с прилаганите мелиоративни практики. Екологичното състояние на почвата по отношение на съдържанието на тежки метали е добро. Заключение е, че анализът на почвата е от решаващо значение за предлагане на подходящи действия за подобряване на състоянието на градските зелени площи. Появата на нови инвазивни болести и вредители в зелените зони на град Кърджали се определя като отрицателен ефект, който се увеличава по честота и въздействие върху дървесните и храстови видове, които определят естетическата визия и доброто здраве и социален статус на жителите и посетителите на града.

Ключови думи: ГРАДСКИ ЗЕЛЕНИ ЗОНИ, ПОЧВИ, ДЪРВЕСНА РАСТИТЕЛНОСТ

1. Въведение

В последните десетилетия екологичните проблеми на градската среда се задълбочават поради климатичните изменения, нарастващата концентрация на градското население и свързаната инфраструктура, глобалното замърсяване на околната среда. Ефектите, които се проявяват в градските зелени зони, са свързани с изменение на биоелекологичните условия, необходими за поддържане на дървесната растителност в добро физиологично състояние. Продуктивният потенциал на почвите, основна компонента в урбанизираните зелени системи, зависи от техните свойства и от климатичните условия на регионално ниво. Антропогенното въздействие може да предизвика или усилва процеса на ерозия и деградация на почвата. В резултат на понижаване на тяхната устойчивост се наблюдава увеличаване на вредното въздействие на биотични агенти (насекомни вредители и гъбни патогени).

За пространственото планиране и устройство на урбанизираните територии не е достатъчно да се оцени само състоянието на зелените системи и предоставяните услуги, като се пренебрегва анализът на почвите и присъствието на вредни абиотични и биотични фактори. Интегрираният подход на комбинирана оценка на състоянието на зелената инфраструктура в урбанизираните екосистеми, екосистемните услуги и вреди се приема като надеждна концепция при териториалното планиране в дългосрочен план [1].

Необходимостта от поддържане на зелените зони в добро здравословно състояние е най-значима в силно урбанизирани и гъсто населени райони, каквито са областните градове.

Целта на проучването е да се извърши оценка на състоянието на основните характеристики на почвите в урбанизирани зелени зони в района на град Кърджали във връзка с фитосанитарното състояние на дървесната и храстова растителност в тях, чрез използване на интегриран подход.

2. Материали и методи

В периода 2019-2024 г. се проведеха теренни обследвания и пробонабиране в района на град Кърджали. Взаимодействието между естествените физико-географски условия, определени от местоположението на гр. Кърджали в Източните Родопи и антропогенните фактори, резултат от човешката дейност, влияят различно върху комфортността на обитаване в различните части на града. Обект на проучването са зелени

зони в паркови територии, в които са обособени пробни площадки за оценка на почвите и надземната дървесна растителност.

Парк „Арпезос“ е най-новият парк в гр. Кърджали, открит през септември 2012 г. и е част от цялостен проект за благоустройството на тази част от града, изграден по коритото на главния градообразуващ фактор – река Арда.

Парк за отдих и култура „Простор“ е възникнал като парк за култура и отдих на населението на гр. Кърджали. Създаден е през периода 1958-1959 г. в източната част на града. Замислен изцяло като спортен парк с игрища за волейбол, баскетбол, хандбал и тенис, сега единствено стадионът и отчасти „алеята на здравето“ са спортните площи в парка.

През 2019 и 2024 г. посредством прилагане на единна методика са събрани и анализирани са проби от повърхностния 0-10 см почвен слой по продължение на трансект, преминал от центъра към периферията на двете проучвани зелени зони. Събрани са проби в две повторения от пет точки по трансекта – с общ брой от 10 проби на зелена зона, покриваща пространствената променливост в локален мащаб. Пробонабиране и анализ на параметрите е извършено и през 2024 г. по същия дизайн. За определяне на основните почвени свойства са анализирани средни проби за всяка точка [2, 3], а стойностите са усреднени за съответната зелена зона за двете години, като е определено стандартното отклонение (SD). Определени са следните параметри на почвата: почвена киселинност pH, обемна плътност, текстурата на почвата по Качински [4], органичен въглерод (орг. C) по метода на Тюрин, въглероден запас [5,6]; общ азот N по Kjeldal [7]. Концентрациите на макро- и микроелементи в почвите са определени по стандартните процедури [8] и анализирани с оптичен емисионен спектрометър модел ICP-Varian 715-ES.

Здравословното състояние на дървесната и храстова растителност е оценено в 14 постоянни пробни площи – седем в градски парк „Арпезос“ и седем – в Парк за отдих и култура „Простор“. Здравословното състояние на дървесната и храстова растителност е оценено въз основа на комплексната оценка, включваща показателите процент на обезлистване и промяна в оцветяване на короните. Отчетени са повреди по листата, стъблата, клоните и младите леторасли, причинявани от насекомни вредители и патогенни микроорганизми. В отделните обекти са оценявани минимум 10 индивида от всеки

вид, с изключение на случаите, в които броят на растенията е бил по-малък.

Оценката е извършена по методиката на международната кооперативна програма „Гори“ (ICP Forests) като са оценени повредите, причинени от насекоми вредители и гъбни патогени по листа, стъбла, корени, клони и млади леторасли. В допълнение са отчитани показатели като:

- наличие на изсъхнали, съхнещи или гнили дървета, застрашаващи живота и здравето на хората;
- проникване на инвазивни видове;
- наличие на дървета със симптоми на опасни заболявания или заселвания от високоагресивни ксилофаги, представляващи заплаха за околните насаждения.

За извършване на лабораторни анализи е събран биологичен материал (проби от листа/иглици, клонки, леторасли, пъпки; стъбло и кора), и отнесени в Лабораториите по ентомология и фитопатология в Институт за гората, София. Идентифицирането на гъбни патогени е осъществявано чрез макроскопски и микроскопски наблюдения на плодни тела и спори с помощта на микроскоп Zeiss NU2 и бинокюлар Zeiss Ssemi 305, изолирани са мицелни култури върху изкуствена хранителна среда и др.

Зелената инфраструктура в избраните паркове е заснета с мултиспектрална камера „Parrot Sequoia“, интегрирана със специализирана професионална летяща система „Flying Wing“. Мултиспектралната камера даде възможност за събиране на специализирана информация за състоянието на зелената инфраструктура в градските райони по изключително ефективен начин. Допълнително беше извършена проверка на място за оценка на състоянието на короната на основните дървесни видове в заснетите площи.

За оценката на физиологичното състояние на заснетите зелени територии е използван NDVI (Normalised Difference Vegetation Index), получен чрез цифрово смесване на изобразения, заснети в червения (Red) и близкия до инфрачервения (NIR) диапазон и е изчислен по следната стандартна формула:

$$NDVI = (NIR - Red) / (NIR + Red)$$

NDVI е спектрален индекс, използван за оценка на състоянието на растителността поради поглъщане на хлорофила на специфични дължини на вълната на светлината в червения спектрален диапазон и висока коефициент на отражение в рамките на близкия до инфрачервения диапазон. Индексът варира между -1,0 и +1,0. Зелената растителност обикновено има стойности между 0,3 и 1,0.

3. Резултати и дискусия

3.1. Обща характеристика на почвите в урбанизираните зелени зони „Арпезос“ и „Простор“ в гр. Кърджали

Почвите от проучените два обекта, които са част от градската зелена инфраструктура на Община Кърджали, са формирани под влияние на човешка дейност, в резултат на която са настъпили съществени промени в генетичните им признаци и свойства. Разпространението на антропогенните почви (Anthrosols) има интразонолен характер в зависимост от конкретното локално въздействие на антропогенния фактор, който се проявява в две насоки: изменение на естествените почви или образуване на „нови“ почви. В настоящото проучване типът антропогенни почви, на базата на основните направления на антропогенно въздействие, морфологични особености на профилите и по качествени и количествени характеристики на някои диагностични свойства, е представен от вида почви Урбаногенни (Urbic). Има редица специфични особености, които отличават урбаногенните почви от

естествените почви, които за парк „Арпезос“ са алувиални, пясъчливи и пясъчливо-глинести, а за централен градски парк са излужени канелени горски, според базовата класификация на почвите в България [9]. Факторите, които определят тези специфични особености са: големината на населеното място, технологията на създаване, ползване и поддържане на зелените площи, като прилагане на тежка механизация, утъпкване, често прекопаване, неправилно поливане и торене, интензивно косене, изнасяне на тревата, събиране и изнасяне на листния опад, натрупване на сняг, примесен със сол. При тези условия, в по-старите паркове или крайградските паркове и спортни зони, антропогенизацията в зелените площи се проявява само в горната част на профила на естествените почви.

Почвите в изследваните градски горски паркове се отнасят към Luvisols и Anthrosols [9, 10], както е представено в таблица 1.

Таблица 1: Почви в зелени зони в гр. Кърджали

Зелена зона	Почвен тип	
	Класификация [9]	WRB [10]
„Арпезос“	Урбаногенна с карбонати	Urbic Anthrosols
„Простор“	Канелена горска почва, излужена	Haplic Luvisols

Таблица 2: Основни параметри на изследваните почви

Зелена зона	Орг. C, %	Общ N, %	pH в H ₂ O	C:N	C запас t/ha
„Арпезос“	3,62	0,44	7,45	8,23	22,58
	(± 0,26)	(± 0,18)	(± 0,64)	(± 0,76)	(± 7,24)
„Простор“	3,47	0,93	6,68	3,73	38,13
	(± 0,39)	(± 0,87)	(± 0,46)	(± 0,26)	(± 21,12)

Таблица 3: Параметри на почвите и съдържание на Cu, Zn и Pb (mg/kg)

Зелена зона	Об. плътност g/cm ³	Порьозност %	Cu mg/kg	Zn mg/kg	Pb mg/kg
„Арпезос“	0,65	92	16,42	98,51	39,92
	(± 0,34)	(± 12)	(± 2,44)	(± 11,22)	(± 19,02)
„Простор“	1,02	52	23,88	182,24	117,21
	(± 0,22)	(± 7)	(± 6,13)	(± 9,35)	(± 30,01)

Почвите на изследваните обекти са формирани под въздействието на човешката дейност, в резултат на което са настъпили значителни промени в техните генетични белези и свойства. Разпространението на антропогенните почви (Anthrosols) има интразонолен характер в зависимост от специфичното локално въздействие на антропогенния фактор, което се проявява в две посоки: промяна на естествените почви или образуване на „нови“ почви. В настоящото изследване типът антропогенни почви, въз основа на основните насоки на антропогенно въздействие, морфологичните особености на профилите и качествените и количествените характеристики на някои диагностични свойства, е представен от типа почви Urbanogenic (Urbic). Има редица специфични особености, които отличават градските почви от естествените почви, които за Арпезос са алувиални, пясъчливи и пясъчливо-глинести, а в

парк Простор са излужени канелени гори, според основната класификация на почви в България [3, 10]. Факторите, които обуславят тези особености са: големината на населеното място, технологията на създаване, ползване и поддържане на зелени площи, като прилагане на тежки машини, утъпкване, често копаене, неправилно поливане и торене, интензивно косене, обезтревяване, събиране и отстраняване на листни отпадъци, натрупване на сняг, примесен със сол. При тези условия в постари паркове или крайградски паркове и спортни зони антропогенизацията в зелените площи се случва само в горната част на профила на естествените почви.

Морфологичното описание на почвите по обекти и основните физико-химични характеристики на почвите от изследваните зелени зони остават без промени от публикуването през 2019 г. [13]. Може да се обобщи, че се наблюдава тенденция на значително увеличение на скелетната фракция (над 1 мм или над 3 мм) в повърхностните слоеве на почвите на Арпезос в сравнение с парк Простор. Подобна тенденция се установява по отношение на пясъчната фракция, ясно изразена при почвите в парк Простор. По механичен състав почвите в парк „Арпезос“ се определят като пясъчливи до праховидни, а почвите в парк „Простор“ се определят като пясъчливи. В резултат на тези особености почвите в двете зелени зони могат да се отнесат към такива, с влошено структурно състояние.

Киселинността на почвата се определя във воден екстракт [9], а стойностите на рН изразяват активността на водородните катиони в разтвора (Табл. 2). По този показател градските почви от зелената система на града се определят като неутрални до слабо алкални (по Пелишек), с изключение на почвите в парк Простор, които се характеризират с ниско киселинно до неутрално рН. В пет-годишния период на обследване се наблюдава слаба, но ясно изразена тенденция към алкализация на повърхностния 0-10 см почвен слой.

Запасеността на почвите с хранителни вещества се определя от количественото съдържание на органичен въглерод, общ азот и общ фосфор, както и съотношението между органичния въглерод и общия азот (C:N). Съдържанието и съотношението на хранителните вещества в почвата са пряко свързани с почвеното плодородие и храненето на растенията. Отношението C:N е около 8 в парк „Арпезос“ и около 4 в парк „Простор“, като стойностите в годините не се изменят съществено. Съотношението C:N е показател за благоприятните условия за съществуване и развитие на почвеното биоразнообразие и стабилността на почвената структура. Според получените стойности за съотношението C:N, регистрирано под 14 в двете зелени зони типът на хумуса е отнесен към Мул [4].

Почвеното органично вещество (ПОВ) се оценява по съдържанието на органичен въглерод, респ. хумус в почвата. По количествено съдържание на орг. С и по механичен състав почвите спадат към среднохумусните (3-5%) [11]. Запасите от въглерод в почвата [3], въз основа на данни от измервания на съдържанието на органичен въглерод в % и обемната плътност в g/cm^3 в почвен слой 0-10 cm [2]. Съществува доста голяма вариация на въглеродните запаси между средните стойности при двете изследвани зелени зони. По-високият запас в парк „Простор“ се обяснява с по-високата обемна плътност на почвата в сравнение с другата зелена зона.

Подобно на въглерода, съдържанието на общ азот в изследваните почви ги определя като много добре запасени (над 0,35%) в парк „Арпезос“ и отлично запасени (над 0,55%) в парк „Простор“ [12].

По отношение на съдържанието на тежки метали и металоиди, резултатите от анализите на изследваните почви показват, че не е регистрирано наднормено съдържание, т.е. над пределно допустимите концентрации (ПДК) на тежки метали в почвите от зелената система на града. Определени

като общо съдържание в mg/kg суха почва при екстракция с царска вода [14, 15], съгласно Наредба № 3 от 1 август 2008 г. за нормите за допустими съдържание на вредни вещества в почвите [16] (Табл. 3). Най-вероятно този факт е резултат от прекратяването през последните години на добива и преработката на оловно-цинкови руди.

3.2. Здравословно състояние на зелената инфраструктура в парк „Арпезос“

Резултатите от извършените теренни обследвания в избраните градски паркове в Кърджали показват, че градът се характеризира с добре развита зелена инфраструктура с преобладаване на местни дървесни видове.

Парковото пространство в „Арпезос“ е оформено в отделни кътчета с различно предназначение - места за отдих, детски зони, изгледни зони, водни каскади, развлекателни и бизнес сгради, и др. Оценката на здравословното състояние на дървесната и храстова растителност в парка е извършена върху сравнително малък брой видове (19 бр.), поради скорошното изграждане на централната му зелена част. С най-голямо участие са видовете *Acer platanoides* L., *A. pseudoplatanus* L., *Buxus sempervirens* L., *Cupressus arizonica* Greene, *Platanus acerifolia* Willd, *Quercus rubra* L. и *Robinia pseudoacacia* L.

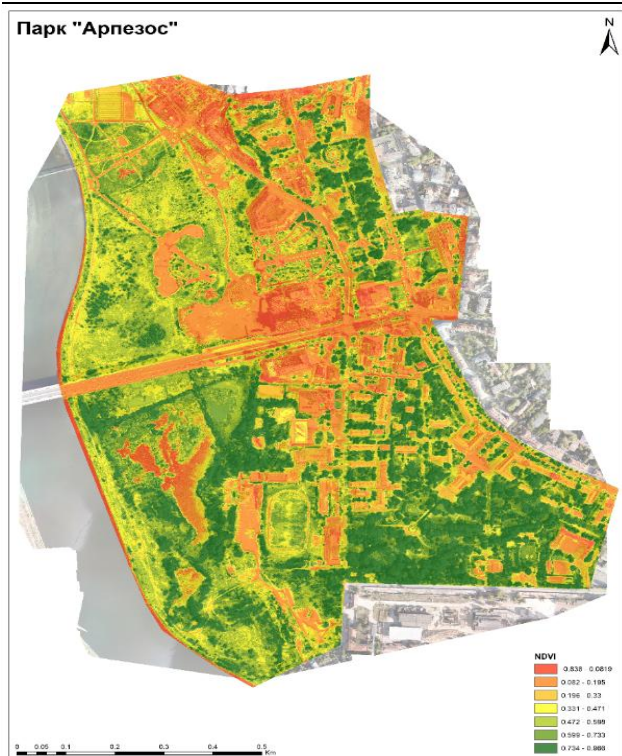
В резултат на проведените наблюдения и оценката на комплекса от насекоми вредители и гъбни патогени и общото фитосанитарно състояние на растителността в изследваните обекти е установено, че паркът е с добре развита зелена система и сравнително висок процент на озеленени площи, които са поддържани в добро санитарно състояние. От всички оценени видове 79% са без или със слабо обезлистване и промяна на отцветяването на короните. Сред останалите, 15,8% са със средна степен на увреждане и 5,2% са силно обезлистени.

В най-лошо състояние са храстите от чемшир (*B. sempervirens*), при които степента на повреда е между 70 и 100% в резултат на нападение от инвазивния насекомен вредител *Cydalima perspectalis* (Walker).

В слаба степен са засегнати дърветата от яворолистен чинар (*P. acerifolia*) от чинаровата коритуха (*Corythucha ciliata* Say) и развитието на антракноза по клоните и листата на дърветата, изразяваща се във формиране на раковини, изсъхване на клоните и увяхване на листата, с причинител гъбният патоген *Apiognomonia veneta* (Sacc. & Speg.) Höhn.

След обработка на изображенията от БЛС е създаден NDVI модел на заснетата територията на парк „Арпезос“ (Фиг. 1). Картната схема ясно показва наличие на зелени площи с висока стойност на жизненост на растителната покривка, както и тези - с липса на растителна покривка или растителност в незадоволено състояние. Над 50% от изследваната площ растителният индекс е над 0,75, което е показател за добро физиологично състояние и потвърждава резултатите, получени от теренно обследване на растителността в парка.

Поддържането на дървесната и храстова растителност в парк „Арпезос“ повишава качеството на живот и съответните екологични условия, включително предотвратяване на рискове, както и подобряване на физическата среда на градските центрове и агломерации като част от по-широкообхватната стратегия за социално и екологично възраждане. Създаването на зелена зона в самия център на града, в територия със значително замърсяване и подложена на екстремни температурни вариации, се очаква да подобри значително състоянието и привлекателността на градската среда за населението и гостите на града.



Фигура 1: Картно изображение на NDVI в заснетата територия в парк „Арпезос“

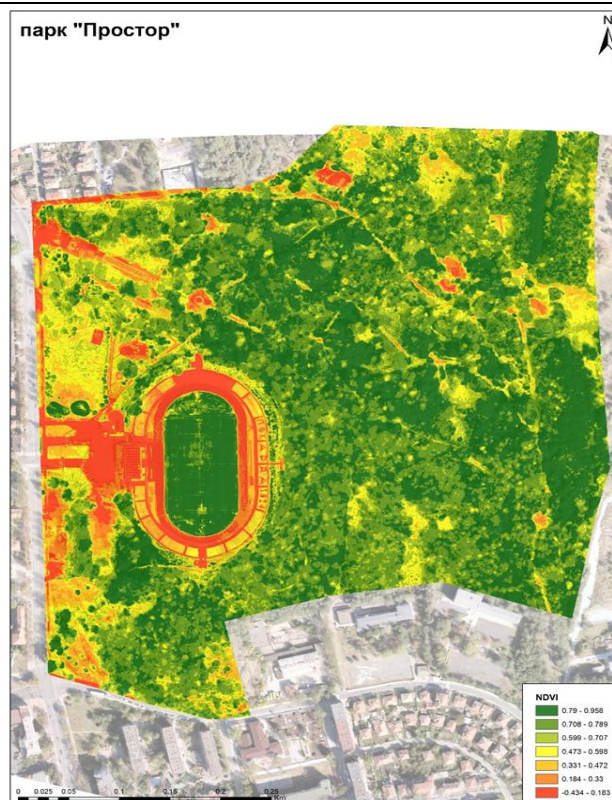
2.2. Здравословно състояние на зелената инфраструктура в парк „Простор“

Понастоящем парк „Простор“ изпълнява функцията на лесопарк, където се провежда периодично санитарно прочистване на стари и загинали дървета, и обновяване с нови, предимно местни дървесни видове. При теренната оценка на здравословното състояние на дървесната и храстова растителност в парка са обследвани общо 30 вида. С най-голямо участие са видовете *Pinus nigra* Arn., *Quercus cerris* L., *Q. robur* L., *Q. rubra*, *R. pseudoacacia*.

Оценката на здравословно състояние показва, че използваната растителност за озеленяване на парка е в сравнително добро здравословно състояние, с изключение на част от видовете, по които са установени повреди от инвазивни насекомни вредители и гъбни патогени. По иглиците на всички обследваните дърветата от черен бор (*P. nigra*) са отчетени покафенявания и изсъхвания на младите леторасли, причинени от гъбния патоген *Diplodia sapinea* (Fr.) Dyko & Sutton. Насекомните вредители *Cinara pini* (Linnaeus 1758) и *Thaumetopoea pityocampa* (Denis & Schiffermüller, 1775) също са причинили повреди по иглиците, като вторият вид е силен алерген, причиняващ кожни алергии и е установен в близост до детска площадка.

При видовете от род *Quercus* са отчетени средни до силни повреди от инвазивния насекомен вредител *Corythucha arcuata* (Say, 1832), причиняващ депигментация и преждевременно опадване на листата.

Въпреки наличието на новоустановени инвазивни видове на територията на парк „Простор“, здравословното състояние на дървесната и храстова растителност може да бъде отчетено като добро поради поддържането и своевременно отстраняване на силно засегнати от вредители и патогени дървета. Показател за това са и високите стойности на NDVI (между 0,75 и 0,98) при над 80% от заснетия участък от парка (Фиг. 2). По-ниски стойности на индекса (между 0,47 и 0,75) се наблюдават в западната част на парка, където са разположени по-голяма част от местата за отдих, детските зони и широки алеи.



Фигура 2: Картно изображение на NDVI в заснетата територия в парк „Простор“

Обследваните зелени зони в гр. Кърджали се поддържат в добро здравословно състояние и се прилагат лесовъдски и защитни подходи и мероприятия за контрол на настъпили каламитети на вредители и инвазивни заболявания в тях. Осигуряването на услугата, обаче, е най-наложителна в уязвимите централни зелени зони, където потокът от население е най-голям и използването на интродуцирани растителни видове за озеленяване е най-широко, което често е причина за поява на нови вредители и патогени.

Наскоро появилите се инвазивни видове, както патогени, така и насекоми вредители, се развиват по-агресивно при продължителна суша или други абиотични и антропогенни нарушения. Разширяването на огнищата на болести и вредители може да застраши здравословното състояние на местни дървесни и храстови видове.

За територията на проучваните зелени системи в парковете „Арпезос“ и „Простор“ контролът на вредителите се определя като препоръчителен с оглед на голямото значение за поддържане на зелените площи в добро състояние, което е свързано с предоставянето на екосистемните услуги. Появата на нови инвазивни болести и вредители в зелените зони на град Кърджали се определя като негативен ефект, който се увеличава по честота и въздействие върху дървесните и храстови видове, които определят естетическата визия на парковете и доброто здраве на жителите и посетителите на града.

Анализираните характеристики на урбанизираните почви индикират за негативни изменения на някои почвени свойства в изследвания 5 годишен период – тенденция към алкализация, уплътняване и наличие на тежки метали. Антропогенното влияние върху почвите в парковите зони в района на гр. Кърджали посредством прилагания интегриран подход се оценява като негативно със средна до висока степен на въздействие. Това допълнително води до влошаване на условията на месторастене за интродуцираните дървесни видове в градската среда и налага прилагането на интегриран подход при оценка на състоянието на зелените зони.

4. References

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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 μm (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 ml of 50 % (v/v) methanol. The final extracts were filtered with PTFE filters (0,45 μm , 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 μ m, Supelco), thermostated at 25 °C. A gradient of acetonitrile (HPLC purity) and ultrapure water (0,055 μ S) 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 (Digester 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 $\pm$ 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, μ g L ⁻¹ LOD 0,1 μ g L ⁻¹ LOQ 0,2 μ g 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, μ g L ⁻¹ LOD 0,1 μ g L ⁻¹ LOQ 0,2 μ g 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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GIS-Based Multi-Criteria Decision Making Approach as a Tool for Land Suitability Analysis - A Review

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Abstract: Land suitability analysis plays a crucial role in land use planning and decision-making processes. The utilization of Geographic Information Systems (GIS) in land suitability analysis has become increasingly prevalent in recent years. GIS combined Multi-criteria decision analysis (MCDA) is a powerful process that integrates geographical data to make informed decisions. By considering multiple spatial factors, this method generates a comprehensive map highlighting the optimal locations for specific land-use purposes. This review paper aims to examine the application of GIS-based MCDA in land suitability analysis, based on a comprehensive review of the literature. Moreover, the review examines case studies that have applied GIS-based MCDA in land suitability analysis across various disciplines, including agriculture, urban planning, and environmental management. Overall, this review paper provides valuable insights into the role of GIS-based MCDA as a tool for land-use suitability analysis, highlighting its significance in sustainable land management practices.

Keywords: LAND SUITABILITY ANALYSIS, GIS, MCDA

1. Introduction

Land suitability analysis is an essential component of effective land use planning, aimed at identifying the best uses for land based on its inherent characteristics and potential [1]. As urbanization and population growth intensify pressures on land resources, there is an increasing need for sophisticated analytical tools that can provide deeper insights into land evaluation processes. Geographic Information Systems (GIS) have emerged as a pivotal tool in this arena, enabling the integration of spatial data and analytical processes that enhance decision-making capabilities [2].

The integration of GIS with Multi-Criteria Decision Analysis (MCDA) represents a substantial advancement in land suitability assessments. This synergistic approach not only allows for the incorporation of diverse data sources including socio-economic, environmental, and physical criteria but also facilitates a more participatory decision-making framework by engaging stakeholders in the evaluation process [3]. This approach results in the creation of comprehensive suitability maps that guide land use decisions in a transparent and informed manner [4]. The versatility of GIS-based MCDA has led to its application across diverse fields, from agriculture, where it helps optimize crop production [5] to urban planning, where it aids in identifying optimal locations for infrastructure development [6]. In environmental management, it supports the identification of areas suitable for conservation or restoration [7]. Each of these disciplines benefits from the ability to incorporate a wide range of criteria, analyze trade-offs, and visualize complex spatial relationships, making GIS-based MCDA an invaluable tool for sustainable land use. However, despite its widespread adoption, the application of GIS-based MCDA is not without challenges. Issues such as the availability and quality of data, the appropriate selection of criteria, and the subjective nature of weighting decision factors can affect the accuracy and reliability of land suitability models [8].

Despite its growing adoption, the methodologies and effectiveness of GIS-based MCDA in land suitability analysis warrant further examination. This review aims to provide a comprehensive assessment of GIS-based MCDA applications in land-use suitability analysis, drawing on a range of case studies across different disciplines. By synthesizing existing research, this paper seeks to highlight the role of GIS-based MCDA in promoting sustainable land management and to offer insights into its future potential for improving land-use decisions.

2. Methodology

This literature review follows a systematic approach to identify and evaluate studies that utilize GIS-based MCDA in land suitability analysis. A Boolean search utilizing keywords and phrases was employed to navigate scientific research engines and platforms. The search strategy involved querying academic databases, including Google Scholar, Scopus, and Web of Science, using keywords such

as: GIS; Multi-Criteria Decision Analysis; Multi-Criteria Evaluation; site suitability; land suitability; and land use planning focusing on publications from 1999 to 2024. However, we referred to a few articles prior to the year 2000 that are important to understanding concepts or methods. Each identified study was assessed based on its methodological, the clarity of its MCDA framework, and the integration of GIS technology.

3. GIS in Land Suitability Analysis

3.1 Principles of Geographic Information System

GIS is an essential tool that facilitates the collection, management, analysis, and visualization of spatial data [9], playing a vital role in various fields such as urban planning, environmental management, agriculture, forestry, geology etc. Three fundamental principles of GIS are: data collection, data management, and spatial analysis. Each of these components contributes to the system's ability to handle and interpret complex spatial datasets effectively.

The first principle, data collection, involves gathering geographic information from a variety of sources including remote sensing technologies, field surveys, and existing databases. Geographic data can be divided into two primary types: vector and raster. Vector data represent discrete geographic features via points, lines, and polygons, which are particularly useful for depicting unique objects like roads and land parcels. In contrast, raster data consists of a grid of cells, with each cell containing value information, enabling the representation of continuous variables [10].

After collecting data, managing it well is crucial. This means setting up a strong database that effectively organizes, stores, and retrieves different types of spatial data. Relational database management systems (RDBMS) are commonly used to handle attribute data, linking it to geographic features through unique IDs. It is also important to keep metadata, which documents where the data comes from, its accuracy, and how it has been processed, ensuring transparency and the ability to replicate results [11]. Good data management is vital due to the complexity of spatial datasets, which often involve combining information from many sources. GIS help users integrate various datasets of different scales and formats, allowing for comprehensive analysis, particularly in assessing land suitability.

The third principle, spatial analysis, serves as the core functionality of GIS, enabling users to examine relationships, patterns, and trends within spatial data. Various analytical techniques can be applied, such as overlay analysis, buffering, and spatial interpolation, which help derive meaningful insights. For example, overlay analysis allows users to superimpose different layers of information to evaluate land suitability based on combined criteria [12]. Additionally, GIS supports advanced capabilities such as network analysis, which helps assess transportation networks and optimize routes, and suitability modeling, which utilizes weighted factors to

identify the best locations for specific land uses based on multiple criteria [4].

Moreover, GIS excels in visualizing complex spatial datasets through diverse formats such as maps, charts, and 3D representations [13] [14]. This capability enhances the interpretability of spatial relationships and is essential for effective communication of findings to decision-makers and stakeholders.

The fundamental principles of GIS encompass systematic data collection, effective data management, and thorough spatial analysis, enabling the handling and interpretation of complex spatial datasets. Through these principles, GIS significantly enhances our ability to derive insights into spatial relationships and patterns, making it an invaluable tool for land suitability analysis and numerous other applications across various domains.

3.2 Applications of GIS in Land Suitability Analysis

GIS have become indispensable in land suitability analysis, where they facilitate the evaluation of various factors influencing land use. One of the primary applications of GIS in this context is the integration of environmental data, including hydrology and soil types, which significantly affect land productivity and sustainability. For example, GIS can be employed to analyze watershed characteristics, assess drainage patterns, and identify flood risk areas, providing essential insights for planning agricultural land or urban development [15]. Soil characteristics, such as texture, pH, and fertility, can also be mapped to determine the most suitable crops for specific locations, enabling optimal agricultural practices [16]. In addition to environmental considerations, socio-economic data plays a critical role in land suitability analysis [17]. GIS allows researchers to incorporate population density, land ownership patterns, and access to essential services such as transportation and healthcare. By overlaying these socio-economic factors with environmental data, decision-makers can identify ideal locations for housing development, commercial establishments, or infrastructure projects. Furthermore, GIS helps in the evaluation of regulatory constraints, such as zoning laws and land-use policies, which can impact land development decisions. By mapping these constraints alongside other data layers, planners can make informed choices that align with legal and environmental sustainability standards [18].

GIS has many uses in land suitability analysis that help us understand how physical and social factors interact. This overall perspective not only helps find the best ways to use land but also encourages collaboration among stakeholders by providing clear visual data. This promotes better decision-making for sustainable land management.

4. MCDA in Land Suitability Analysis

4.1 Understanding Multi-Criteria Decision Analysis

MCDA is a systematic approach used to evaluate and prioritize conflicting criteria in decision-making processes, especially in complex scenarios such as land use planning. MCDA is important because it can take many different factors into account at the same time, just like how real-life problems are often complex and involve many aspects. The methodology begins with the identification and definition of relevant criteria, which can encompass a diverse range of factors including environmental, economic, social, and regulatory considerations [4]. The criteria must be carefully selected to ensure they align with the objectives of the decision-making process and adequately capture the various dimensions of land use suitability.

Once the criteria are defined, the next step involves assigning weights to reflect the relative importance of each criterion in relation to the decision objectives. Weighting can be performed through various techniques, which aim to derive a consensus on the significance of each factor [19]. This weighting process is critical, as it directly influences the outcomes of the analysis and ensures

that more crucial factors have a proportionate impact on the final decision.

After establishing criteria and weights, alternatives are evaluated against these criteria using a range of quantitative and qualitative assessment methods. Common techniques include scoring systems, where alternatives are rated based on how well they meet each criterion, and aggregation methods that synthesize these scores into a singular value representing overall performance [20]. The results of an MCDA give a clear way for everyone involved to see the trade-offs between different goals, helping them make better land use decisions. This makes MCDA an important tool for managing the complexity of land use planning, ensuring that various interests and goals are considered in the decision-making process [21].

4.2 Common MCDA Techniques Used in Land Suitability Analysis

MCDA techniques are vital in land suitability analysis, particularly when integrated with GIS. One of the most widely used methods is the Analytic Hierarchy Process (AHP), which allows decision-makers to structure complex problems into a hierarchy, facilitating comparisons among various criteria [19]. One significant strength of AHP is its ability to integrate both qualitative and quantitative data. However, AHP has limitations, particularly in managing subjective biases in the pairwise comparison process. The technique can also become difficult when dealing with a large number of criteria or alternatives due to the exponential growth of pairwise comparisons [22].

Another common technique is the Weighted Sum Model (WSM), which aggregates different criteria by applying weights according to their importance. WSM is straightforward and easy to understand [23], making it accessible for various stakeholders. The WSM excels in addressing single-dimensional problems; however, challenges arise when applied to multidimensional scenarios [24].

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [25] is another effective MCDA method used in land suitability analysis. This method determines the best option by comparing the geometric distance from each alternative to an ideal solution and a negative-ideal solution. TOPSIS is advantageous due to its intuitive approach and ability to incorporate both benefit and cost criteria simultaneously. The TOPSIS method has two main drawbacks. Firstly, the normalization of the decision matrix often results in a narrow scale for the criteria, which can hinder effective ranking and fail to accurately represent the true superiority of options. Secondly, the method does not incorporate risk assessment for decision-makers, limiting its comprehensiveness in evaluating alternatives [26].

Another technique involves Fuzzy Multi-Criteria Decision Making (FMCDM) [27], which enhances conventional MCDA methods by integrating fuzzy logic to address uncertainty and imprecision in the assessment of criteria. While FMCDM provides a robust framework for dealing with uncertainty, it can be more complex to implement and may require advanced statistical and computational skills, which might limit its accessibility for some users.

5. Integration of GIS and MCDA

5.1 Synergistic Benefits

The combination of GIS and MCDA provides unique synergistic advantages that greatly improve land suitability assessments. The synergistic benefits of combining GIS and MCDA can be summarized as follows: (i) *Improved Accuracy*: Enhanced spatial analysis leads to more precise assessments of land suitability; (ii) *Visual Clarity*: GIS visualizations make complex data more accessible improving stakeholder understanding and engagement; (iii) *Getting stakeholders involved*: Supporting community participation in the planning process; (iv) *Comprehensive Analysis*. This approach brings together different aspects of land use, leading to a more detailed understanding [28].

5.2 Case Studies of GIS-Based MCDA in Land Suitability Analysis

The study by Hussain et al. in 2024 [29] investigates agricultural land suitability in Southern Punjab, specifically the Multan region, using the AHP and MCDA methods. The researchers defined clear objectives and relevant criteria, created a hierarchical framework, and conducted pairwise comparisons to assess the relative importance of various factors. The findings revealed that 43% of the land was highly suitable for agriculture, with the most fertile areas characterized by silty clay or clay soils. The study produced a detailed suitability map, serving as a valuable resource for sustainable land use planning and agricultural policy decisions.

The research conducted by Chenying Li et al. in 2022 [30] focuses on the site selection for urban parks in Nanjing, China, emphasizing sustainable urban development. This study employs a combination of GIS and the Fuzzy-Analytic Hierarchy Process (F-AHP) to evaluate multiple criteria, including environmental factors, accessibility, and human activity. Key findings highlighted that areas in western and eastern Nanjing demonstrated the highest suitability for urban parks, with carbon storage being the crucial factor influencing site choice. The combined approach helps urban planners make better decisions by creating helpful maps for choosing park locations.

Kumi-Boateng, B. et al. in 2016 [31] address the urgent need for irrigational reservoirs in the Upper East Region of Ghana, where agriculture heavily depends on increasingly unreliable rainfall and drying rivers. Employing a MCDA within a GIS framework, the researchers evaluated five factor criteria alongside three constraint criteria to identify optimal sites for irrigational dams. The findings revealed that only 3.69% of the area was deemed suitable initially; however, applying the constraint criteria narrowed this down to just 0.45%, pinpointing optimal locations for dam construction. The optimal sites were primarily concentrated in the central part of the region, highlighting critical areas for enhancing agricultural resilience. This research offers valuable insights for water resource management and agricultural sustainability.

The research conducted by [32] Sayed Ishaq Deliry and Hakan Uygucgil in 2020 focuses on land suitability analysis for sustainable urban development in Eskisehir, Turkey. Urban planning necessitates careful consideration of various criteria, making GIS a crucial tool for effective site selection. This study identifies suitable locations based on six primary criteria: safety, connectivity, socio-economic factors, compactness, topography, and eco-environmental conservation alongside ten sub-criteria. By integrating the AHP with GIS, the researchers assessed geophysical and socio-economic data. The findings revealed that 44% of the area is of low suitability for sustainable development, while 42% is deemed unsuitable. Only 0.01% of the region is highly suitable, highlighting significant challenges for future urban growth in Eskisehir. This research underscores the importance of GIS-based methodologies in navigating complex urban planning landscapes.

The study conducted by Karakuş, C.B. and Yıldız, S. in 2022 [33] focuses on identifying suitable dam sites in Sivas, Turkey, utilizing GIS and the AHP as part of a MCDM framework. The research evaluates various criteria, including elevation, slope, proximity to infrastructure, and hydrological factors, to determine optimal locations for dam construction. The findings indicate that a significant portion of existing and planned dams falls within varying levels of suitability, highlighting potential challenges for future developments. The suitability mapping produced serves as a valuable resource for decision-makers in regional water resource management, emphasizing the importance of incorporating multi-faceted criteria to support sustainable development in the area.

The research by Debasish Roy et al. in 2022 [34] addresses the critical issue of landfill site selection for municipal solid waste management in Siliguri, West Bengal. The study employs a GIS and MCDA to evaluate potential sites based on various factors, such as elevation, geology, and proximity to rivers and residential areas.

Utilizing the AHP, the authors prioritized these criteria and conducted an overlay analysis to identify suitable locations. The findings provide essential

insights and guidelines for urban planners, facilitating effective waste management while addressing environmental and public health concerns.

6. Challenges and Limitations

Using GIS-based MCDA for land suitability assessment faces several challenges and limitations. A significant issue is the availability of reliable and accurate data, which can negatively influence the results of the analysis [35]. High-quality, up-to-date, and accurate data are often essential for effective MCDA. Additionally, the subjective nature of criteria weighting leads to potential prejudices, given that stakeholders may assign different levels of importance to specific factors [36].

Bringing together different types of data makes things more complicated. When the data comes in different sizes, formats, or categories, it can make it hard to analyze everything clearly. To fix this problem, a lot of preparation work is needed, which can take a lot of time and resources.

Lastly, computational demands can be a significant limitation, as advanced GIS analyses with multiple criteria may require considerable processing power and time, especially for large datasets. Addressing these challenges is crucial for enhancing the reliability and effectiveness of GIS-based MCDA in land suitability studies.

7. Future Directions

Future research in GIS and MCDA should prioritize several key areas to enhance effectiveness. Technological advancements, particularly in machine learning and artificial intelligence, can improve data processing within GIS-MCDA frameworks [37]. Additionally, enhancing stakeholder involvement is essential for more effectively meeting community needs and achieving fair outcomes. Moreover, enhancing the adaptability of GIS-MCDA frameworks to cope with changing environmental conditions is essential, utilizing real-time data and predictive modeling to offer resilient solutions. These efforts will contribute to creating a more robust framework for land suitability assessments amongst ongoing environmental changes.

8. Conclusions

In this study, we have conducted a comprehensive review of the existing literature to highlight the essential role that GIS and MCDA play in land suitability analysis. This examination reveals that the integration of GIS and MCDA significantly enhances the decision-making process for a variety of spatial issues, encompassing site selection, land susceptibility assessments and land-use planning. Specifically, *Table 1* and *Table 2* which include 45 research papers and 6 Proceedings of International conferences reviewed, illustrates the importance of GIS-based MCDA in facilitating informed decision-making across these fields.

The application of MCDA techniques proves to be particularly beneficial in addressing complex environmental and civil engineering challenges. *Table 3* delve deeper into the practical applications of MCDA, showcasing its relevance in diverse fields such as environmental management and infrastructure development, along with a discussion of various weighting methods and their impact on MCDM models.

Figure 1 outlines the distribution of reviewed publications over the years, emphasizing the growing interest in GIS-based MCDA. Our literature review indicates a significant rise in the use of GIS-integrated MCDA methodologies to address various spatial challenges in recent years, reflecting an increasing trend in their adoption. *Figure 2* showcases the range of references included in this review.

Table 1. References on Multi Criteria Decision Analysis

Number	Refer.no.	Author/Year of publication	Application	Method used
1	[38]	Johnny K.W. Wong , Heng Li (2008)	Selection of Intelligent building system	MCA/AHP
2	[39]	Sarath.M et al. (2018)	Site suitability	MCA/AHP/GIS
3	[33]	C. B. Karakuş, S. Yıldız (2022)	Dam site selection	MCA/AHP/GIS
4	[40]	Sallwey, J. et al. (2019)	Site suitability (aquifer recharge)	Review (GIS-MCDA)
5	[41]	Joshua, Jonah Kunda et al. (2013)	LSA for agriculture planning	MCDA/AHP/GIS
6	[42]	Sarı, F., & Koyuncu, F. (2021)	Suitability of agricultural crops	MCDA/GIS
7	[43]	Maddahi, Zeinab, et al. (2017)	LSA for rice cultivation	MCDA/Fuzzy AHP/GIS
8	[44]	Villacreses, Geovanna, et al. (2017)	Wind farms suitability	MCDA/AHP/GIS
9	[45]	Martine Nyeko (2012)	Land Use Resource Planning	MCDA/GIS
10	[46]	Owusu, Seth, et al. (2017)	Land suitability for aquifer storage/recharge	MCDA/GIS
11	[47]	Balew, Abel, et al. (2022)	Suitable landfill site selection	MCDA/GIS
12	[48]	Hamide Aliani et al. (2021)	Urban development suitability	TOPSIS/WLC/ANP/GIS
13	[49]	Octaviansyah, Decky, et al. (2024)	Best road selection	MCA
14	[50]	Withanage, Neel Chaminda, et al. (2024)	Suitable areas for ecotourism	GIS-integrated MCDA
15	[51]	Rashid Ahmad et al. (2024)	Rainwater harvesting (RWH) structure	MCDA/AHP+FAHP/GIS
16	[52]	Muhammad, Akhtar Malik, et al. (2023)	Potential Groundwater recharge zones	MCDA/GIS+RS
17	[53]	Rashwan, Mohamed, et al. (2024)	Landslide susceptibility	MCA+GIS
18	[54]	Md. Saalim Shadmaan et al. (2023)	Earthquake vulnerability	GIS based MCDA (AHP)
19	[55]	Rikalovic, Aleksandar et al. (2014)	Industrial site selection	MCDM/GIS
20	[56]	Akay, A. E., & Erdoğan, A. (2017)	Forest fire risk	MCDM/GIS based AHP
21	[57]	Hansen, H. S. (2005)	Wind Farm Development	GIS-based MCDA
22	[58]	Hammami, Salma, et al. (2019)	Flood susceptibility	MCDA based AHP/GIS
23	[59]	Prasetyo, Daniel Hary (2018)	Public school - site selection	MCDA based AHP/GIS
24	[60]	Abdul Rasam, A.R. (2016)	Risk map	GIS-based MCDA
25	[61]	Das, P. T., & Sudhakar, S. (2014)	LSA for orange & pineapple	MCDM/GIS
26	[62]	Perveen, F., et al (2007)	Crop-land suitability analysis	MCDA based AHP/GIS
27	[63]	Kamau, Samuel W., et al. (2015)	Land suitability analysis	GIS-based MCE/RS
28	[64]	Quinta-Nova, L. C., et al. (2020)	Fruits suitability	MCDA based AHP/GIS
29	[65]	Saeedavi, Z., et al. (2017)	LSA for urban green space planning	MCA (AHP)/GIS
30	[66]	Ullah, K. M., & Mansourian, A. (2016)	Urban land-use planning	GIS-based AHP
31	[67]	Granados-Dieseldorff, P.A.B.L.O. (2009)	Habitat suitability	GIS
32	[68]	Beedasy, J., & Whyatt, D. (1999)	Tourism planning	SDSS
33	[69]	Gorsevski, Pece V., et al.(2013)	Wind farm site selection	SDSS
34	[70]	Nurda, Nety, et al. (2020)	Extension of Potential Forest Areas	MCDA/GIS+RS
35	[71]	Malczewski, J. (2006)	GIS- based MCDA	Review
36	[72]	Abu-Taha, R. (2011)	Renewable energy analysis	MCDA-review
37	[73]	Dalalah, Doraid et al. (2010)	Construction	MCDM-AHP
38	[74]	MASRON, Tarmiji, et al. (2015)	Tourism planning	SDSS (GIS)
39	[75]	Prakash, T. N. (2003, December)	Land Suitability Analysis	MCDM-Fuzzy AHP/GIS
40	[76]	Yohannes, H., & Soromessa, T. (2018)	Land Suitability Analysis	MCDM-ANP/GIS
41	[77]	Hussain, S. et al. (2024)	LSA for agriculture	MCDM-AHP/GIS
42	[31]	Kumi-Boateng, B. et al. (2016)	Site selection-irrigational reservoirs	MCDM-AHP/GIS
43	[30]	Chenying Li et al. (2022)	Site selection for urban parks	GIS based Fuzzy AHP
44	[78]	Fu Yang et al. (2008)	Urban land management	GIS/RS/AHP
45	[79]	Hossen, B. et al. (2021)	Land suitability analysis	GIS-based MCDA

One important finding from this review is that GIS-based MCDA can handle different types of data, which helps provide detailed information about land suitability. This flexibility allows everyone involved—from local planners to decision-makers—to make smarter choices that address both current needs and future sustainability goals. The ability to see data on maps helps engage stakeholders better and encourages teamwork in planning. It also makes it easier to share results and explain the reasons for land-use decisions.

Despite its advantages, this review also acknowledges several limitations and future challenges associated with GIS-based MCDA. The accuracy of assessments can be affected by the quality and availability of data, especially in areas where information is scarce. Additionally, the subjective nature of the MCDA methods can lead to inconsistent results. To overcome these issues, future research should focus on improving data integration, refining decision-making processes, and creating standardized methods to ensure more reliable analyses. Ongoing study in this area is crucial for enhancing the effectiveness of GIS-based MCDA in adapting to changing land-use needs and environmental challenges. By addressing these limitations, GIS-based MCDA can become an even more valuable tool for sustainable land management.

Table 2 References from the Proceedings of the International Conference on MCDA

References	Author	Title
[80]	Eltarabishi F et al.(2020)	Multi-Criteria Decision Making Methods And Their Applications– A Literature Review
[81]	Radulescu, C.Z. et al.(2010)	A hybrid multi-criteria method for performance evaluation of romanian South Muntenia Region in context of sustainable agriculture
[82]	Ziaei M, Hajizade F. (2011)	Fuzzy analytical hierarchy process (FAHP): a GIS-based multicriteria evaluation/selection analysis
[83]	Abujayyab SK (2017)	GIS modeling for landfill site selection via multi-criteria decision analysis: A systematic review
[84]	Kuznichenko, S. (2020)	Suitable site selection using two-stage GIS-based fuzzy multi-criteria decision analysis.
[85]	Wigati SS et al. (2019)	Bibliometric analysis for site selection problems using geographic information systems, multi-criteria decision analysis and fuzzy method.

Table 3 Bibliographic References for Books on MCDA

References	Author	Book title
[86]	Dean, Marco (2020)	Advances in Transport Policy and Planning
[87]	Ozsahin, Dilber Uzun, et al., (2021)	Application of MCDA in environmental and civil engineering
[88]	Zardari, Noorul Hassan, et al. (2014)	Weighting methods and their effects on MCDM model outcomes in water resources management

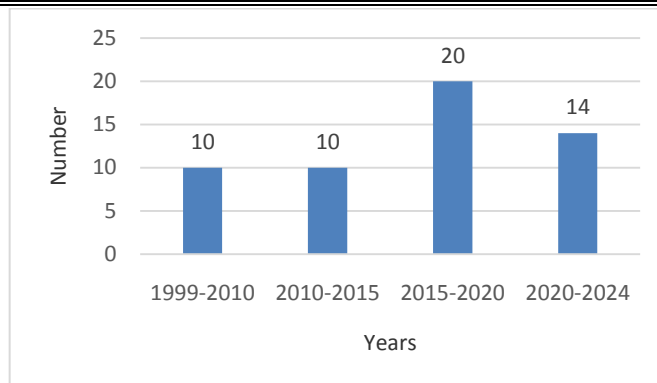


Fig.1 Number of reviewed papers, books and conference proceedings over the years

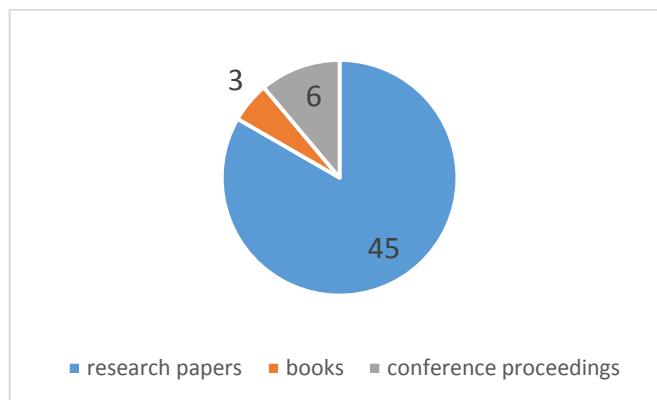


Fig.2 Number of referred references

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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 $^{+}\text{NH}_4\text{-N}$, 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}
$^{+}\text{NH}_4\text{-N}$	2	112,014	,000***	3	12,539	,000***	6	1,683	,141 ^{NS}
$^-\text{NO}_3\text{-N}$	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.

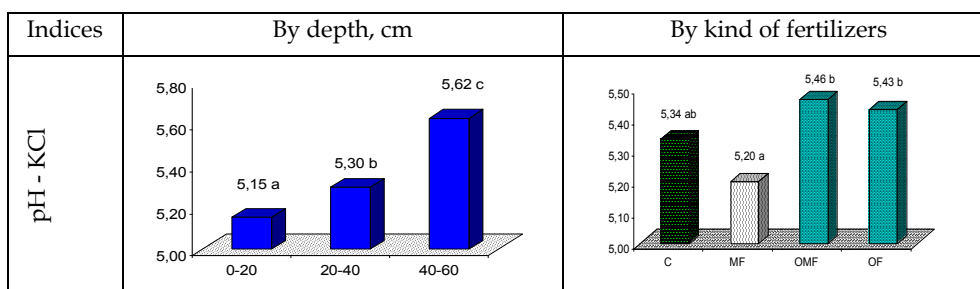
Different types of fertilizers also affect mineralization processes, but the differentiation in values is much less pronounced. In all three incubation periods, the lowest amounts of mineralized nitrogen were found after fertilization with Excel^{Orga}. As with the forms of Min. N, the influence of the 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.



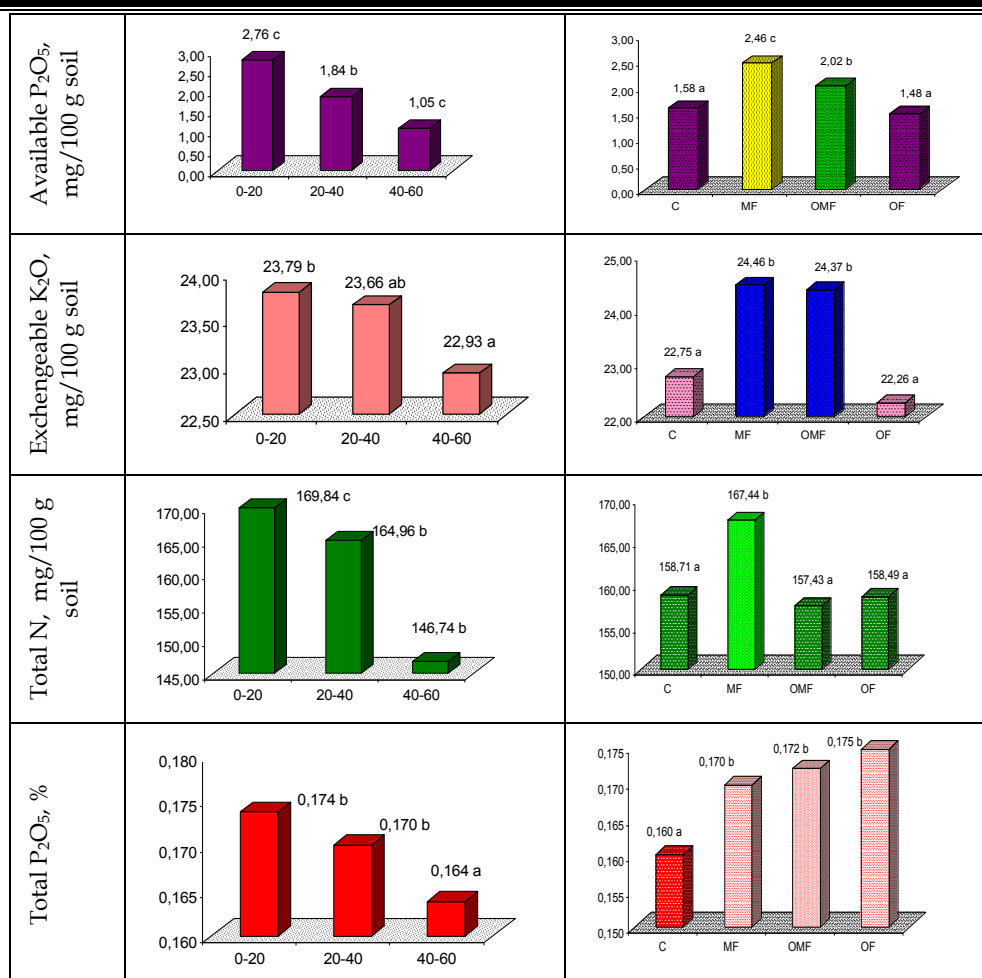


Figure 1. Changes in soil acidity values, available forms of phosphorus and potassium, and total nitrogen and phosphorus in the soil

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

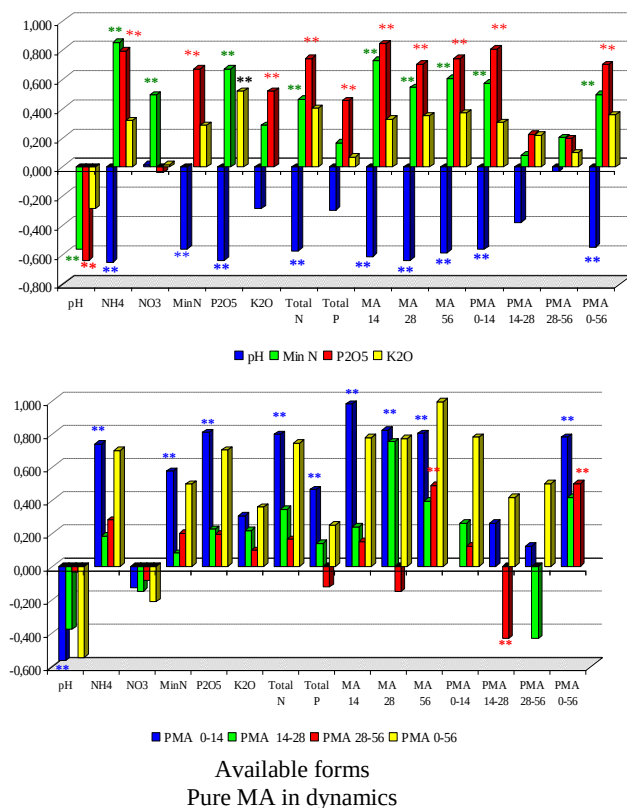


Figure 2. Strong correlative relationships between investigated agrochemical indices of soil fertility (Pearson Correlation)

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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Research on the conditions of reclamation of agricultural soils disturbed by military operations

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Abstract. *The article studies and analyzes the impact of military operations on the soil cover, in particular, damage and destruction of the fertile soil layer as a result of detonation of various explosive objects (missiles, bombs, artillery shells, etc.) and its contamination with heavy metals and other harmful substances. A method is proposed for the technical reclamation of damaged land as a result of bombing. It involves first cleaning the craters from damaged and contaminated soil with heavy metals and other hazardous substances. It is proposed to use a new working body for this purpose. If a dangerous concentration of heavy metals and other hazardous substances is found on the surface of the crater, the removed contaminated soil layer must be disposed of. If the removed layer of the sinkhole surface contains an acceptable concentration of contaminants, the removed layer can be left at the bottom of the funnel. A flexible screw conveyor with a sectional auger working body can be used to dispose of the removed contaminated soil layer. To restore the relief, it is necessary to backfill the craters, i.e. level the surface. After that, the land can be disked and cultivated, and plowed if necessary.*

KEYWORDS: AGRICULTURAL SOILS, CONTAMINATION, RECLAMATION, EXCAVATION, WORKING BODY, EXCAVATOR BOOM.

Thousands of hectares of Ukrainian land were bombed during the aggressor's full-scale invasion of Ukraine. Military actions lead not only to mechanical and physical deterioration of the soil, but also to its chemical contamination.

Deformation of the soil cover due to the formation of craters from bombing or demining of territories, movement of military equipment, troop movements, construction of protective structures, and bombing sites lead to disruption of the soil structure. The consequence of this impact is compaction, waterlogging, and contamination of the territory with war products [1]. The main mechanical impact on the soil is compaction with damage to the humus layer, which has direct negative consequences, such as disruption of the soil's water balance and the development of wind and water erosion. Physical impact involves changes in the physical parameters of the soil as a result of the use of weapons and military equipment, i.e. vibration, radioactive and thermal effects. Chemical impact changes the natural physical and chemical parameters of the soil cover, primarily pH, cation exchange and humus content. It also increases the concentration of toxic chemicals [2].

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

Currently, about a third of Ukraine's agricultural land has been affected by the hostilities. During explosions and the operation of military equipment, large amounts of toxic explosives and heavy metals enter the soil. The soil is chemically damaged [3].

A very negative aspect is that pollutants can move around. This happens in two ways:

- horizontal, which occurs immediately after the bombing, primarily due to air transport;
- vertical, due to factors such as ion diffusion, transfer with the flow of moisture or plant root systems, soil mesofauna, and human activities [4].

Most often, pollutant migration occurs through groundwater, which has the ability to retain heavy metals through selective uptake (adsorption). Many factors influence the proportion of heavy metals that migrate. In particular, soil composition, organic matter in the soil, moisture, microbiological activity, etc. are important. The presence of plants also affects the mobility of explosives and heavy metals [2].

In craters caused by missiles, bombs and mines, and in places where military equipment burned, the content of heavy metals in soil samples exceeds the norm by 10-20 times. These include mercury, arsenic, lead, iron, copper, and chromium [3].

Rocket and bomb explosions pollute not only the air. Harmful substances do not stay in the air for long, but return as precipitation and accumulate in the soil. Sulfur, which is a component of a large part of ammunition, remains in powder form not only in the craters but also around them, and in contact with precipitation it turns into sulfuric acid. And this is very bad for the

soil, because millions of organisms that form the upper living layer of the soil and the ecosystem are burned in this acid.

Toxic elements such as lead, cadmium, arsenic, and mercury will be absorbed by plants with background levels ten times higher than normal. Other elements, such as zinc and nickel, will seriously inhibit crop growth [5].

So, soil contamination can be a hidden danger. If potential areas of contamination are not identified and recorded in time, harmful substances will leach into grain or other agricultural products and poison the crop. This is a direct threat to food security and export opportunities.

Physical and mechanical damage can be seen with the unaided eye, but to determine the chemical impact, it is necessary to analyze it, because heat, explosion, and soil rupture all have an impact. This also destroys the biological component of the soil - the microbiota, humus, and other substances responsible for the biological activity of the soil are practically "burned out". For example, high concentrations of hydrocarbons can cause symptoms of poisoning in earthworms [2].

Products grown on such lands may be unsafe for consumption, so such lands require measures appropriate to the level of contamination: reclamation or even conservation. Conservation is recommended for the most damaged lands (i.e., those with more than 75% of the land area damaged), as the cost of remediation for this level of damage is so high that it is no longer economically feasible.

Fig. 1 shows a field damaged by artillery shell craters [5].

The conservation of the most damaged areas also allows communities to improve soil biodiversity, increase their ability to adapt to climate change, and reduce the risks of wind and water erosion. In other words, conservation, in addition to the natural restoration of the sites themselves from pollution, has a number of related environmental benefits for the entire territory [6].



Figure 1. A field disfigured by artillery shell craters

However, if the level of heavy metal contamination due to explosions is high, and a dangerous pollutant can easily migrate

into groundwater (depending on soil and climatic conditions), then improvement measures are unavoidable! The issue here is not one of economic feasibility, but of environmental safety of the state. Before conservation of the most damaged areas, it is necessary to remove or clean the damaged soil layer and then utilize it. Almost all studies show highly contaminated profiles of the topsoil (0-10 cm). With increasing depth, the level of contamination decreases, except for those potentially toxic elements that have relatively higher levels of accumulation with increasing depth. Contamination is generally limited to the first half meter of depth [7].

If the damage to the surface of the plots is 75-100% of the area, the damaged plots can be preserved and nature can start the process of self-healing, as further import of good quality soil is costly. If the damage amounts to 50-75% of the area of the plots, the land is subject to reclamation.

In order to carry out reclamation, i.e. to transform contaminated land into a usable area, it is necessary to conduct thorough monitoring of the areas of soil damaged and contaminated as a result of hostilities, which will allow timely measures to be taken to rehabilitate them, as well as to establish the boundaries of contaminated areas in order to restore them [8, 9].

Land monitoring to maximize coverage of the entire potentially affected area using modern technologies:

- high-precision satellite data for remote monitoring and digitization of areas affected by hostilities;
- drones for both photo and video recording and magnetometric surveys for remote detection and identification of metal and explosive objects for further demining and neutralization.

This will allow you to record, digitize, and determine the level of damage to each potentially dangerous area of the field. Progressive farms and holdings that already use precision farming elements on their fields can digitize damaged areas, sinkholes, etc. with their own resources. Next, you need to take samples in the affected area (separately) and the surrounding area (separately). Based on the analysis of pollutants (especially heavy metals), the optimal reclamation option can be selected [10].

To restore the areas damaged by the 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 “sterilization” occurs, 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 and require serious investments in organic fertilizers, ameliorants, phytomelioration, etc. [11, 12].

If dangerous concentrations of heavy metals and other dangerous substances are found on the surface of the crater, the removed contaminated soil layer must be disposed of. If the removed layer of the sinkhole surface contains an acceptable concentration of pollutants, the removed layer can be left at the bottom of the sinkhole [13, 14].

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 leveling the surface.

Deep sinkholes (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 sinkhole should be covered with mineral soil first, and the top layer (20-30 cm) should be covered with fertile chernozem. 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 explosion craters, the need for mineral and fertile soils is calculated in the working land management project.

Fig. 2 shows the appearance of craters from air bombs.



a



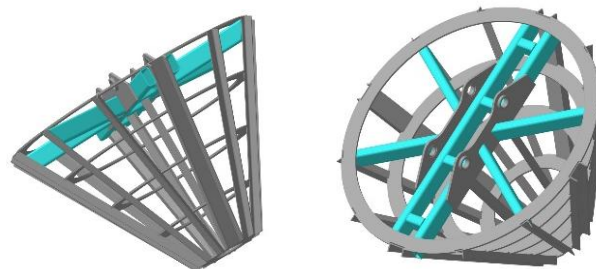
b

Figure 2. The appearance of craters caused by bombs:
a – shallow crater (0.5 m); b – deep crater (8 m)

To remove and clean the damaged surface layer of soil in the crater formed as a result of explosions, it is recommended to use a working tool that will allow mechanizing this process. This working tool is attached to the boom of an excavator with a hydraulic system. Fig. 3 shows a general view of an excavator with a working body installed to clean the damaged soil inside the craters and a general view of this working body. It contains a frame made in the form of circles to which channels and angles are welded.



a



b

Figure 3. General view of an excavator with an excavating tool for cleaning damaged soil inside sinkholes (a) and general view of this tool (b)

This working body can be rotated by a hydraulic motor connected to the excavator's hydraulic network and can be rotated at an angle to the horizon. As the working body rotates, the angle of the sinkhole whose surface needs to be cleaned will be selected. The ribs of the channel shelves and angles welded to the working body will allow you to remove the top layer of the sinkhole surface from damaged contaminated soil containing heavy metals and other harmful substances.

To dispose of 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.

The working body is made in the form of a cut-off cone, the inner surface of which is hollow, and is attached to the excavator boom with brackets.

The excavator operation scheme with the working body installed is shown in Fig. 4.

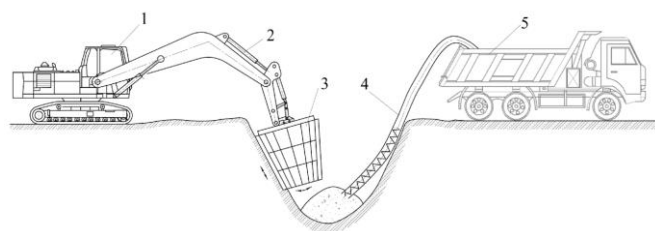


Figure 4. Schematic of an excavator with an installed working body for cleaning damaged soil inside sinkholes:

- 1 – excavator; 2 – excavator boom; 3 – working body;
4 – screw conveyor with a sectional auger working body;
5 – truck

In this way, technical land reclamation can be carried out, which involves first cleaning the craters from damaged and contaminated soil with heavy metals and other dangerous substances. After that, it is necessary to backfill the craters, i.e. level the surface. After that, the land can be used for disking and cultivation, and, if necessary, plowing.

Subsequently, to restore land productivity and soil fertility after technical reclamation, it is necessary to carry out a set of agrotechnical, agrochemical and phytomeliorative measures by deoxidizing soils, applying organic and mineral fertilizers and sowing perennial grasses.

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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].

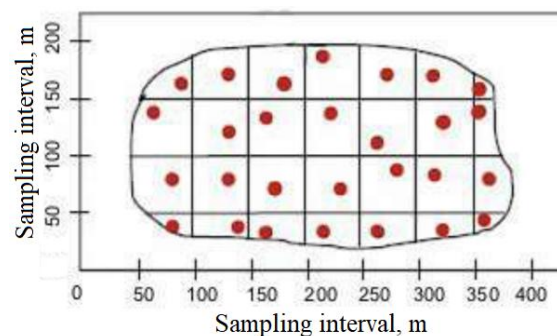


Figure 1. Scheme of systematic random sampling on a rectangular grid

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.

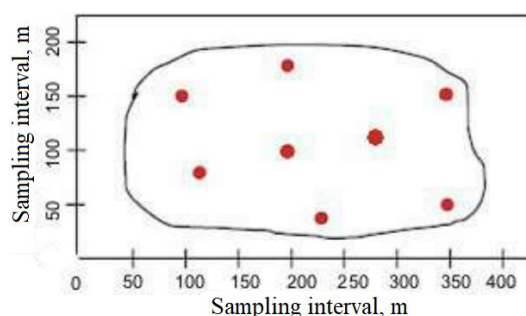


Figure 2. Scheme of simple random sampling on a rectangular grid

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.

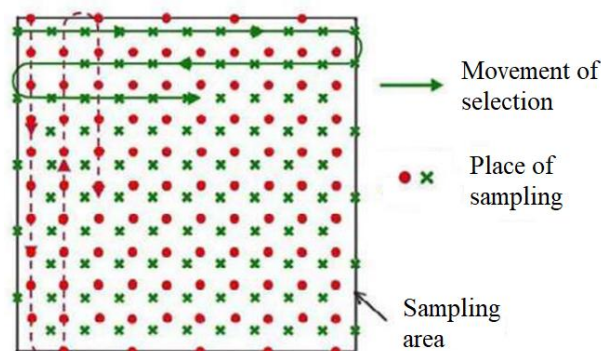


Figure 3. Scheme of 100-incremental sampling using a systematic random approach

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].

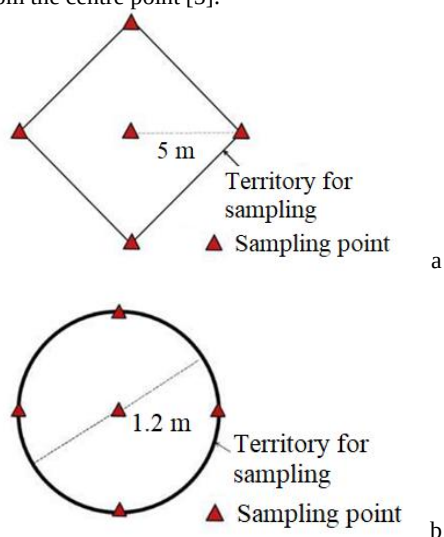


Figure 4. Soil sampling schemes: a) box sampling plan; b) wheel sampling plan

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].

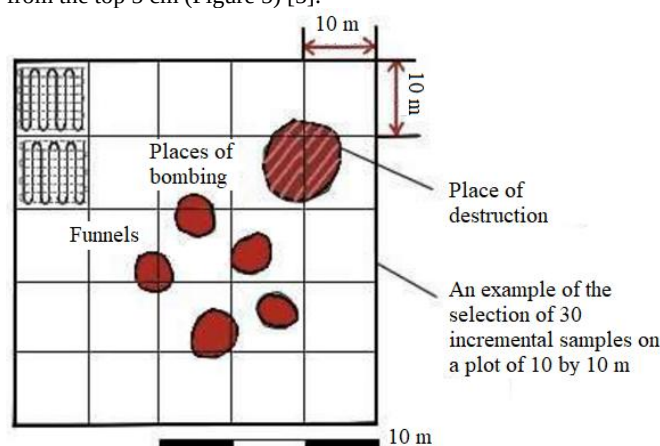


Figure 5. Scheme of taking 30 incremental samples on a 10×10 m plot

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 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).

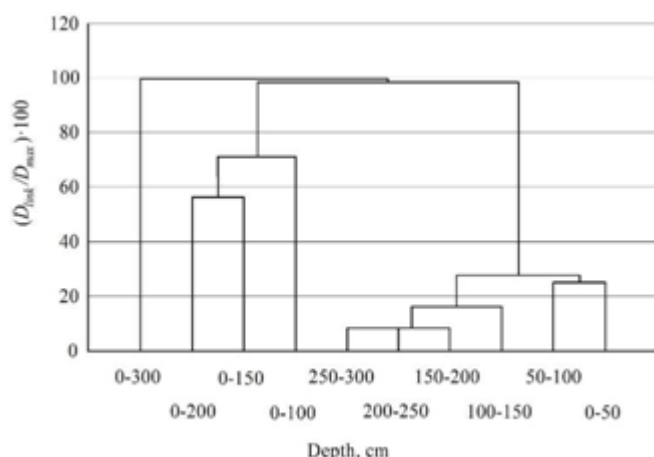


Fig. 1. Clustering of soil horizons within the periodically flushing water regime

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**

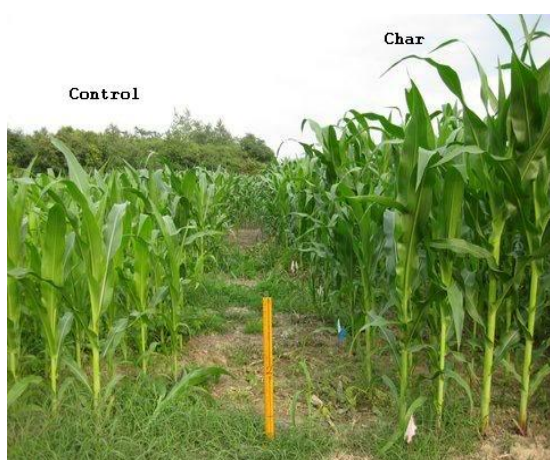


Fig.2 Application of **BioCCS** practices in the production of water-loving agricultural crops - for example, in corn and in afforestation in reforestation projects with highlighted yield and economic effects.

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.

Migration ability and bioaccumulation of ^{152}Eu from Calcaric Chernozem soil to peppermint (*Mentha Piperita L.*) and its transfer to tincture and tea

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Abstract: Europium is widely used in industry and improper waste management in its recycling can cause environmental pollution. ^{152}Eu is obtained as a result of neutron activation of the control rods of nuclear reactors and may enter the soils after nuclear accident. The distribution of ^{152}Eu in the environment and its transfer through the food chain can threaten the human health through its beta and gamma radiation. Therefore, knowledge of the geochemical forms of Eu and its transfer from soil to plants is important for the risk assessment in case of environmental pollution. The paper presents the results of a model study on the mobile geochemical forms and bioaccumulation of ^{152}Eu from chernozem soil to peppermint (*Mentha Piperita L.*). Peppermint plant was planted in a pot with Calcaric Chernozem soil, taken from the 0-10 cm surface layer. Aqueous solution of $^{152}\text{EuCl}_3$ was spiked in the soil, simulating radioactive contamination. The peppermint was grown during 8 months and samples of the soil and peppermint stems and leaves were taken at the 5th and 8th month after the radioactive contamination. The transfer factors (TFs) soil-to-plant were determined. The water-soluble, exchangeable and bound to humic and fulvic acids forms of ^{152}Eu were studied after the 1st, 5th and 8th month after the contamination. The transfer of ^{152}Eu from the mint leaves to tea and tincture was examined. The results showed higher TFs for the soil-leaves than soil-stems system. More than 40% of ^{152}Eu , accumulated in the dry leaves was found to be extracted in the tea, while no radioactive europium was found in mint tincture.

Keywords: EUROPIUM-152, PEPPERMINT, HUMIC AND FULVIC COMPLEXES, TRANSFER FACTORS, WATER EXTRACT, TINCTURE

1. Introduction

Europium (Eu, Z=63) belongs to the group of the light rare earth elements and has two characteristic oxidation states: Eu(II) and Eu(III). It is present in the Earth's crust at a concentration of about 1.8 milligrams per kilogram (mg/kg), while its concentration in seawater is about 0.00013 micrograms per liter. Traces of ^{152}Eu and ^{154}Eu are found in soil from radioactive waste. It can also be present in some nuclear facilities, such as reactors and spent fuel reprocessing plants [1]. Eu has wide industrial applications, such as in the production of fluorescent glass, phosphors, mobile phones, smartphones, portable wireless installations and optical fibers. Europium is also used in old fashioned TV-screens (cathode ray tube TVs, CRTs) or luminescence lamps [2-5] and may enter the nature during recycling process. Europium can enter the human body through food, drinking water or inhalation. Gastrointestinal absorption from food or water is a major source of internal intake of europium in the general population. Europium is not well absorbed in the body after ingestion, only about 0.05% of the ingested amount is absorbed into the bloodstream through the gastrointestinal tract. Of the europium that reaches the blood, 40% is deposited in the liver, and another 40% is deposited on the bone surface, where it can irradiate the bone cells. Thus, deposited europium is preserved in the body with a biological half-life of almost 10 years (3500 days). An additional 6% of absorbed europium is deposited in the kidneys, where it is retained with a short biological half-life of 10 days. The rest of the absorbed europium is released [1].

Radioactive europium poses both an external and an internal health hazard. The strong gamma-radiation from ^{152}Eu and ^{154}Eu causes external irradiation. While in the body, europium poses a health hazard from both gamma rays and beta particles, with the primary health hazard associated with an increased likelihood of causing liver and bone cancer [1].

Therefore, the data on the migration ability, bioavailability and transfer of radioactive isotopes of europium in food and beverages is important when preparing predictive risk assessments in case of pollution. Knowledge of the soil to medicine plant transfer of contaminants is important to prevent pollutant's uptake in the human body above the permissible levels.

The subject of investigation in the present paper is the accumulation of radioactive europium from chernozem soil to one of the most popular herbs – the peppermint (*Mentha Piperita L.*).

Mentha Piperita L. has established choleric, antispasmodic, local anesthetic and antiseptic effects. Peppermint is used for pain in the stomach and intestines, for biliary dyskinesia, liver diseases, flatulence, as well as for removing the symptoms of intoxications of gastrointestinal origin [6-10]. Although less common, peppermint is used for headaches, epilepsy, and depression. Peppermint, and especially peppermint oil, is used alone and in combinations to treat hemorrhoids by topical application. A very common form of peppermint oil with chlorophyll is in oral breath lozenges. The most essential in the action of mint and the essential oil contained in it is their cholagogic and choleric action. It is experimentally established that the infusion of mint leaves increases bile secretion [11].

Peppermint is a widely used herb and the accumulation of pollutants in it from contaminated soils is of interest in a number of studies [12, 13].

To assess the transfer of pollutants in the soil-plant system, are used the transfer factors (TFs). They are defined as the ratio of the radionuclide content in the plant (or in part of the plant) to that in the soil (Bq kg^{-1} dry weight plant tissue/ Bq kg^{-1} dry weight soil). Their values can vary significantly, depending on the soil characteristics, plant species and agricultural practice [14].

The use of radionuclides as tracers of stable isotopes is an efficient approach to trace the path of the elemental contaminants through the soil phases and via the food chain.

The aim of the present study is to investigate the bioaccumulation of ^{152}Eu from Calcaric Chernozem soil to stems and leaves of peppermint (*Mentha Piperita L.*) and its transfer to peppermint tea and tincture. Water-soluble and exchangeable forms of ^{152}Eu , as well as its complexes with humic and fulvic acids in soil were determined.

2. Materials and Methods

Peppermint plant was sampled and transplanted into a plant pot filled with Calcaric Chernozem soil, taken from the 0-10 cm surface.

The main characteristics of the soil are presented in Table 1.

Table 1. Main characteristics of the studied Calcaric Chernozem soil

Soil texture	pH		Humus, %	Sand, %	Silt, %	Clay, %
	KCl	H ₂ O				
Clay loam	7.1	7.8	2.59	32.9	36.8	30.3

Aqueous solution of $^{152}\text{EuCl}_3$ (pH 5.5) was spiked into the plant pot, simulating radioactive contamination.

The peppermint was grown at 15-22 °C and 20-30 % soil moisture during 8 months. Samples of the soil and peppermint stems and leaves were taken at the 1st, 5th and 8th months after the radioactive contamination. The plant parts and the soil samples were air dried to constant weight and the transfer factors (TF) soil-plant were determined.

Water-soluble, exchangeable and bound to humic and fulvic acids forms of ^{152}Eu were determined by using the following extraction procedures:

Water-soluble forms of ^{152}Eu : 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.

Exchangeable forms of ^{152}Eu : 2 g dry weight of the studied soil samples were mixed with 20 cm³ of 0.01 M CaCl_2 , as described in [15]. End-over-end extraction was performed by shaking at about 20 °C for 3 h at 30 rpm, followed by vacuum filtration of the leachates through 0.2 µm cellulose nitrate filters.

Complexes of ^{152}Eu with humic and fulvic acids: 5 g dry weight of the soil sample were shaken twice for 1 h with 15 ml 0.1 M $\text{Na}_2\text{P}_4\text{O}_7$ (pH = 9) to extract the complexes with humic (HA) and fulvic acids (FA) as described in [16]. The fulvic complexes were separated by adding $\text{K}_2\text{H}_2\text{SO}_4$ to the extracts, which caused precipitation of the humic complexes. The extracts were filtered by 0.20 µm cellulose nitrate filters.

The radionuclide content in the different fractions was measured in the supernatant, and the extraction yield was determined by dividing it by the initial radioactivity of the sample.

All the extracts, soil and plant samples were measured by γ -spectrometry. HPGe detector Canberra 7221 coupled to a 16000-channel analyzer DSA-1000 was used to measure ^{152}Eu by its gamma peak at 121.78 keV.

The preparations of the tincture and the peppermint tea were carried out as follows:

Tincture: 2 g dry leaves were mixed with 30 ml 86 % $\text{C}_2\text{H}_5\text{OH}$, left for six weeks (at 18 °C) in darkness and filtered. Afterwards the radioactivity of ^{152}Eu in the tincture was determined by γ -spectrometry.

Water extract (Peppermint tea): 0.5 g dry leaves were added to 200 cm³ distilled water and were gently boiled for 20 minutes. The leachant was filtered and the radioactivity of ^{152}Eu in it was determined by γ -spectrometry.

3. Results and Discussion

3.1. Distribution of ^{152}Eu in the soil phases

The results from the extraction of the complexes of ^{152}Eu with humic and fulvic acids and the water-soluble and exchangeable forms of the radionuclide after 1, 5 and 8 months after the soil contamination are presented in Figs. 1-2.

The data presented in Fig. 1 show that 42% of europium was bound to humic and fulvic acids in the first month after contamination. Its exchangeable form is only 1.5% of its total radioactivity, while the water-soluble form amounts to 11%. Tracking the change in the geochemical forms of ^{152}Eu over time (Figs. 1-2) shows that its % content in the complexes with fulvic acids on the fifth and eighth months after the pollution does not change significantly and remains 13-14%. In contrast, the humic acid complexes significantly decreased with the time and amounted to less than 2% at the fifth and about 4% at the eighth month after europium application to the soil. This corresponds to a 15- and 7-fold decrease in europium content in this form compared to the data from the first month after the contamination.

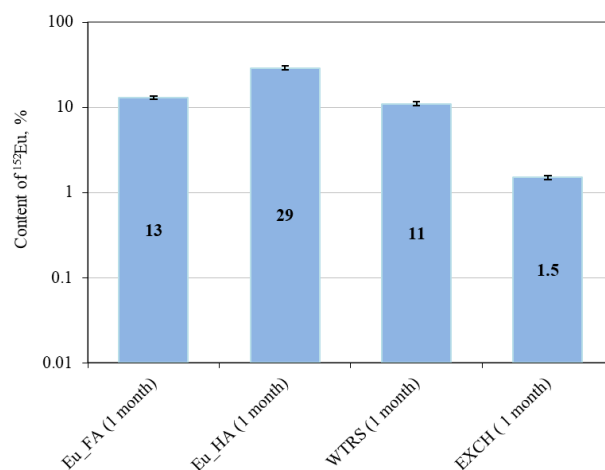


Figure 1 Content of ^{152}Eu in % in the extracted fulvic complexes (Eu_FA), humic complexes (Eu_HA), watersoluble forms (WTRS) and exchangeable forms (EXCH) after 1 month after the soil contamination.

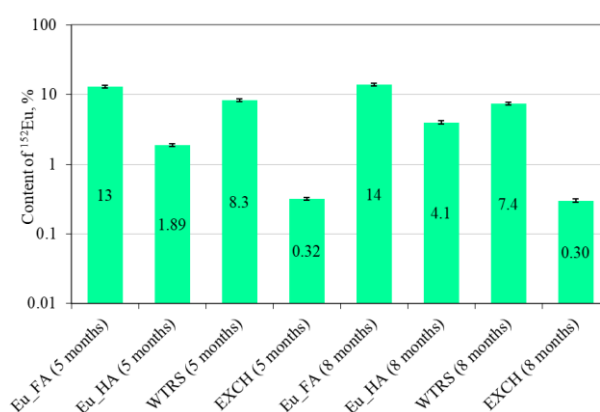


Figure 2 Content of ^{152}Eu in % in the extracted fulvic complexes (Eu_FA), humic complexes (Eu_HA), watersoluble forms (WTRS) and exchangeable forms (EXCH) after 5 and 8 months after the soil contamination.

The content of radioactive europium in the water-soluble fraction was also reduced by 24% from the first to the fifth month and by 33% to the eighth month after contamination. The europium content in the exchangeable soil fraction also decreased fivefold. These changes can be explained by the redistribution of ^{152}Eu between soil phases with the time and binding in less mobile forms.

3.2. Transfer factors values after 5 months and 8 months vegetation on the contaminated soil

The values of TFs in the soil-leaves and soil-stems systems, determined on the fifth and eighth months after the pollution are presented on Fig. 3.

It can be seen that the values of the TFs of ^{152}Eu for the leaves are four to five times higher than the TFs for the stems of the peppermint. The data show that TFs from the fifth to the eighth month increased by 75% for the soil-leaves system and by 39% for the soil-stems system. The accumulation of ^{152}Eu from the soil to the plant determines the need to investigate the degree of transfer of the radionuclide to products for consumption. It is necessary for assessing the danger of its entry into the human body in case of radioactive contamination of the soil.

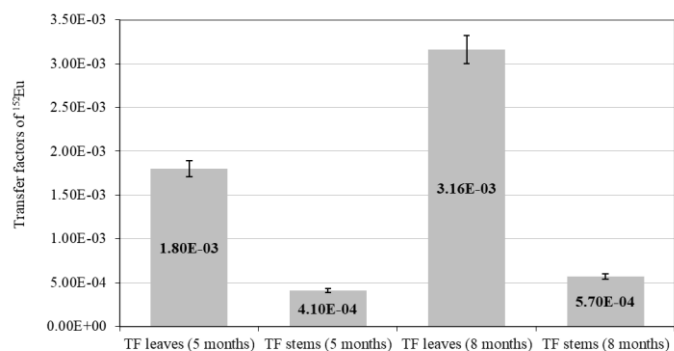


Figure 3 Transfer factors of ^{152}Eu from soil to mint leaves and mint stems after 5 and 8 months after the soil contamination.

3.3. Leaching of ^{152}Eu from peppermint to alcohol tincture and tea

The results, obtained from the measurements of the peppermint tea samples showed that $42 \pm 2\%$ from ^{152}Eu was leached.

No ^{152}Eu was detected in the tincture. This result showed that the radionuclide is bound to the hydrophilic part of the plant.

4. Conclusions

The present study showed that the entrance of radioactive europium solution to Calcaric Chernozem soil over a period of 8 months resulted in bioaccumulation by *Mentha piperita* L. that was 4 to 5 times greater in leaves than in stems.

An increase in the soil-stems and soil-leaves TFs was measured with the increase of the exposure time of the plant to the soil pollutant. The amount of ^{152}Eu bound to fulvic acids in the soil was found to remain constant from 1 to 8 months after the contamination. The content of the radionuclide bound in complexes with humic acids, as well as in water-soluble and exchangeable geochemical form, significantly decreased with the time.

42 % from ^{152}Eu , accumulated in the peppermint dry leaves was found to be leached in the mint tea and could endanger the human health. No danger of contamination of 86 % $\text{C}_2\text{H}_5\text{OH}$ peppermint tincture with ^{152}Eu was found, when radioactive contaminant entered the soil in aqueous solution.

The data obtained from the present study can be used in the assessment of the danger of internal radiation exposure with radioactive europium in case of nuclear contamination.

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Conditions for restoration of agricultural land after the bombing

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Abstract. *The main indicators of the impact on agricultural fields of the military actions that are currently taking place in Ukraine are determined. In particular, not only the damage to the surface relief, but also the contamination of fields with chemicals has been established. The indicators of soil contamination, as well as the directions of further use of the fields and general rehabilitation measures for agricultural land affected by chemicals are determined.*

KEYWORDS: FERTILE SOILS, CHEMICAL CONTAMINATION, RECOVERY, SINKHOLE, MECHANICAL CLEANING

As a result of the ongoing hostilities in Ukraine, agricultural land is being severely damaged and destroyed, and its condition, especially its environmental condition, has deteriorated significantly.

The explosions create a blast wave and sinkholes on the field that destroy the terrain, as well as chemical contamination. The consequences of the blast wave are the formation of sinkholes of various sizes, 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].

In this case, chemical pollution is considered based on three components. These include contamination by potentially toxic elements, contamination by explosives, and conventional contamination due to high temperatures.

In addition, chemical contamination of agricultural land can have different degrees: from acceptable to moderately dangerous and hazardous. In this case, uprooting the standard: «DSTU 7243:2011 Soil quality. Technogenically contaminated lands. Inspection and use» land plots with very dangerous and extremely dangerous degrees of 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 a survey of such land and a rapid soil analysis on the land plot based on the results of the analysis of samples taken on the land plot [3].

The approaches most commonly used in soil sampling are as 5 cm. Thereafter, the sampling intervals should be close enough to each other, such as 5-10 cm or 20-30 cm, to ensure relevant depth segregation. Almost all studies show highly contaminated profiles of the topsoil (0-10 cm). With increasing depth, the level of contamination decreases, except for those potentially toxic elements that have relatively higher accumulation levels with increasing depth. A thorough study of soil contamination is usually limited to the first half meter of its depth [4].

Another important point is the following. It is also necessary to take into account the depth of groundwater when determining the sampling site, since the mechanisms of pollutant migration 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 pollutants to deeper layers.

To assess the degree of contamination, agricultural soils are classified by comparing them to the maximum permissible concentration and background content of hazardous substances that pollute the soil. In this case, the main calculated indicators of the degree of pollution are the concentration coefficient K_c and the total pollution indicator Z_c [2]. These indicators are determined by calculations based on field measurements.

Thus, the concentration factor K_c is calculated using the following simple formula:

$$K_c = C_i \cdot (C_f)^{-1}, \quad (1)$$

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

After that, it is possible to determine the total pollution index Z_c which can be calculated using this expression:

$$Z_c = \sum K_c - (n - 1), \quad (2)$$

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

Based on the measurements and analysis of soil samples taken near the towns of Sloviansk and Shchastia (Donetsk Oblast), directly in the areas of fields where shells hit and 500 meters away, the average value of chemical contamination indicators was generally at the level of background values. At the same time, soil samples were taken from the test site using the «envelope» method with an average of 5 points. Systematic exceedances of 1.1 to 1.3 times were recorded for mercury, vanadium, cadmium, non-radioactive strontium and gamma radiation. The maximum exceedance for some indicators was 1.2-2.0 times the background level, and only in some cases the exceedance reached 7-17 times.

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 explosion was 150 times higher than the background. The concentration of vanadium was $100 \text{ mg} \cdot \text{kg}^{-1}$, and there was no vanadium in the clean sample at all. Titanium-based alloys with vanadium additives are used in aviation and missile technology.

There was also a 2.3-fold exceedance of sulfates, 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 $150 \text{ mg} \cdot \text{kg}^{-1}$. The content of sulfates in the same sample exceeded the norm 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 the products. Commission Regulation (EC) No. 1881/2006 of December 19, 2006 laying down maximum levels of certain contaminants in foodstuffs sets the following permissible levels of lead ($\text{mg} \cdot \text{kg}^{-1}$) of wet weight):

- Vegetable (cabbage), leafy and cultivated mushrooms – 0.30;
- Cereals, wheat, rice, legumes, soybeans, and berries – 0.20;
- Fruits and vegetables (excluding cabbage and leafy vegetables) – 0.10.

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

Based on the above, pollution indicators, areas of use and rehabilitation measures were formulated for agricultural land damaged by military operations in cases where chemical contamination occurred [2].

Table 1. Indicators of contamination, areas of use and remediation of agricultural land

Total soil pollution index Z_c	Level of contamination (% of the area) of the	Categories of land suitability	Areas of application	Proposed rehabilitation measures
Acceptable pollution index Z_c less than 16	Very low level contamination up to 10% of the land area	Definitely suitable	Growing crops without restrictions	Not conducted
Moderately hazardous pollution index Z_c up to 32	Low-level pollution (10-25% of the land area)	Suitable for	Growing crops without restrictions, subject to product quality control	Agronomic measures, liming, application of organic and mineral fertilizers
Dangerous pollution index Z_c from 32 to 64	Medium level pollution (25-50% of the land plot area)	Not very suitable	Use for industrial crops without obtaining food from them	Agrotechnical measures, phytoremediation, chemical reclamation
Very dangerous pollution index Z_c from 64 to 128	High-level pollution (50-75% of the land area)	Conditionally suitable	Use for pastures and cultivation of essential oil crops	Physical and chemical reclamation
Extremely dangerous pollution index Z_c more than 128	Very high level of pollution (75-100% of the land area)	Not applicable	Withdrawal from intensive use. Preservation	Involvement or natural recovery

Determining and analyzing pollution indicators makes it possible to choose the optimal reclamation option. In this case, the choice of land remediation methodology is based on a cumulative assessment of the level of damaged land, which involves determining the category of land use suitability.

To carry out this restoration of agricultural fields damaged by explosions, it is first and foremost necessary to digitize the areas using satellite / UAV / ground monitoring with reference to the coordinate system of each specific field. All areas should be digitized, regardless of the state of damage and the extent of the impact. This is also necessary because, even if the physical damage to the soil of an agricultural field is minor, it may be chemically contaminated. So, we can recommend this approach. In case of damage to the surface of a field where 75-100% of the area is affected, it is recommended to preserve the damaged areas and allow the process of self-healing to occur naturally, since removing the damaged soil and bringing in high-quality soil in its place will be quite costly from an economic point of view.

Furthermore, if the damage amounts to 50-75% of the area of the plots, the soil cover requires mandatory reclamation.

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

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

After agricultural fields have been cleaned from the source of contamination and debris, it is necessary to take measures to restore the soil damaged by explosions. According to the developed recommendations, if there are relatively shallow craters, up to 0.5 m in size, they can be covered with the 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 [7, 8].

If there are deep sinkholes on damaged agricultural fields, measuring more than 0.5 m, they should be filled with soil in the following sequence. It is necessary to ensure that the order of soil

layers is close to the order of undamaged areas, so the sinkhole should be filled with mineral soil first, and the upper fertile soil layer up to 30 cm deep should be filled with already fertile soil. If the soil is backfilled in a chaotic manner, it is likely that such a field will be low-productive for further crop cultivation and its full restoration will require additional measures, such as additional application of organic fertilizers, ameliorants, phytomeliorants, etc. Based on measurements of the parameters of explosion craters, the required need for mineral and fertile soils is calculated in the working land management project [7, 8].

To restore the 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 "sterilization" occurs, 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. [9, 10]. Subsequently, after leveling 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 fertilizers and sow grasses to intensify natural biochemical treatment processes.

Conclusions.

1. Based on the study of literary sources and their analysis, the conditions for restoring agricultural land after bombing have been formed, which should be carried out in the following sequence:

- after cleaning agricultural fields from the source of contamination and debris, it is necessary to monitor their size;
- Based on the analysis of the monitoring, develop specific measures to be taken in each case of soil damage.

2. The following algorithm is recommended for the restoration of soils damaged by explosions by mechanical means:

- relatively shallow craters, up to 0.5 m in size, are recommended to be filled with soil mass left at the explosion site (at an acceptable concentration of pollutants) or mineral soil (loam, loess loam, sandy loam, sand), followed by leveling the surface;
- sinkholes larger than 0.5 m should be backfilled with soil mass in an order of soil layers that is close to the order of undamaged areas, so the sinkhole should first be filled with mineral soil;

3. Restoration of agricultural fields damaged by explosions and contaminated with heavy metals and hazardous chemicals is recommended in the following sequence:

- First, it is necessary to remove or clean and remove for disposal the damaged surface soil layer inside the explosion crater, since this layer of damaged soil, in addition to chemical contamination with heavy metals, also contains a burnt (baked) fertile soil layer, dehydration and "sterilization" occurred, which kills both pathogenic microorganisms and beneficial biota;
- Further restoration should be carried out in the manner described above, with the obligatory observance of alternating layers of the grant.

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Resilience in Water Management: Addressing Climate Change Challenges in Albania

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Abstract: Albania has significant water resources, yet seasonal fluctuations and inefficient usage increasingly threaten these. This study examines the repercussions of changes in the hydrological cycle on the country's land and ecosystems, as well as the broader social, economic, and environmental pressures. Through qualitative and quantitative analyses of industrial and agricultural practices, alongside the effects of urban population growth, we highlight how these factors exacerbate climate change impacts on water resources. Specifically, we investigate shifts in water quality and quantity, alterations in precipitation patterns, and the intensification of temperatures, evaporation, humidity, and soil aridity. The National Strategy for Water Resources Management (2018–2027) aims for sustainable water usage and improved quality across all resources by 2027, while also addressing disaster risks associated with droughts and floods. However, Albania faces escalating challenges in water resource management, impacting both supply and demand. Climatic trends indicate a decline in rainfall and river flows, particularly during summer, as well as increased soil dryness and more frequent extreme weather events. Currently, hydropower plants generate nearly 90% of the country's energy, further straining water resources. According to the SPEI Annual Drought Index, by 2100, Albania is projected to face a marked decline in precipitation, compounded by heightened dryness and reduced moisture levels. Recent data shows that the number of days exceeding 20°C has doubled and tropical nights have tripled compared to historical averages. Over the past three decades, floods and landslides have accounted for significant economic losses, with 40.2% and 33.5% of damages respectively. To address these challenges, urgent and long-term measures are required, including the sustainable management of water resources, modernization of distribution networks, and enhanced water efficiency to mitigate waste.

Keywords: CLIMATE CHANGE, WATER RESOURCES, METEOROLOGICAL CONDITION, RESILIENCE, HYDROLOGICAL CYCLE

1. Introduction

A historical approach to water management (drinking water, rainwater, and wastewater) emerged early in human history, gaining significant momentum in industrialized cities in Europe and the United States during the late 19th century [1-2]. In the early 20th century, population growth and economic development directly impacted the water supply-demand balance [3]. Moreover, the projected impacts of climate change are expected to undermine the ability of many existing water supply systems to meet the future and current needs of populations [4-5].

The concept of "sustainable water resources management" was defined [6] as "the use of water that supports the ability of human society to endure and thrive into the indefinite future without compromising the integrity of the hydrological cycle or the ecological systems that depend on it." This principle emphasizes considering climate change and incorporating both supply and demand strategies while accounting for the impacts of anthropogenic activity. Undoubtedly, spatial planning can play a critical role in implementing water quality management and adapting to climate change in the water supply sector. The concentration of pollutants in soil and water has serious consequences for the well-being of residents [7].

From a spatial planning perspective, economic and service sectors—such as housing, energy, economic development, water transport, urban waste, and social and health welfare—affect land use in social, economic, and environmental contexts [8]. This perspective recognizes that natural and environmental resources support human societies, and land-use decisions are made within the broader social and economic context.

This paper aims to demonstrate the correlative relationship between the potential of spatial planning under climate change impacts and the promotion of sustainable water resource management.

Albania is considered a country rich in relatively abundant water resources, with freshwater flowing from east to west [9]. The country's major rivers contribute a total annual water flow volume of $39,220 \times 10^6 \text{ m}^3/\text{year}$ [10] with 95% of this flow discharging into the Adriatic Sea and 5% into the Ionian Sea [11].

The hydrological cycle is a dynamic and integrated component of the Earth's geophysical system, continuously influenced by climatic conditions. Changes in temperature affect evaporation rates, cloud characteristics, soil moisture, and precipitation and

snowmelt patterns. Shifts in precipitation impact the timing and magnitude of floods and droughts, alter flow regimes, and change groundwater recharge characteristics. Groundwater supplies 80% of the population's drinking water needs and contributes 23% of the annual flow. On a broader scale, climate change can alter major regional atmospheric circulation patterns and the frequency and intensity of storms. While much global climate research focuses on how climate change will affect the water balance—particularly precipitation, evaporation, and runoff—it remains unclear exactly how hydrology and water management systems will be impacted, and how these challenges can be addressed [12]. According to the Intergovernmental Panel on Climate Change [13], the water sector will bear the brunt of most climate change impacts. These impacts on the urban water sector can be categorized into two main aspects: water as a resource and water as a hazard. As a resource, the availability of good quality water is essential for the well-being of the growing urban population. It is also vital for many economic activities in and around cities, including peri-urban agriculture, food production, and other industrial operations [14].

Since the early 1990s, the IPCC has identified anthropogenic influences on climate, which have led to catastrophic global changes such as rising temperatures, sea-level rise, and ocean acidification [15-16]. Clean, sufficient, and fresh water is critical for population well-being and natural ecosystems. It plays a vital role in human health, industrial production, energy generation (both directly and indirectly), transportation systems, extensive outdoor recreation, and waste disposal [17].

The population's capacity to safeguard water resources and maintain water quality is fundamental to supporting livelihoods, ensuring human well-being, and driving socio-economic development. This includes protecting against water pollution [18], mitigating water-related disasters, and maintaining ecosystems in the face of climate change [19].

2. Materials and Methods

This study analyzes climate data on average monthly temperatures and precipitation for the period 2020–2021, compared to the 30-year average from 1961–1990. Meteorological measurements from various climatic zones and subzones of the country were used to assess several factors influencing the quality and quantity of surface and groundwater, such as soil moisture, soil dryness, evaporation, and transpiration. By integrating findings from literature reviews and qualitative methodologies, water data and results were compared over a specific period. Climatic pressures were examined for their interactions across different

spatial and temporal scales, impacting water availability. This availability depends not only on the quantity of water in various sources but also on its quality. The structure of this study focuses on analyzing parameters to conceptually describe the relationships between extreme weather conditions and water availability in nature (see Fig. 1).

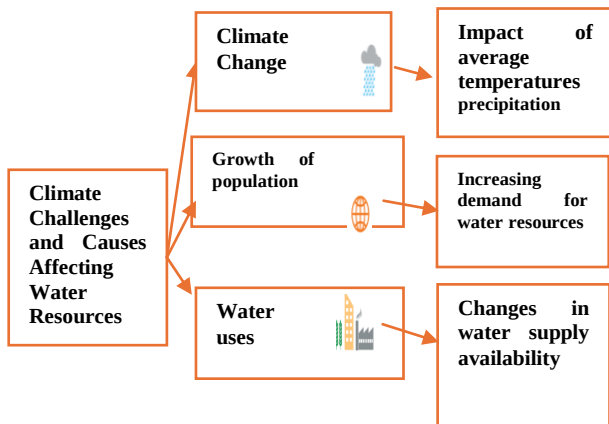


Fig. 1 Structure of study methodology

3. Results and discussions

Albania is characterized by relatively abundant freshwater resources. The country's hydrographic basin covers an area of 43,305 km², of which 14,557 km² is within the Drin and Vjosa river basins, shared with neighboring countries such as Greece, North Macedonia, and Kosovo. Major rivers, including the Drin, Buna, Mati, Ishmi, Erzeni, Shkumbini, Vjosa, and Semani, are grouped into six watersheds that flow from east to west across the country [20]. These rivers are a vital source of hydropower, with several artificial lakes constructed for electricity generation. The energy sector utilizes approximately 14 billion m³ of water annually through the hydroelectric power system. Additionally, these artificial lakes are used for irrigating agricultural lands. Along the Adriatic-Ionian coastal zone, numerous lagoons play a critical role in tourism, ecosystem protection, and fishing [21].

Human activities are driving increases in atmospheric concentrations of greenhouse gases and aerosols, which, if left unchecked, will continue to rise, exacerbating climate-related challenges. Albania faces mounting difficulties with water quality due to growing demand for water resources, particularly in regions where inland waters are scarce. As atmospheric greenhouse gas concentrations increase, global average precipitation is also expected to rise, directly affecting the quality and quantity of surface water. Changes in river flow could have dual effects: improving water quality by diluting pollutants when flows are high or worsening it when flows are scarce [17].

Future changes in runoff and water resources depend on a variety of factors, particularly precipitation and temperature. These climate variables have a direct impact on surface and groundwater systems. Rising global average temperatures, coupled with increasing monthly average temperatures in Albania, will intensify greenhouse gas concentrations. If emissions remain unchecked, temperature increases will become more pronounced. Consequently, the region may face a significant rise in wildfires, droughts, food shortages, and environmental and human risks [22].

Numerous studies indicate that climate change will increase the frequency and intensity of precipitation events. Reduced snowfall and earlier snowmelt into watercourses are expected to heighten the probability of flooding earlier in the year and reduce water flow during late spring and summer. Increased atmospheric CO₂ concentrations will influence vegetation's water use, potentially reducing transpiration rates in some plant species under certain conditions. Other factors influencing plant transpiration include

vegetation type, soil conditions, and groundwater interactions. Projected trends of more frequent droughts and floods are anticipated to alter water flow patterns, potentially causing reduced spring flows and increased winter flows. These changes will have significant implications for agriculture and water management. Additionally, more intense rainfall, river erosion, and flooding are likely to damage water management infrastructure and services [23].

According to a study [24] data from 10 meteorological stations across Albania showed that during 2020, the average maximum annual temperatures increased by +2.8°C above the multi-year average of 1961–1990. Concurrently, the average annual precipitation decreased by 300 mm [25]. Comparisons of minimum air temperatures in 2021 revealed an increase of +1.1°C above the same multi-year average. Similarly, the average maximum temperature in 2021 increased by 2.3°C, while the minimum temperature rose by 0.9°C. These findings indicate a consistent trend of rising temperatures and declining precipitation.

The analysis reveals that Albania is increasingly experiencing conditions of reduced precipitation and elevated temperatures. River flows, particularly during the summer, have significantly decreased. For instance, measurements at the Rogozhin Bridge on the Shkumbin River show that summer season flows (June–August) account for only 8% of the annual flow, compared to 77% during the winter and spring seasons [26].

Furthermore, the study [27], analyzed precipitation data from 21 meteorological stations, revealing that in 2020, precipitation ranged from 122.9 mm to 959.7 mm less than the 30-year averages (1961–1990), with only four stations recording higher values. Precipitation data for 2021 also showed a reduction in rainy days compared to the 30-year average, exacerbating drought conditions. These findings suggest that precipitation levels are likely to decrease in a more stable and intensified manner throughout the year, with negative implications for Albania's water resources and agricultural productivity.

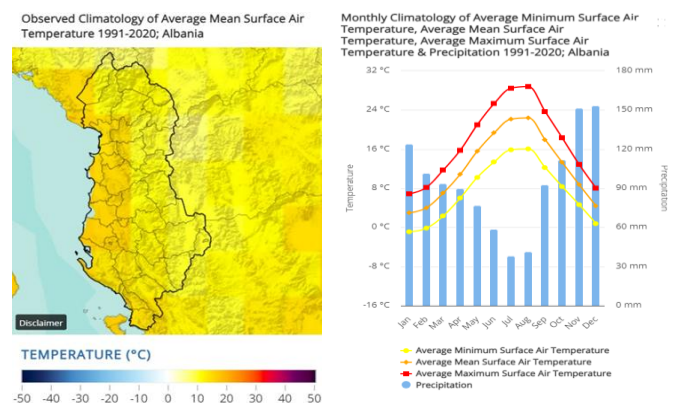


Fig. 2 Average air temperature and precipitation in Albania for the period 1991-2020 (CCKP, 2022)

Fig. 2 shows the average air temperatures and precipitation in Albania for the period 1991-2020, highlighting a significant increase in temperatures. The circulation of water back to the atmosphere occurs through evaporation from land and water surfaces, as well as transpiration from plants. The process of water evaporation depends on several factors, including climatic and landscape conditions such as humidity, wind speed, water and energy availability, vegetation and soil characteristics. As temperatures rise, the energy available for evaporation increases, and the atmospheric demand for water from land and water surfaces also grows.

Increasing average temperatures generally lead to an increase in the potential for evaporation, although factors such as lower radiation and increased atmospheric water vapor content may reduce evaporative demands. Vegetative cover is also crucial, as

plants absorb precipitation and return water to the atmosphere. Different types of vegetation have distinct characteristics in terms of evaporation. With rising temperatures, soil moisture deficits are likely to increase, as well as the amount of precipitation in a given area.

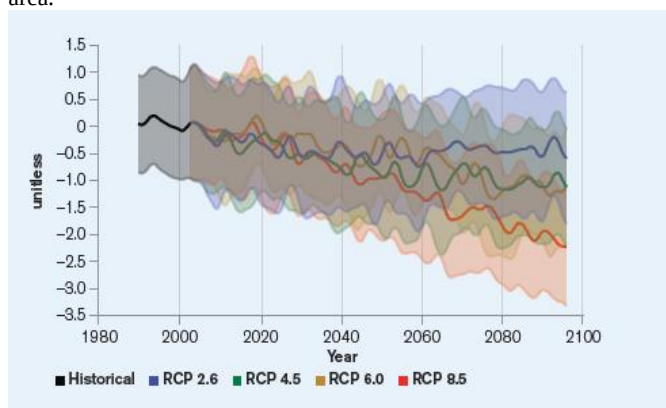


Fig. 3 Annual drought index SPEI, Albania (CCKP, 2020).

According to the Climate Change Knowledge Portal [28], (see Fig. 3) presents the Standardized Precipitation Evaporation Index (SPEI), which measures the extent of water deficits in Albania. Negative values on the graph represent dry conditions, with values below -2 indicating severe drought. Positive values indicate increasing wet conditions. Based on the graph, the significant decline in the SPEI, by more than 2 units from the baseline period to the end of the century, suggests a strong correlation between reduced precipitation and an increased probability of drought.

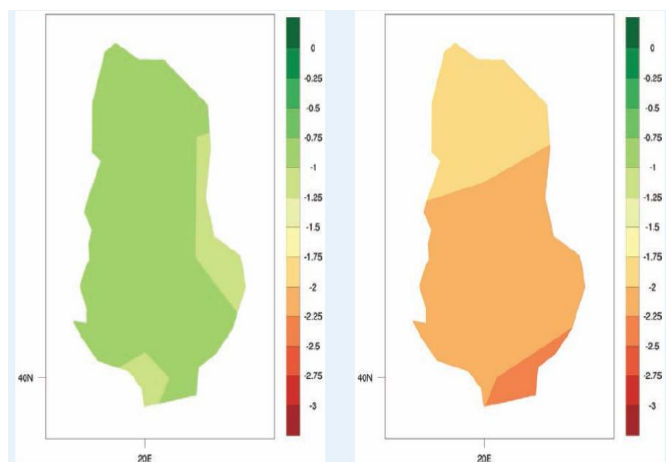


Fig. 4 Spatial representation of SPEI across Albania for the period 2040–2059 (left) and 2080–2099 (right), according to RCP8.5

Additionally, the report [28], specifies that Albania will experience water stress by the 2050s and severe water stress by the 2090s, with the greatest droughts occurring in the central and southern regions. This phenomenon is illustrated in Figure 3, which shows the spatial variation of the annual drought index across Albania.

Water quality and quantity significantly impact natural ecosystems, human health, and economic activities. Conversely, human activities directly affect both water quality and quantity. Global climate change has the potential to substantially alter water resources by changing temperature patterns, flow rates, timing, and the ability of watersheds to assimilate waste and pollutants. The sustainability of water bodies, land use, and agricultural practices is heavily influenced by these changes [29].

In regions sensitive to climate change, particularly those vulnerable to increased temperatures and variability in precipitation,

there will likely be even greater impacts on both surface and groundwater quality and availability.

The amount of water accumulated and stored in soil is influenced by factors such as vegetation type, soil composition, porosity, evaporation rates, and rainfall intensity. Soil moisture is a critical hydrological variable of particular importance to sectors like agriculture. Groundwater use in agriculture accounts for up to 8.7% of total consumption.

When atmospheric precipitation falls, part of it flows into rivers, lakes, or seas, while another portion is absorbed by vegetation, and a smaller amount infiltrates to replenish groundwater. According to the study [24], a reduction in precipitation of up to 8% by 2050 will require increased water storage capacities for agriculture. Additionally, increased temperatures will raise transpiration and evaporation rates, potentially causing a moisture deficit in Albania of up to 18%—roughly equivalent to 700 m³ of water per hectare for agricultural use. The combination of reduced precipitation and rising temperatures will intensify drought conditions and reduce available water for irrigation, with agricultural productivity per unit area potentially decreasing by 25–35%. In areas with decreased precipitation, soil moisture may be significantly reduced. Conversely, in areas with increased precipitation, soil moisture may rise, though this will depend on the rate of evaporation driven by higher temperatures.

The primary source of groundwater is atmospheric precipitation. In some areas, current groundwater usage is already unsustainable. The impacts of climate change on specific groundwater basins, as well as on the overall dynamics of groundwater recharge and water quality, can significantly affect long-term basin sustainability.

A decrease in precipitation in the future, similar to the conditions observed in 2020 and 2021, could reduce groundwater recharge, adversely affecting energy and agricultural production. Increased monthly temperatures will likely shorten the infiltration period and accelerate evaporation. Projections indicate that precipitation will continue to decline across all seasons, exacerbating irrigation shortages, particularly in saline soils, where salinity levels could increase to 10 times the maximum limit [27].

4. Conclusion

The study emphasizes the need for collaboration among all water users and stakeholders to achieve a shared vision for the protection, conservation, and sustainable management of water resources. It is recommended that water resources planning, and adaptation strategies be integrated into the development strategies for key sectors such as agriculture, energy, and infrastructure—sectors that are most vulnerable to the impacts of climate change, affecting economic, social, environmental, and foreign exchange balances at the national level. Ministries should coordinate efforts across sectors to develop climate change adaptation strategies and action plans.

Particular attention should be given to ensuring the productivity and sustainability of irrigation and drainage systems, improving water use efficiency, and mitigating the risks of floods and droughts. Climate change impacts place significant pressure on water resources, with potential negative effects on human health, economic stability, and the environment. These impacts are driven by extreme weather events, including floods and fluctuations in temperature extremes across the country.

Adaptation strategies for water resources must be tailored to specific regions, as they are closely linked to local climatic conditions. Therefore, decisions related to land use, drainage, infrastructure planning, and water supply and treatment are influenced by a variety of public and private stakeholders. Effective adaptation to climate change requires coordination and cooperation among various actors and interest groups, along with the fulfillment

of responsibilities by local municipalities, especially following the transfer of many competencies from the central government to local authorities for water management.

5. Summary

Albania is characterized as a country with a relatively high presence of water resources. However, resources and reserves are vulnerable due to seasonal variations and inefficient water use. This study aims to analyze and evaluate the possible consequences of a drastic change in the hydrological cycle, causing a series of impacts on the land in the context of the pressures exerted on the social, economic, and environmental sectors. A qualitative and quantitative analysis of industrial, agricultural activities, etc., together with a growing population and concentration in the country's big cities, contribute to climate change processes. Also, it affects water resources in terms of their quality and quantity, variability and time, form and intensity of rainfall as well as increasing temperatures, evaporation, humidity, and soil dryness. In the National Strategy for Water Resources in Integrated Management (2018–2027), sustainable use of water resources was foreseen, for achieving water quality in all water resources by 2027, reducing and managing disaster risk for drought, and floods, and increasing scientific knowledge on water. And yet, the challenges the country is facing in terms of water resource management are worsening both in supply and demand for providing sufficient water resources.

Climatological conditions in Albania have shown variability in reducing the amount of rainfall and its intensity, decrease in river flows, mainly during the summer months, decrease in water penetration into the ground, predicted trends for droughts, more frequent floods, etc. Almost 90% of energy production is provided by hydropower plants, which brings a serious problem to the country's water resources. According to the SPEI Annual Drought Index, our country, by the year 2100, is likely to experience a significant increase in reduced precipitation, increased dryness, and lack of moisture. The data shows that the number of days with temperatures of 20 °C has doubled and the number of tropical nights has tripled, compared to the long-term average rate. During the last 30 years in Albania, almost 40.2% of economic damage was caused by floods and 33.5% by landslides. Therefore, sustainable management of water resources, modernization of the distribution network, reduction of wastage, and increase of water efficiency are some of the emergency and long-term plans that should be undertaken.

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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.

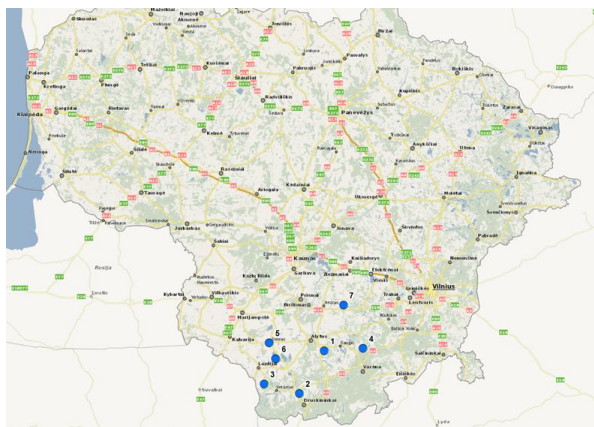


Fig. 1 The lakes researched included Alovė, Aviris, Galstas, Pabėzninkai, Giluitis, Dusia, and Guostus in Lithuania

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
Pabėzninkų 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 Pabėzninkai 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 Pabėzninkai 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.

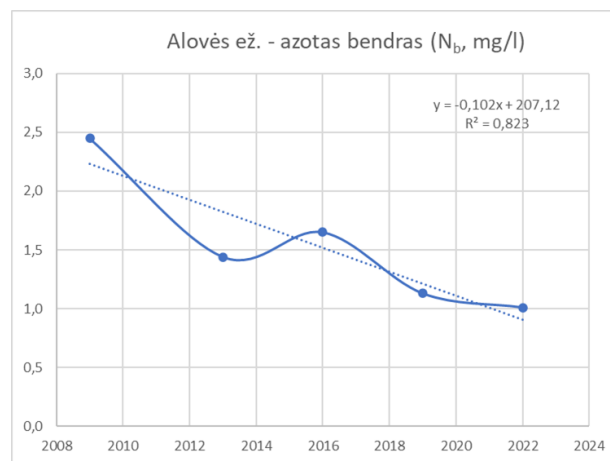


Figure 2 Total nitrogen in Alovė Lake (Nb, mg/l)

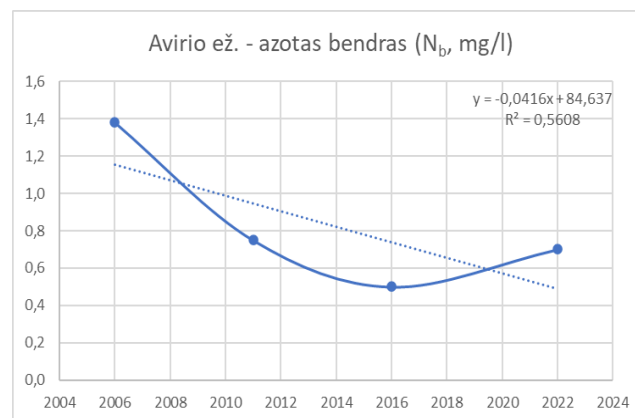


Figure 3 Total nitrogen in Aviris Lake (Nb, mg/l)

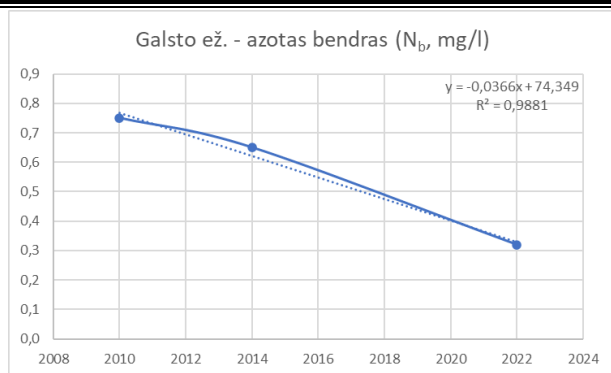


Figure 4 Total nitrogen in Galst Lake (N_b , mg/l)

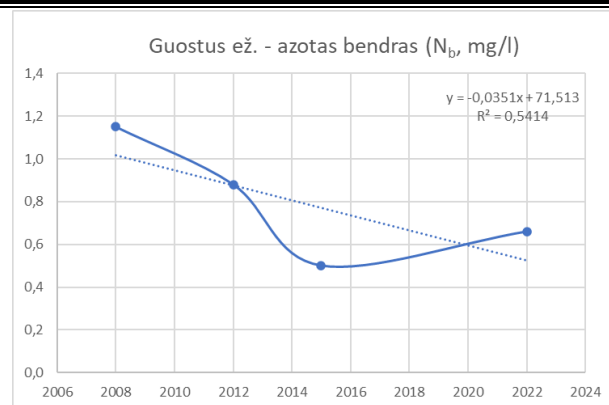


Figure 8 Total nitrogen in Lake Guostus (N_b , mg/l)

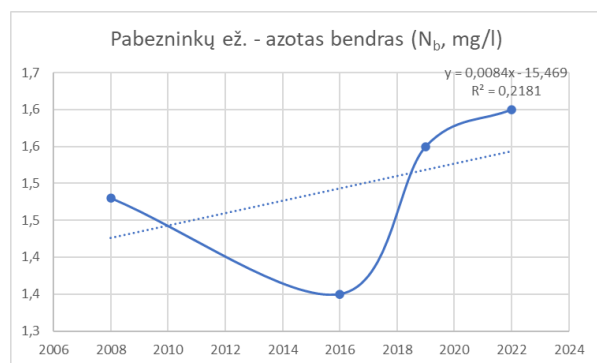


Figure 5 Total nitrogen of Lake Pabzninkai (N_b , mg/l)

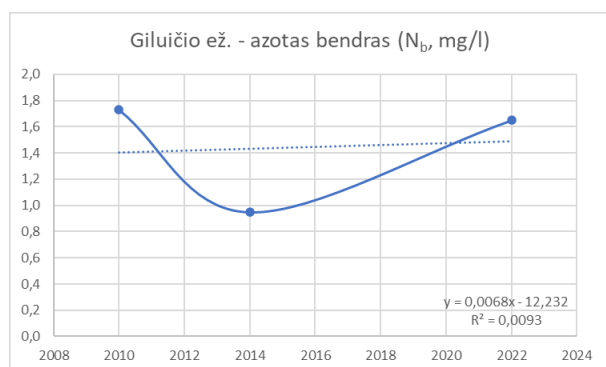


Figure 6 Total nitrogen of Lake Giluitis (N_b , mg/l)

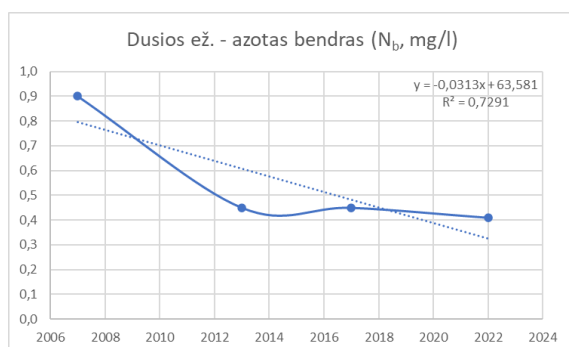


Figure 7 Total nitrogen in Lake Dusia (N_b , mg/l)

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.

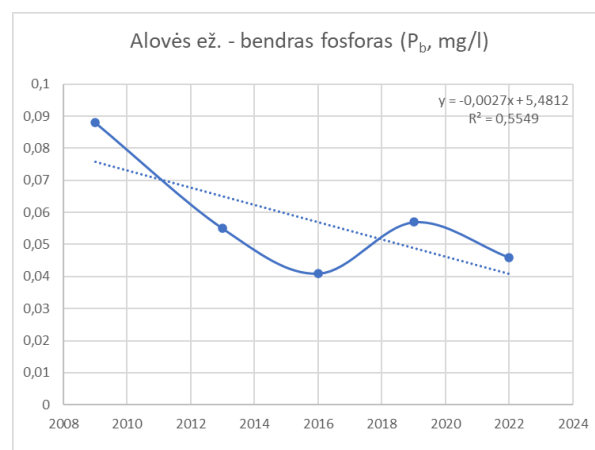


Figure 9 Total phosphorus of Alovė Lake (P_b , mg/l)

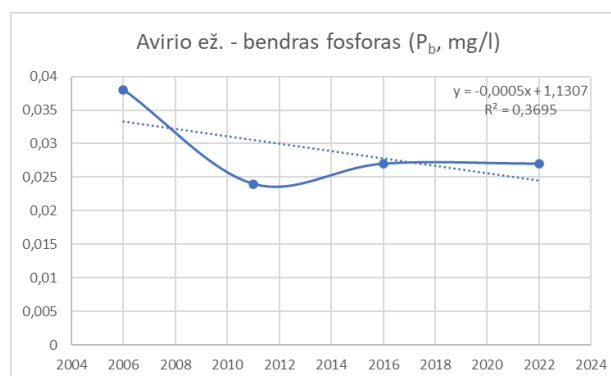


Figure 10 Total phosphorus of Lake Aviris (P_b , mg/l)

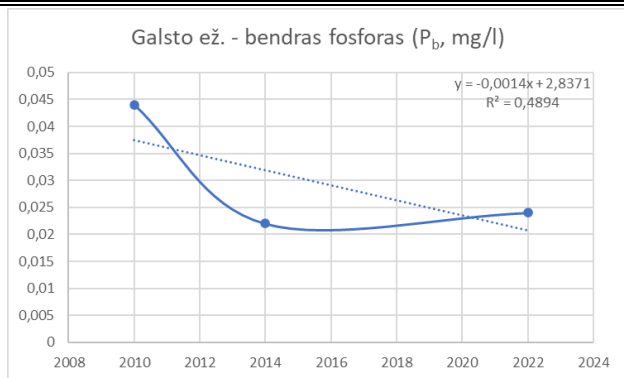


Figure 11 Total phosphorus of Galst Lake (P_b , mg/l)

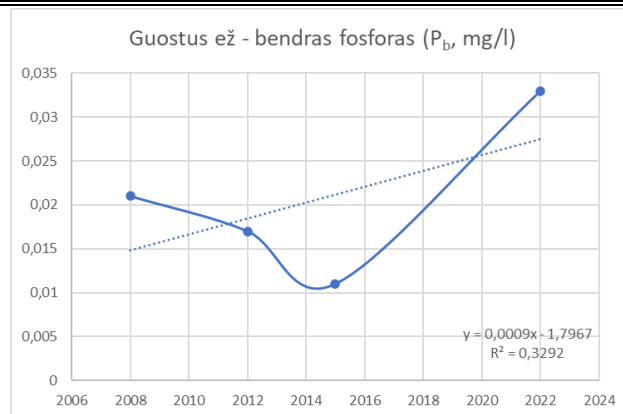


Figure 15 Total phosphorus of Lake Guostus (P_b , mg/l)

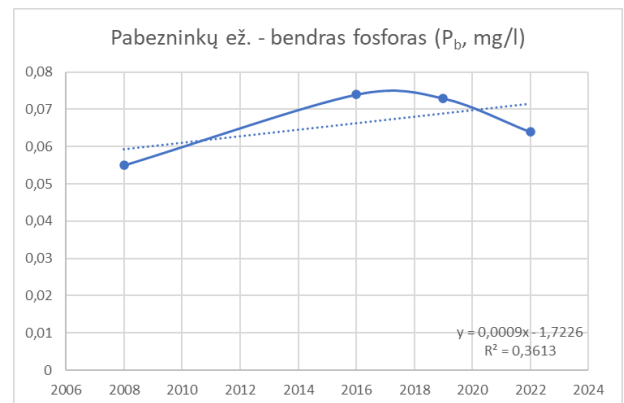


Figure 12 Total phosphorus of Lake Pabėzninkai (P_b , mg/l)

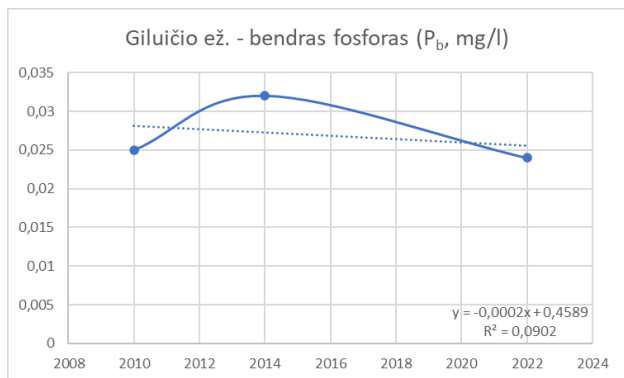


Figure 13 Total phosphorus of Lake Gilučiū (P_b , mg/l)

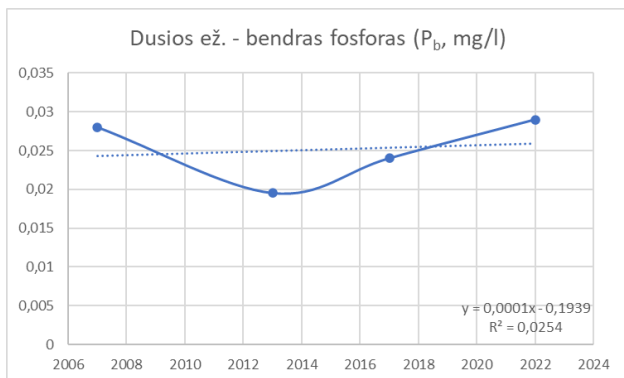


Figure 14 Total phosphorus in Lake Dusia (P_b , mg/l)

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); Guostus (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	Ežero 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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Utilization of solar energy in application of drip irrigation in gardens of mountainous and foothill areas of uzbekistan

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Abstract: Under the conditions of climate change, the provision of clean drinking water for population and irrigation water for crops has become one of the main problems in the world. With population growth and development of economic sectors, water resources deficit in the Republic of Uzbekistan and Central Asian countries is increasing from year to year. With population growth and development of economic sectors, water resources deficit in the Republic of Uzbekistan and in Central Asian countries increases from year to year. The solution of water deficit problem lies in water saving and rational water use. The main objective of scientific research is application of water and energy saving technologies in fruit orchards located in mountainous and foothill zones and in different soil-reclamation conditions of the Republic of Uzbekistan (Republic of Karakalpakstan, Bukhara, Kashkadarya, Namangan, Surkhandarya and Khorezm provinces), where water and electricity deficit is strongly felt. As a result, water saving in fruit orchards in comparison with traditional irrigation amounted to 67.4 % in the Republic of Karakalpakstan, 76.1 % in Bukhara province, and on average in the republic the saving reached 60÷80 %. In order to reduce the human factor in garden irrigation, all processes were automated. A mobile solar system with a capacity of $N=4.0\div4.2$ kWh (8 photovoltaic solar panels with a capacity of 500 W each) was manufactured to provide energy to the pumping unit supplying water to the drip irrigation system. Also, a system of cooling of solar panels was developed to increase the efficiency factor at high temperatures ($t = 40\div50^{\circ}\text{C}$).

KEYWORDS: WATER DEFICIT; WATER- AND ENERGY-SAVING TECHNOLOGIES; GARDENS; DRIP IRRIGATION; SOLAR ENERGY, PANEL COOLING SYSTEM; IRRIGATION AUTOMATION.

1. Introduction.

Nowadays, providing the rapidly growing population with environmentally friendly food is becoming one of the major problems on Earth. Therefore, all countries of the world, and the United Nations, have food security programs [1]. In our country, the program "On measures to further ensure food security of the country" was adopted by the decree of the President of the Republic of Uzbekistan in 2018 [2].

Agriculture is the main source of food security and the main consumer of water resources. Today, our republic is allocated an average of 51÷53 billion m³ of water resources under the limit, of which: 90÷91 % - for irrigation of 4.3 million hectares of agricultural land; 4.5 % - to the sphere of communal and household economy; 1.4 % - to industry; 1.2 % - to fish farming; 0.9 % - to energy; 1.0 % - for other branches of economy. [3]. With the growth of population and development of economic sectors, water demand also increases. The deficit of water resources in the Republic of Uzbekistan and in Central Asian countries increases from year to year [4]. The most optimal solution of water deficit problem is water conservation and reasonable water use [5].

Application of non-traditional methods of irrigation provides 30÷45% increase in crop yield and 25÷30% increase in labor productivity, 45÷60% decrease in water resources consumption [6]. To date, the following methods of water-saving technologies are applied in our republic: irrigation with short furrows; sprinkling; use of hydrogel granules; land leveling with laser devices; irrigation from under the soil; irrigation with portable flexible plastic pipes and polyethylene trays; irrigation along furrows with film perforated cover; subirrigation (raising the groundwater table); drip irrigation and others.

The use of renewable energy to replace traditional fossil fuels reduces CO₂ emissions and is a greener option to overcome the threat of global warming. These benefits are particularly noticeable in rural and agricultural areas where access to the grid is problematic [7, 8].

In the countries of Central Asia and in the Republic of Uzbekistan, the most available renewable energy source is solar energy. On average, we have more than 300 sunny days per year with a duration of 14÷16 hours, the average temperature is +42⁰ C (in desert areas the temperature can rise to +70⁰ C); the capacity of solar energy reaches 1900÷2000 kW/m² [9, 10].

The use of photovoltaic systems will provide the necessary electricity for pumping units and control equipment required for the effective operation of the integrated drip irrigation system [11].

The purpose of the research work is to introduce a complex automated drip irrigation system using renewable energy sources to ensure energy and water resources conservation, timely and efficient irrigation in agriculture. As a result, there will be an opportunity for additional development of new lands, determination of irrigation norms for fruit orchards in 6 regions of the republic, also crop yields will increase, labor costs will decrease, which will reduce poverty and increase profit of rural population, as well as ensure sustainability of food security in the country/region.

The project has been implemented in gardens of water users of the Republic of Karakalpakstan, Bukhara, Kashkadarya, Namangan, Khorezm and Surkhandarya provinces. In future, the project will be implemented in all horticultural farms of the Republic of Uzbekistan and in Central Asian countries.

Table 1: Objects of the study

№	Location of research objects
1	Republic of Karakalpakstan, Beruni district, farm "Ozod intensiv bog".
2	Khorezm region, Gurlensky district, "Mevazor gardens" Ltd.
3	Bukhara oblast, Kagan district, "Training and Research Center" of Bukhara Institute of "Natural Resources Management".
4	Kashkadarya province, Kasan district, "Karshi Canal Operation Department".
5	Surkhandarya province, Sariosi district, farm "Mindal Agro".
6	Namangan province, Novonamangan district, "Samarkand Golden Fiber" farming enterprise



To implement an integrated automated drip irrigation system using renewable energy sources to ensure conservation of energy and water resources, timely and efficient irrigation in agriculture, an integrated drip irrigation system consisting of the following three systems is proposed (Fig. 2).

1. Drip irrigation system.
2. Solar energy system with pumping units.
3. Irrigation automation system.

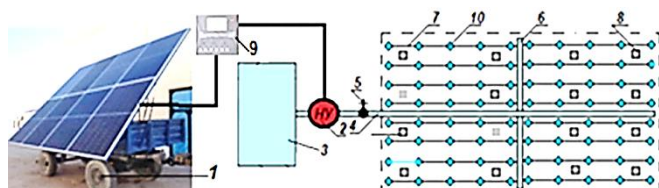


Fig. 1. Scheme of the complex automated system drip irrigation:

1-mobile solar power unit; 2-pumping unit; 3-tank for water; 4-pipeline for water supply; 5-crane for water flow regulation; 6-distribution pipes; 7-irrigation pipeline with drippers; 8-automation devices; 9-control unit; 10-fruit trees.

3. Results and discussion

3.1 Drip irrigation system.

Traditional drip irrigation system is a pressure system. It is known that the main sources of surface water resources - Amu Darya, Syr Darya and Zarafshan rivers move large amounts of sediment (Table 2) [13], which quickly clog the drip lines of the system [14]. Therefore, the liquid entering the drip lines must be purified to acceptable values (Table 3). Water is pumped by a pump from the source to the settling tank, and from the settling tank to the filters (Fig. 3).

Table 2. Size and number of suspended particles in water sources.

Diameters of suspended sediment fractions (mm) and their quantity (%)									D average, mm
2.0-1.0	1÷0.5	0.5÷0.2	0.2÷0.1	0.1÷ 0.05	0.05÷ 0.01	0.01÷ 0.005	0.005÷ 0.001	>0.001	
Zarafshan River (Hydropost 124, Navaiy, 2015.10.08)									
-	-	20.3	26.3	27.5	3.4	2.5	5.5	14.5	0.133
Sirdaryo River (Hydropost 1, Kal village, 2017.08.06)									
-	22.5	18.5	9.9	15.4	4.9	28.8	-	-	0.264
Amudaryo River (Hydropost 83, Tuyamuyun gorge, 2017.29.06)									
-	7.5	16.8	16.9	22.1	4.6	1.3	17.4	13.4	0.161

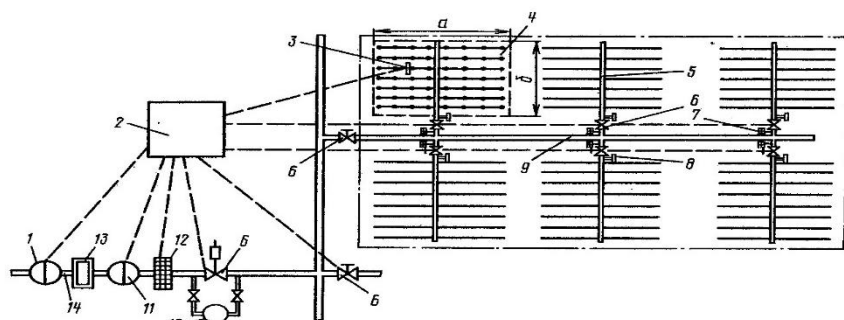


Figure 3. General scheme of the drip irrigation system irrigation:

1-main pump; 2-management computing complex; 3-meteorological station; 4-field of experience (module); 5-site pipeline; 6-closing-regulating fittings; 7-"compact" filter; 8-fertilizer connection complex; 9-distribution pipe; 10-fertilizer application device; 11-pump; 12-water cleaning filter; 13-regulating collecting basin; 14-main pipe.

Table 3. Permissible values of concentration and size of suspended particles contained in irrigation water of drip irrigation systems.

Size of through holes, mm	Permissible concentration of suspended particles in water and their sizes	
	Concentration, g/l	Particle size, mm
< 1	0.03 - 0.05	< 0.05
1-2	0.05 - 0.1	< 0.07
> 2	0.1 - 0.3	< 0.1

3.1.1 Efficiency of drip irrigation system

As a result of 3-year field studies on drip irrigation conducted in Surkhandarya province, water savings amounted to 39.4÷41.7% in soybean and sunflower irrigation, as well as 58.3÷62.0% in orchards and vineyards [6]. Taking into account saving up to 60% of water under drip irrigation in comparison with furrow irrigation, the purpose of the conducted research works was to develop new irrigation rates for drip irrigation of fruit orchards. Comparison of research results of furrow irrigation and drip irrigation is presented in Table 4.

Table 4. List of irrigation regime for orchards and vineyards by hydromodule districts of the Republic of Karakalpakstan, Kashkadarya, Surkhandarya, Khorezm, Bukhara and Namangan regions of the Republic of Uzbekistan.

№	The organization where the project is being implemented	Information about the orchard					Types of irrigation						Water saved, %
		Mechanical, structure of the soil, %	Groundwater	Type of tree	Age of tree	*Planting scheme	Furrow irrigation			Drip irrigation			
							Irrigation period/day	Irrigation norm, m ³ /ga	Age of tree	Irrigation period/day	Irrigation norm, m ³ /ga	Number of irrigation	

1	Republic Karakalpakstan, Beruni district «Ozod intensive bog» farm (N-I-A-b-V)	-heavy sand and clay-12,1%; -medium sandy-32,5%; -light sandy-38,0%; -sandy -17,4%.	3,5	apricot	2	4x3	$\frac{11.05}{\div}$ $\frac{31.08}{113}$	3600	4	$\frac{11.05}{\div}$ $\frac{31.08}{113}$	1102	18	69,4
2	Khorezm region, Gurlan district «Mevazor gardens» LLC (N-I-A-b-V)	-heavy sand and clay-30%; -medium sandy -47%; -light sandy -19,4%; -sandy -3,6%.	2,5	apple	3	5x3	$\frac{10.05}{\div}$ $\frac{31.08}{114}$	3600	4	$\frac{10.05}{\div}$ $\frac{31.08}{114}$	1026	18	71,5
3	Bukhara region, Kogon district, Bukhara Institute of Natural Management «Educational and scientific center» (C-I-A-b-V)	-heavy sand and clay-18,3%; -medium sandy -30,9%; -light sandy -49,7%; -sandy -5,7%.	2,5	apricot, peach	1	6x5 5x3	$\frac{21.04}{\div}$ $\frac{15.09}{148}$	5300	6	$\frac{21.04}{\div}$ $\frac{15.09}{148}$	1265	27	76,1
4	Kashkadarya region, Koson district, «Agrosuvtexmontaj» LLC, Department of Exploitation of Karshi Main Canals(C-I-A-b-V)	-heavy sand and clay -14,3%; -medium sandy -32,5%; -light sandy -38,0%; -sandy -17,4%.	3,0	apricot, almond	1	6x5 6x4	$\frac{11.04}{\div}$ $\frac{26.09}{168}$	4800	6	$\frac{11.04}{\div}$ $\frac{26.09}{168}$	1566	30	67,4
5	Surkhandarya region, Sariosia district, “Mindal-agro” farm (C-I-A-b-V)	-heavy sand and clay -21,7%; -medium sandy -50,0%; -light sandy -29,0%; -sandy -0,3%.	5,5	apple	7	5x4	$\frac{16.04}{\div}$ $\frac{15.09}{153}$	4900	7	$\frac{16.04}{\div}$ $\frac{15.09}{153}$	1350	27	72,5
6	Namangan region, New Namangan district, «Samarkand oltin tolası» farm (C-II-A-c-IV) .	-heavy sand and clay -39,0%; -medium sandy -39,7%; -light sandy -17,4%; -sandy -3,9%.	3,5	plum	1	5x5	$\frac{11.04}{\div}$ $\frac{10.09}{152}$	4300	7	$\frac{11.04}{\div}$ $\frac{10.09}{152}$	1120	28	74,0

*Planting scheme: the first number is the distance between rows; the second number is the distance between trees (seedlings)

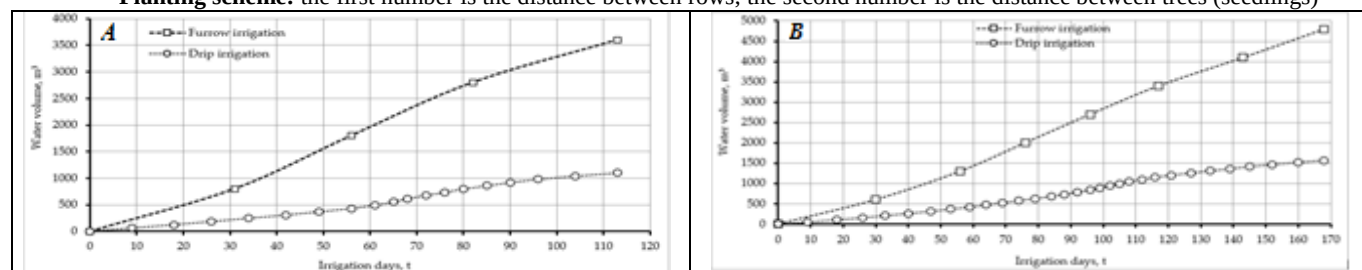


Figure 4. Relationship between irrigation rate and vegetation period- $m=f(T)$ by regions: A - Republic of Karakalpakstan; B - Kashkadarya region.

3.2 Solar energy system with pumping units

The use of mobile photovoltaic system will provide the necessary electricity for pumping units and control equipment of drip irrigation system. In summer period the air temperature in the regions of Central Asian countries, in particular in the Republic of

Uzbekistan, rises up to $t=40\div50^{\circ}\text{C}$. As a result of temperature increase the efficiency of photovoltaic battery (PVB) decreases up to 80%. To avoid the loss of efficiency, PVBs were equipped with a cooling system, which allows maintaining the temperature at $t=25^{\circ}\text{C}$ (Fig. 5 and Table 5) [11].

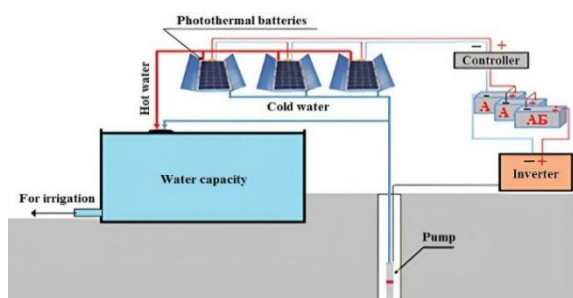


Figure 5. Schematic diagram of water lifting, redundancy and flow rate using autonomous photovoltaic installation.

3.3 Irrigation automation system

To reduce the role of human factor in the drip irrigation system, automation means are introduced, which will control the drip irrigation process on the basis of a special program that takes into account the water demand of plants [12]. By studying the type of soil on the site and its water-physical properties such as water permeability, capillarity, maximum field moisture capacity, volume, comparative soil weight and porosity depending on the growing season, the estimated soil moisture for these crops is established. All these data are put into the irrigation management program.

Table 5. Physical and technical characteristics of FTB parts with power of 4000 W

Maximum power of PVB, $P_{\max}$	500W	8 PVB
PVB efficiency factor, η	20, 3%	20,3%
PVB no-load voltage, U_{oc}	22,8V	22,8V
PVB short-circuit current, I_{sc}	8,9 A	8.9 A
Filling coefficient of VAC, ff	0,71-0,73	0,71-0,73
Cellular polycarbonate heat collector (HC) capacitance, V	17 liters	17x8=136 liters
Thermal conductivity of honeycomb polycarbonate, r	0,2÷3,9 W/m·°C	0,2÷3,9 W/m °C

Conclusions

1. The most cost-effective water-saving technology is drip irrigation, which allows: to achieve savings of water resources up to 50 percent and more; additional development of new agricultural lands; increase crop yields; reduce costs for irrigation works, as well as for the treatment of crops.

2. Application of mobile solar photo thermal battery (PTB) for power supply of drip irrigation systems will allow its implementation in hard-to-reach mountainous and foothill regions.

3. The efficiency of the mobile PTB system is ensured by the possibility of its universal use throughout the year and for a variety of purposes (not only for irrigation systems).

4. Due to cooling of PTB in summer time (at $t = 40 \div 50^{\circ} \text{C}$) it is possible to increase its efficiency up to 50 percent.

5. Application of the integrated drip irrigation system will increase incomes and improve the living standards of agricultural producers and the population, which will lead to poverty reduction, to increase the reliability and stability of food supply to the population.

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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.

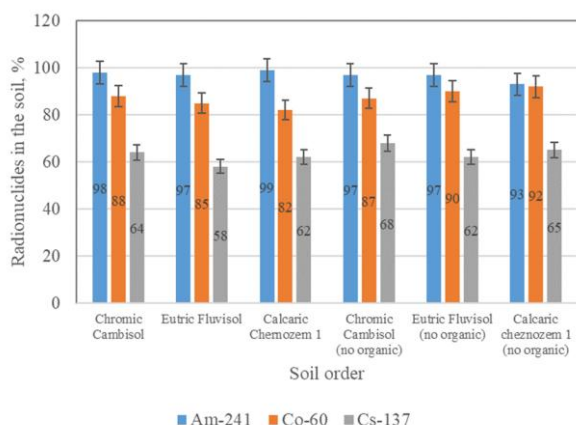


Figure 1 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction, 75 min after the contamination of natural soils with normal CEC and after removal of their organic matter.

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.

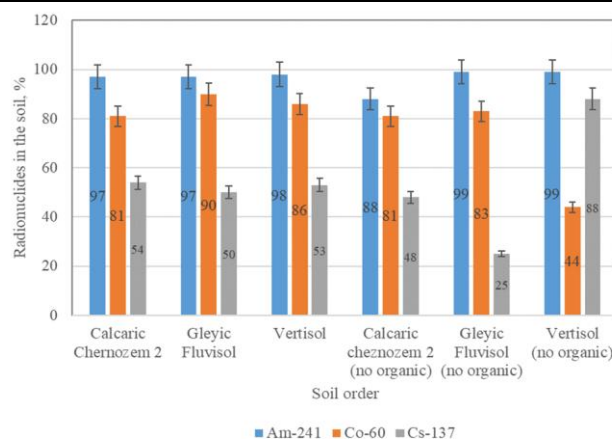


Figure 2 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 75 min after the contamination of natural soils with low CEC and after removal of their organic matter.

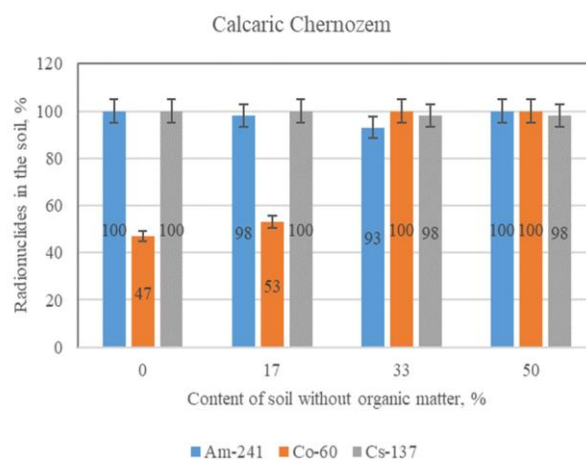


Figure 3 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Calcaric Chernozem 1 soil, containing different content (%) of soil without organic matter.

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.

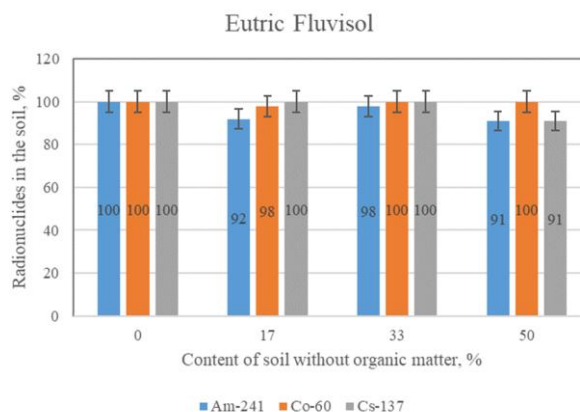


Figure 4 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Eutric Fluvisol soil, containing different content (%) of soil without organic matter.

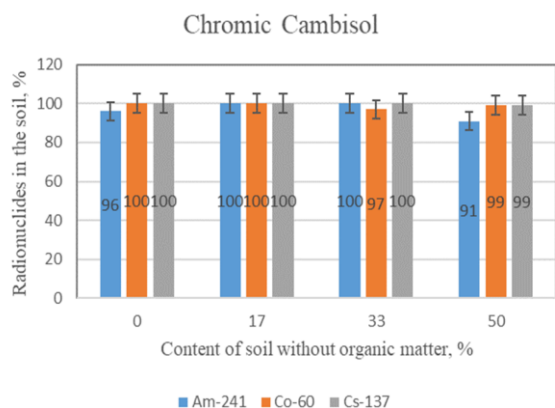


Figure 5 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Chromic Cambisol soil, containing different content (%) of soil without organic matter.

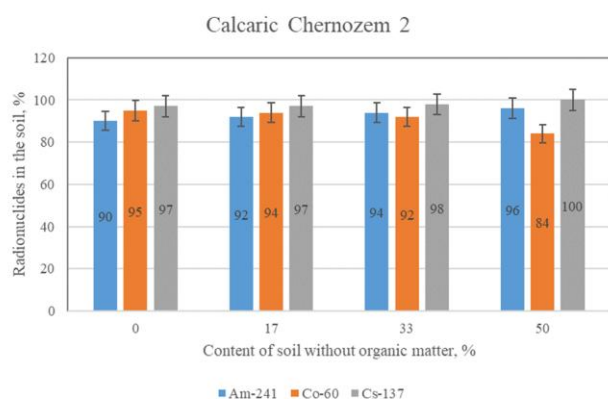


Figure 6 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Calcaric Chernozem 2 soil, containing different content (%) of soil without organic matter.

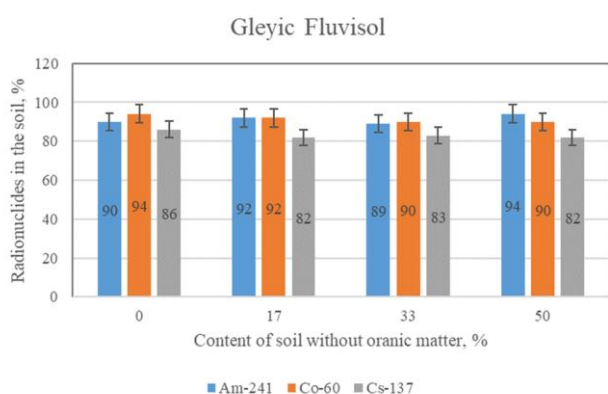


Figure 7 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Gleyic Fluvisol soil, containing different content (%) of soil without organic matter.

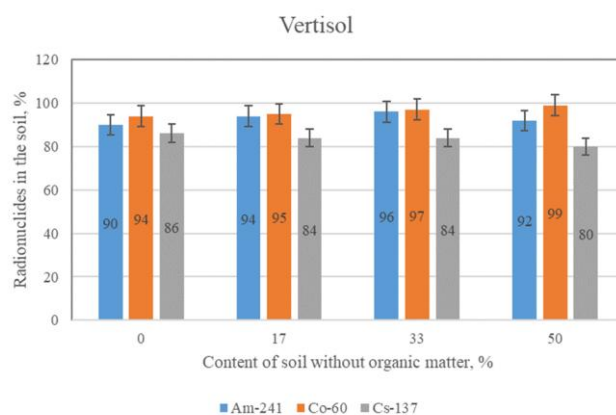


Figure 8 Content of ^{241}Am , ^{60}Co and ^{137}Cs (in %) in the soil after water extraction 3 weeks after the contamination of Vertisol soil, containing different content (%) of soil without organic matter.

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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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/k g	O. M %	P mg/kg	K mg/k g
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).

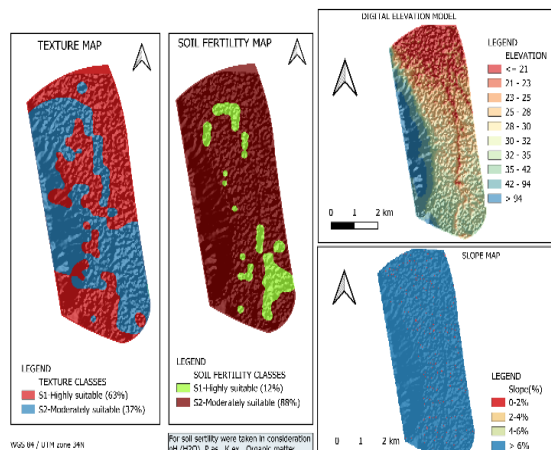
	Profile No.	GPS Co-ordinates		horizon, cm	Ph (water)	Organic matter, %	Available P, ppm	Ex. K, me/100g	Ex. Na, me/100g	% clay <0.002mm	% silt 0.002 - 0.05mm	% sand 0.05 - 2.0mm	fine sand, 0.05 - 0.10, %	sand, 0.1 - 2.0, %	Texture by analyses
Ana e Malit	1	4372645	4654349	23	8.5	1.0	7.0	0.2	0.1	6.8	25.7	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

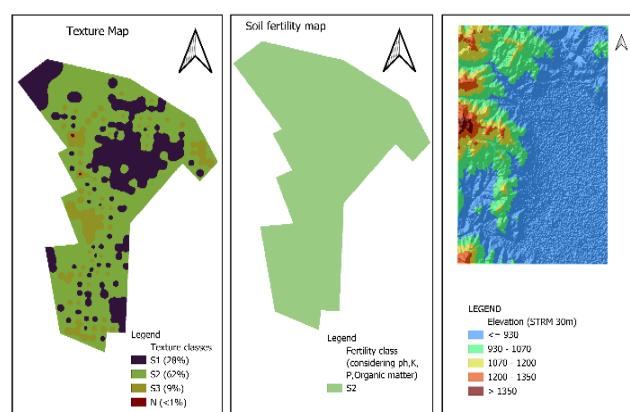
Classification	Index
Highly Suitable	S1
Moderate Suitable	S2
Not suitable	N

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



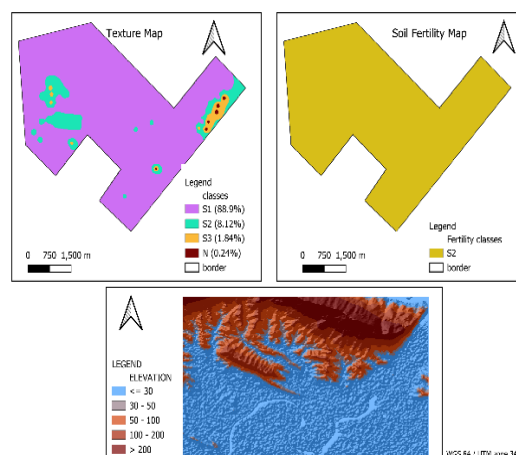
The GIS-based land suitability analysis for *Nigella sativa* L. in the Preza Commune of the Tirana District, focusing on soil texture and fertility, reveals promising potential for cultivation. The results indicate that 63% of the area falls under the highly suitable category (S1) based on soil texture 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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Influence of effective microorganisms on the biological activity of the soil in greenhouse pepper cultivation

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Abstract: The article presents the results of a study of the influence of effective microorganisms *Trichoderma viride*, *Bacillus subtilis* and *Enterobacter cloacae* on the biological activity of the soil when growing pepper on the plot with mineral fertilization (fertilizer rate $N_{22} P_{16} K_{20}$ kg/da). The experiment was carried out at the Maritsa Vegetable Crops Research Institute, Plovdiv in an unheated steel-glass greenhouse with the Pirouette F1 variety, planted according to the scheme (90/60/40 cm). The studied microbial substances were used as 0.1% aqueous solutions of the standardized biological preparations "Trichodermine" (*Trichoderma viride*, strain Trv1, titer 2.10^{10} c/ml); "Extrasol" (*Bacillus subtilis*, titer 1.10^{10} CFU/ml) and a bacterial preparation based on *Enterobacter cloacae* (titer 1.10^{10} CFU/ml) at a consumption rate of 10 L of solution per 20 m². The biological activity of the soil in the experiment was followed in different phenological phases of the development of the culture using the methodology for cultivating diluted aqueous soil solutions on solid nutrient media. As a result of the studies, it was established that the use of bioproducts based on *Trichoderma viride*, *Bacillus subtilis* and *Enterobacter cloacae* leads to optimization of the structural composition of the microbiome in the soil. Among the tested biopreparations with the greatest efficiency is the biopreparation "Trichodermine". The introduction of the biopreparation "Trichodermine" increases the biogenicity of the soil by 12% towards the middle and by 74% - towards the end of the growing season. The agrochemical effectiveness of the application of the biopreparation "Trichodermine" to regulate the nitrogen-phosphate-potassium nutritional regime has been established. During the period of active harvesting, the content of mineral forms of nitrogen in the variant with "Trichodermine" increases to 50%, of mobile phosphorus - to 40%, of mobile potassium - to 71%. An article confirms the expediency and effectiveness of the application of biological preparations to optimize the structural composition of the microbiome in the soil and regulate the nitrogen-phosphate-potassium nutritional regime.

KEYWORDS: CAPSICUM ANNUUM, TRICHODERMA VIRIDE, BACILLUS SUBTILIS, ENTEROBACTER CLOACEAE, MINERAL NUTRITION, SOIL MICROORGANISMS

1. Introduction

The use of fertilizers and chemical products for plant protection in agrocenoses is one of the main sources of anthropogenic impact on the soil cover. Crop productivity depends 2/3 on mineral fertilizers and 1/3 on organic fertilizers [1]. The main requirements when choosing a system for fertilizing crops are optimizing the nutritional regime and meeting the needs of plants for macro- and microelements during the growing season, especially during the critical periods of plant growth and development [2]. The application of mineral fertilizers compensates for the loss of soil minerals after their extraction from the crop. In recent years, fertilization is considered not only as a means of increasing yields, but also their use is associated with the quality of the produced products. The correct selection of nutrients changes the direction of biochemical processes in plants and makes them resistant to diseases [3, 4]. Mineral fertilizers influence the biological activity of the soil. The excessive use of mineral fertilizers and pesticides leads to suppression of the protective functions of the soil and an increase in the infectious background of phytopathogens [5, 6, 7]. When growing greenhouse vegetable crops, fast-acting fertilizers containing basic mineral elements NPK are used. They increase yield, but nitrogen and phosphorus fertilizers applied in large quantities can serve as pollutants of wastewater, soil and produce [8, 9]. To optimize plant nutrition and reduce soil toxicity, biological products containing antagonists or hyperparasites of phytopathogenic fungi can be used. Fertilizers affect the process of soil colonization with antagonists [10 - 14]. Nitrogen fertilizers increase the accumulation of the saprophytic fungi *Trichoderma* and *Gliocladium* [15, 16]. In turn, *Trichoderma* fungi help to absorb the difficult-to-dissolve forms of phosphorus from the soil [17, 18]. The aim of the work was to evaluate the influence of the effective microorganisms *Trichoderma viride*, *Bacillus subtilis* and *Enterobacter cloacae* on the biological activity of the soil and the agrochemical efficiency of the system of basic mineral fertilization in the cultivation of greenhouse pepper.

To achieve this goal, the following tasks were solved:
study of the influence of the biopreparations "Trichodermin", "Extrasol" and a bacterial preparation based on *Enterobacter cloacae* on the biological activity of the soil;
to determine their influence on the agrochemical efficiency of mineral fertilization with NPK;
among the studied biological products, to choose the most

effective one for optimizing the structural composition of the soil microbiome in the studied fertilization system.

2. Materials and methods

The experiment was carried out on the territory of the Maritsa Vegetable Crops Research Institute, Plovdiv in an unheated steel-glass greenhouse with the Pirouette F1 variety, planted according to the 90/60/40 cm scheme. The studied microbial substances were used as 0.1% aqueous solutions of the standardized biological preparations "Trichodermin" (*Trichoderma viride*, strain Trv1, titer 2.10^{10} c/ml); "Extrasol" (*Bacillus subtilis*, titer 1.10^{10} CFU/ml) and a bacterial preparation based on *Enterobacter cloacae* (titer 1.10^{10} CFU/ml) at a consumption rate of 10 L of water per 20 m². As a standard, organic fertilizer "Humustim" (humic acids) was used, applied as an aqueous solution at a consumption rate of 5 ml/10 L of water for 20 m² after transplanting and during mass flowering. Agrochemical analysis of the soil samples was done before planting the experiment and one month after transplanting the plants to a permanent place, which coincides with the period of the first pepper harvests. The nitrogen content ($NH_4-N + NO_3-N$) was determined by the distillation method; mobile P_2O_5 and mobile K_2O according to Egner-Riem, soil reaction pH_{H_2O} - potentiometrically. The applied norms of mineral NPK fertilizers were carried out in accordance with the recommendations of the laboratory of Agrochemistry based on primary agrochemical analysis of the soil. The one-month fertilizer rate $N_{22} P_{16} K_{20}$ kg/da according to the Technical Content: ($N_{1.8} P_{0.7} K_{2.4}$ g/plant ammonium nitrate 34%, triple superphosphate 18% and potassium sulfate 50%) was introduced according to the following scheme: in the first application - 5 kg/da ammonium nitrate + 10 kg/da triple superphosphate + 4 kg/da potassium sulfate; second application - 5 kg/da ammonium nitrate + 2 kg/da triple superphosphate + 5 kg/da potassium sulfate; third application - 5 kg/da ammonium nitrate + 2 kg/da triple superphosphate + 5 kg/da potassium sulfate; fourth application - 7 kg/da ammonium nitrate + 2 kg/da triple superphosphate + 6 kg/da potassium sulfate with an interval of 10 days.

Total soil microbiological activity (CFU/g) and number of fungal colonies in 1 g of dry soil in percent (%) were read. For this purpose, soil samples were taken from each variant at the beginning, middle and end of the growing season. Selection of the soil samples was made according to the following methodology: samples for analysis were taken from five locations on the "envelope" principle from a depth of 0–20 cm [19], after which they were mixed to obtain a total

sample. Samples dried to 60% of the marginal field moisture (MFM) were used for the analysis of the number of soil microorganisms. The biological activity of the soil was determined according to the generally accepted microbiological method for cultivating diluted aqueous soil solutions on solid nutrient media [20], the taxonomic affiliation of the fungi - according to the key determinant of Pidoplichko [21]. Aqueous solutions of the soil samples with a dilution of 1.10^3 were sown on agarized nutrient media - PDA, Czapek, Saburo in Petri dishes and were incubated at a temperature of $+ 23^\circ\text{C}$ for 10 days in a thermostat. Number of bacterial colonies - on the third day, actinomycetes and fungi - from the third to the tenth day after sowing, inclusive. Microbiological analysis and diagnosis of the fungi were made according to morphological signs after the formation of the colonies. The number of microorganisms (thousand/g soil) was determined by counting the colonies of bacteria, actinomycetes and fungi on individual sectors.

$$X = \frac{A \times D^2 \times 20}{d \times 5}$$

X- number of fungal colonies in 1 g of soil; A - number of colonies on 5 agar circles; D- diameter of Petri dish; d- diameter of agar circle.

3. RESULTS AND DISCUSSION

3.1. Study of the influence of the biopreparations "Trichodermin", "Extrasol" and a bacterial preparation based on *Enterobacter cloacae* on the biological activity of the soil.

The microbiological analysis of the soil samples showed that the biological activity of the soil in the experiment changed throughout the vegetation period (Table 1). The highest values of the total biological activity of the soil (TBAS) were obtained in the variants with the introduction of the bioproducts "Trichodermin", "Extrasol" and organic fertilizer "Humustim". Among the biopreparations studied, the biopreparation "Trichodermin" is the most effective. The introduction of the biopreparation "Trichodermin" increases the biogenicity of the soil by 12% towards the middle and by 74% - towards the end of the growing season. The study of the composition of soil microorganisms in this variant shows that the amount of bacteria increases - from 0.48 mill/g at the beginning to 1.18 mill/g of dry soil towards the end of the growing season, of actinomycetes - from 1.43 mill/g g to 5.19 mill/g, respectively. The structural composition of micromycetes in the soil is reduced to four functional groups: saprophytes, pathogens, antagonists and toxin-producing fungi [22]. The use of bioproducts leads to optimization of the structural composition of micromycetes in the soil and to suppression of pathogenic microflora [23]. In the course of the experiment, it was established that in the soil samples taken from the variant with mineral nutrition, the composition of the micromycetes was dominated by toxin-producing fungi of the genera *Penicillium*, *Aspergillus* and *Fusarium* (Table 2). The content of fungal colonies in the soil taken from the variants with the introduction of the biological preparations "Trichodermin" and "Extrasol" is significantly weaker than in the control, and in the composition of the micromycetes, fungi of the genus *Trichoderma* are more often found (Figure 1). The content of micromycetes in the soil is maximum at the beginning of the growing season, after which a reduction of the fungal colonies is observed both in the variant with mineral fertilization and in the variants with bioproducts. The obtained results show that biological products have an impact on the soil biome. The introduction of 0.1% aqueous solutions of the standardized biological preparations "Trichodermin" (*Trichoderma viride*, strain Trv1, titer 2.10^{10} s/ml); "Extrasol" (*Bacillus subtilis*, titer 1.10^{10} CFU/ml) and a bacterial preparation based on *Enterobacter cloacae* (titer 1.10^{10} CFU/ml) at a consumption rate of 10 L of water per 20 m² ensures stability of the functional relationships between the main ecological-trophic groups of microorganisms.

Table 1: Biological activity of the soil in a greenhouse experiment with bioproducts during the growing season. Pirouette F1 variety, 2022

	Number of microorganisms in one gram of soil			
	Total,	Fungi,	Bacteria,	Actino

Variant/Phase	million/g	thousands/g	million/g	mycetes, million/g
	Before conducting the experiment			
General sample	1,770000	50,000	0,240000	1,490000
The first harvest				
<i>E. cloacae</i>	3,380000	340,000	0,600000	2,440000
Effect	47,63	85,29	60,00	38,93
<i>B. subtilis</i>	3,180000	160,000	0,600000	2,420000
Effect	44,34	68,75	60,00	38,43
<i>T. viride</i>	2,010000	370,000	0,480000	1,430000
Effect	11,94	86,49	50,00	0,00
Humustim	9,680000	300,000	1,970000	7,410000
Effect	81,71	83,33	87,81	79,89
Control ($N_{22}P_{16}K_{20}$)	2,560000	440,000	0,440000	1,680000
Effect	30,86	88,64	45,45	11,31
End of vegetation				
<i>E. cloacae</i>	2,190000	60,000	0,160000	1,970000
Effect	19,18	16,67	0,00	24,37
<i>B. subtilis</i>	2,280000	50,000	0,290000	1,940000
Effect	22,37	0,00	17,24	23,20
<i>T. viride</i>	6,440000	70,000	1,180000	5,190000
Effect	72,52	28,57	0,00	71,29
Humustim	4,390000	60,000	1,560000	2,770000
Effect	76,54	0,00	60,26	90,25
Control ($N_{22}P_{16}K_{20}$)	4,670000	70,000	0,190000	4,410000
Effect	77,94	0,00	0,00	93,37

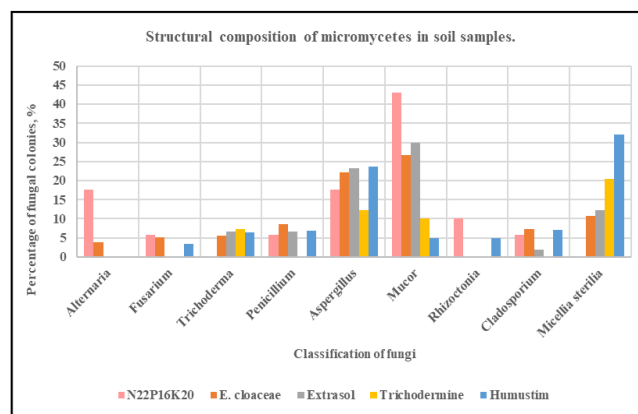


Figure 1. Structural composition of the micromycetes in the soil samples, taken from the variants with introduction of the biological products "Trichodermin", "Extrasol" and a bacterial preparation based on *Enterobacter cloacae*

Table 2. Structural composition of the Micromycete fungi in the soil samples

Variant	Percentage of fungal colonies in Petri dishes by variants, %					
	1	2	3	4	5	6
<i>Alternaria</i>	17,7	3,8	0,0	0,0	0,0	5,5
<i>Fusarium</i>	5,9	5,3	0,0	0,0	3,5	0,0
<i>Trichoderma</i>	0	5,5	6,7	7,25	6,5	5,5
<i>Penicillium</i>	5,9	8,5	6,7	0,0	7,0	2,3
<i>Aspergillus</i>	17,7	22,3	23,3	12,3	23,8	21,8
<i>Mucor</i>	43,0	26,8	30,0	10,0	5,0	6,3
<i>Rhizoctonia</i>	10,0	7,3	0,0	0,0	5,0	12,8
<i>Cladosporium</i>	5,9	2,0	2,0	0,0	7,2	5,3
<i>Mycelia sterilia</i>	0,0	10,8	12,3	20,5	32,2	10,8

Variants: 1 - $N_{22}P_{16}K_{20}$, 2 - *Enterobacter cloacae*, 3 - *Bacillus subtilis*, 4 -

3.2. Study of the influence of biological preparations on the agrochemical efficiency of the investigated system for mineral fertilizers

In the study of the influence of biological preparations on the agrochemical efficiency of imported mineral fertilizers, the following results were obtained (Table 3).

Table 3. Agrochemical analysis of the soil samples in the experiment with Pirouette F1 pepper variety one month after planting the plants in a permanent place.

Variant	pH	EC	N (Total)	P ₂ O ₅	K ₂ O	Ca ²⁺	Mg ²⁺
		mS/cm					
Control (before starting the experiment)	7,03	0,23	50,0	8,70	16,60	12,00	7,20
Without preparations	7.09	0.08	25,0	2,00	8,30	8,0	14,40
Percentage to control, %			-50,0	-68,96	-50,0	-33,33	-50,0
Background (N ₂₂ P ₁₆ K ₂₀)	6.63	0.59	100,0	12,40	28,20	16,00	28,80
Percentage to control, %			+50,0	+29,84	+41,13	+25,00	+75,00
Background (N ₂₂ P ₁₆ K ₂₀) + "Trichodermine"	7,00	0,49	100,0	14,60	58,10	20,00	14,40
Percentage to control, %			+50,0	+40,41	+71,42	+40,00	+50,00
Background Фон (N ₂₂ P ₁₆ K ₂₀) + Humustim	6,89	0,60	100,0	9,00	26,56	24,00	14,40
Percentage to control, %			+50,0	+3,33	+37,50	+50,00	+50,00
Background (N ₂₂ P ₁₆ K ₂₀) + "Extrasol"	6,97	0,42	100,0	12,45	10,79	20,00	7,20
Percentage to control, %			+50,0	+30,12	-35,00	+40,00	0,00
Background (N ₂₂ P ₁₆ K ₂₀) + Enterobacter cloacae	6,67	0,30	100,0	12,00	41,50	12,00	7,20
Percentage to control, %			+50,0	+27,50	+60,00	0,00	0,00

In the variant without the mineral fertilizers and biological preparations, the content of mobile nitrogen decreases by 50%, phosphorus - by 68.96%, potassium - by 33.33%. Importing the biopreparations "Trichodermine", "Extrasol" and a bacterial preparation based on *Enterobacter cloacae* increases the content of mineral forms of nitrogen up to 50%, mobile phosphorus - up to 40.41%, mobile potassium - up to 71.42%. In the variant with the introduction of organic fertilizer "Humustim", these indicators are 50%, 3.33% and 37.50%, respectively. It was established that the application of biopreparations did not significantly change the soil pH_{H2O} in the experiment. A slight increase in pH_{H2O} was reported in the variant with the introduction of the biopreparation "Trichodermine". This shows that the fungus *Trichoderma viride* is able to stabilize the redox conditions of the soil. The results of studies of the influence of the mineral fertilization system and biopreparations on the content of mobile potassium in the soil show the following: in the control, the K₂O content decreased by 55% compared to the indicators in the soil sample taken from the plot before the start of the experiment. In the variant with the studied NPK application system, the K₂O content exceeded the control by 41.0%. For comparison, in the variant with the introduction of "Trichodermine" on a background of NPK, an increase in K₂O compared to the control was 71.42%, *Enterobacter cloacae* + NPK - 60%. In the variants with the introduction of microbial substances - the fungus *Trichoderma viride*, the bacteria *Bacillus subtilis* and *Enterobacter cloacae*, the increase in mobile phosphorus and potassium is explained by the active processes of mineralization in the soil.

The following conclusions can be drawn as a result of the conducted research:

The introduction of biological preparations "Trichodermin" (*Trichoderma viride*) and "Extrasol" (*Bacillus subtilis*) on a standard mineral background (N₂₂P₁₆K₂₀) in greenhouse pepper enhances the process of biological activity of the soil.

The use of effective microorganisms improves the phytosanitary condition of the crop at the expense of the lower content of toxin-producing fungi in the soil.

Inoculation of the soil with "Trichodermine" during greenhouse pepper cultivation enhances the biological activity of the soil and regulates the structural composition of the soil microbial community. The number of colonies of *Trichoderma* spp. in the soil is the main regulating factor.

Among the biopreparations studied, the most effective in terms of regulating nutritional regime in pepper cultivation is the biopreparation "Trichodermine", which increases the content of mineral forms of nitrogen in the soil up to 50%, of mobile phosphorus - up to 40%, of mobile potassium - up to 71% on the mineral background (N₂₂P₁₆K₂₀).

The scientific article confirms the expediency and high agrochemical efficiency of the application of the biopreparations "Trichodermine" and "Extrasol" for regulating the nitrogen-phosphorus-potassium nutritional regime.

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Ternary magneto-biochar-clay composite as efficient adsorbent for aqueous naproxen and carbamazepine from Ishmi river water in Albania

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Abstract: The quality of surface waters in Albania is an issue particularly as the country aims to join the EU. Organic compounds in water matrix are difficult to remove, and recent Ishmi river monitoring shows that the anti-inflammatory such as naproxen is predominant among other pharmaceuticals. The commonly used antiepileptic such as carbamazepine is also detected. Thus, their removal from effluents is of high environmental relevance. Therefore, ternary magneto-biochar-clay (MBC 1:2:1) adsorbent was prepared from low-cost feldspar (FLC), grape cluster stalk waste (GC) biochar, and iron oxide magnetic nanoparticles (MNP), and was used as an adsorbent. Adsorption experiments tested the effect of solution pH (2.5-10) of naproxen and carbamazepine with simulated contaminated and Ishmi river water, after pH optimization. The results showed that the maximum adsorption was achieved at a pH value of 2.5 for naproxen and carbamazepine in a single compound solution. Interestingly, for naproxen in both cases (single and combined), the maximum adsorption was achieved at pH value of 2.5, while for carbamazepine the maximum adsorption was achieved at pH value of 2.5 for single and no significant adsorption was achieved in combined compound solution. The adsorption of naproxen and carbamazepine at optimized pH of 4.5 in Ishmi water remained stable, with the only difference for carbamazepine in single compound, where the adsorption was lower compared to simulated contaminated water. This study demonstrated that in addition to easy handling, the MBC 1:2:1 adsorbent was efficient for naproxen and carbamazepine removal.

Keywords: FELDSPAR; GRAPE CLUSTER STALK; pH; NAPROXEN; CARBAMAZEPINE; ADSORPTION

1. Introduction

Pharmaceutical active compounds presence in the surface water bodies is becoming a challenge with the increase of world population. It is reported that in a global scale, the presence and concentration of pharmaceuticals is problematic, especially in low-to middle-income countries related with poor wastewater treatment facilities or even without any treatment technology (direct discharge) [1]. Pharmaceuticals reach the water bodies mainly through direct discharge of wastewaters, wastewater treatment plants effluent discharges, pharmaceutical industry, livestock, etc.

The commonly used nonsteroidal anti-inflammatory drugs (NSAIDs) such as naproxen, is frequently detected in surface waters [2]. This, as a result of continuous input due to relatively high consumption and preference compared with other NSAIDs. The relatively high inputs and concentrations in the water environment could negatively impact the water species. Naproxen toxicity is confirmed to *Daphnia magna*, zebrafish embryos, microorganisms (*Bacillus thuringiensis*) [3, 4]. Another frequently globally detected pharmaceutical in the water environment is the commonly used antiepileptic, such as carbamazepine [1]. Carbamazepine toxicity is also reported to *Daphnia magna* [5]. Thus, these compounds need to be removed from water.

Adsorption technique, which is also proposed in this study, stands as a cost-efficient, free by-product formation, easy to operate, and environmentally friendly when bio-waste origin material is used for as an adsorbent. In addition, their combination (bio-waste) with other materials such as minerals (clays), and magnetic nanoparticles surpass some of their disadvantages such as low durability, leaching, and make easier the solid-liquid separation (magnetic properties) [6, 7].

Therefore in this study grape cluster stem waste, feldspar clay, and magnetic nanoparticles were combined in a composite, which was used to remove naproxen and carbamazepine in certain pH conditions and from river water. The solution pH is one of the main factors in the sorption process as directly rules the composite charge and compound's speciation in the water.

As Albania is aiming and preparing to join the European Union (EU), it has to monitor, report and to achieve a good quality status

of the water bodies, in accordance with the EU policies (Directive 2000/60/EC).

Ishmi river basin is located in the central north-west part of Albania with more than 30% of the country population living in this area (Census 2023). The area is the most important in the economically aspect with the highest industrial activity, and with no active wastewater treatment plant. A two year (2023-2024) assessment was realized and the study focus compounds were detected with 2.01 and 2.04 µg/L for naproxen, and 0.35 and 0.16 µg/L for carbamazepine, respectively for the two years (Fig. 2). These results are in line and reflect the consumed amounts (only the Albanian state reimbursed amounts) of naproxen with 1879.7 and 1311.8 kg, and carbamazepine with 432.1 and 430.5 kg, respectively for the two years (Fig. 1). The presence in water and the reimbursed consumed amounts of naproxen and carbamazepine represents a potential threat to the water organisms. Therefore, the proposed study aims to test the capacity of the low-cost prepared composite for their removal at different solution pH from Ishmi water.

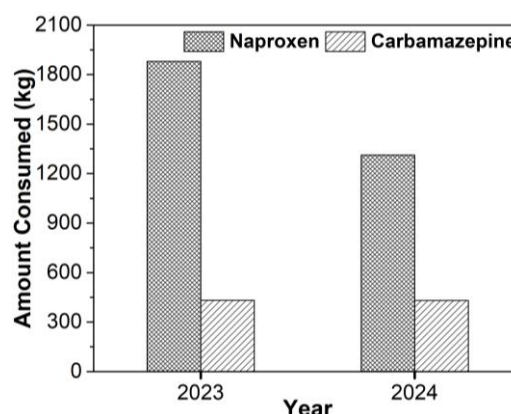


Fig. 1 Amounts of consumed naproxen and carbamazepine for the years 2023 and 2024 in Albania (only state reimbursed amounts)[8]

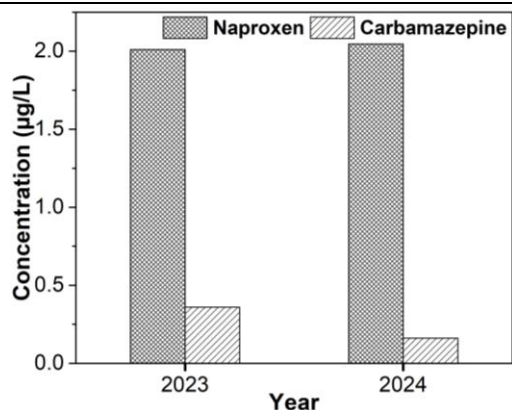


Fig. 2 Concentrations of naproxen and carbamazepine in Ishmi river basin for the years 2023 and 2024 (data in publication process)

2. Materials and Methods

Standards of naproxen and carbamazepine, and sodium azide (NaN_3), were purchased from Merck-Sigma-Aldrich GmbH, Germany. HPLC grade acetonitrile and MilliQ water (Purelab, UK) were used throughout the study. Mettler Toledo Scale (ME 204) and pH meter (inoLab® pH 7110) were used for weighing and pH measurements.

For the preparation of the low-cost ternary magneto-biochar-clay (MBC 1:2:1) adsorbent, the adjusted mass of dried biomass of grape cluster stalk (GC), feldspar clay (FLC), and MNP were used. The GC was collected in a vineyard in the central part of Albania. The GC and FLC were cleaned, washed and dried, while the magnetic nanoparticles (MNP) were prepared by chemical co-precipitation [9] of FeCl_3 (7.8 g) and $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ (3.9 g) in 400 mL water by drop-wise of 2.0 M NaOH addition (until dark colored).

The first step for MBC 1:2:1 preparation, was the MNP preparation as mentioned above, followed by the addition of the calculated mass of GC, and the mixture was shaken for 30 minutes at 200 rpm. After that, the FLC was added and the mixture was shaken for 2 hours at 200 rpm in a horizontal shaker. The mixture was centrifuged for 5 minutes at 2500 rpm, dried overnight at 80°C , transferred into crucibles, and calcined under limited air for 2 hours at a temperature of 500°C . The calcined adsorbents were sieved through a 1 mm sieve size, washed several times with Milli-Q, dried at 40°C over night, and kept in glass bottles for further use.

For the sorption experiments, stock solutions of naproxen and carbamazepine (10000 mg/L) were prepared in acetonitrile:MilliQ (50:50, v:v) and kept at 4°C . The working solutions were prepared from the stock with 100 mg/L NaN_3 , acting as biocide. The acetonitrile percentage was less than 0.1 %, in order to eliminate the co-solvent effect in the adsorption process. The sorption experiments were realized using 5 mg adsorbent mass and 10 mL of 2.5 mg/L naproxen and carbamazepine solution in 20 mL brown glass vials at different solution pH (2.5 – 10). Meanwhile, those with Ishmi river water at pH 4.5 only. The mixture was agitated at 200 rpm for 24 h at room temperature (20°C). Samples were filtered with 1 µm glass fiber filters and measured using HPLC-UV (naproxen at 230 nm wavelength and carbamazepine at 285 nm wavelength with a mobile phase of acetonitrile:0.2% formic acid in water (60:40, v:v), and a flow rate of 0.3 mL/min) The solution pH was adjusted using 0.2 M HCl or NaOH.

3. Results and Discussion

The effect of solution pH is one of the most important vital factors in the sorption process due to the impact and the control of the sorbent charge and speciation of the compounds in the solution [10]. Therefore, the solution pH effect for naproxen and

carbamazepine was tested over five different pH points (2.5 – 10), and the results are given in Fig. 3 and Fig. 4. The highest sorption capacity of naproxen was achieved at solution pH of 2.5 (Fig. 3). The sorption had a decrease trend up to solution pH of 6.5 and after that remained stable until solution pH of 10. This trend could be as a result of the composite charge and naproxen. As the pH_{pzc} of the composite is around 9, at low pH values, the composite is mainly positively charged, indicating high electrostatic interaction between the positive functional composite groups with the ionic naproxen species in the solution. Naproxen has a pK_a of around 4.2 (Pubchem), thus at low solution pH conditions dissociates, while in higher solution pH (> 4.2) mainly exists in the neutral form. Therefore, with the increase of the solution pH the surface of the composite becomes progressively less positively, resulting in a weak electrostatic interaction. Starting from the solution pH of 6.5 up to 10, there is still some adsorption observed from the composite. This behavior indicates that not only the electrostatic interaction is involved in the sorption process; also hydrophobic interactions occur between the aromatic composite groups and the benzene structures of naproxen (in these pH conditions naproxen is in its neutral form). In binary solutions (naproxen and carbamazepine), the same trend was achieved, but the sorption capacity resulted lower compared with single solution system, indicating some competition between the two compounds.

Carbamazepine was also tested at five different solution pH same as naproxen in single and binary solution systems, and the results are presented in Fig. 4. The highest adsorption was achieved at pH 2.5, and the lowest at solution pH of 8 and 10. Carbamazepine has two pK_a values (2.3 and 13.9), thus at all tested solution pH mainly existed in the neutral form (Pubchem). In these conditions the sorption of carbamazepine was mainly driven by interactions mainly from cationic groups of the composite (pH_{pzc} 9) and the benzene ring of carbamazepine. This is also supported by binary solution results trend, which shows that the competition with naproxen was higher at solution pH of 2.5 and 4.5. After that, the competition reduces and at solution pH of 10 was almost the same sorption capacity. The higher competition at low solution pH (where naproxen is ionized), indicates that both compounds compete for the same sorption sites of the composite.

The MBC 1:2:1 composite sorption capacity for naproxen and carbamazepine removal from water was also tested with Ishmi river water and the results are given in Fig. 5 and Fig. 6. It was observed that for naproxen in single system the sorption capacity remained similar, meanwhile in the binary a slight decrease was observed, reflecting the same trend as in the MilliQ (Fig. 5). For carbamazepine, in single system the sorption capacity was slightly lower compared to that of MilliQ, but remained stable in the binary system solution, indicating a relatively low competition with naproxen.

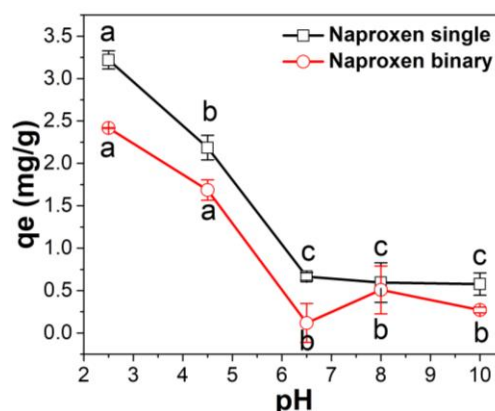


Fig. 3 The effect of pH on naproxen adsorption onto MBC 1:2:1 composite in simulated contaminated MilliQ water (low capital letters – significance at $p < 0.05$)

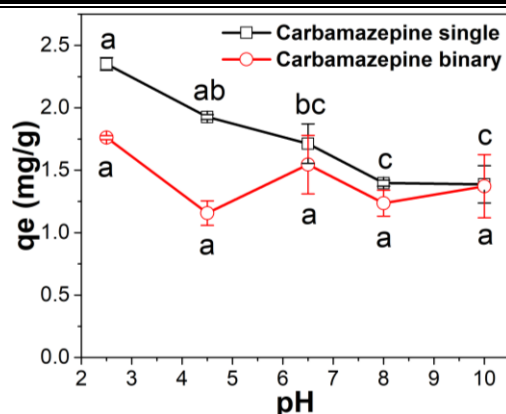


Fig. 4 The effect of pH on carbamazepine adsorption onto MBC 1:2:1 composite in simulated contaminated MilliQ water

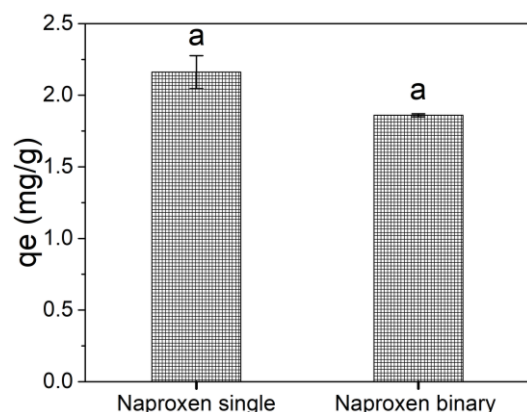


Fig. 5 The adsorption capacity of the MBC 1:2:1 composite for naproxen at pH 4.5 with Ishmi river water

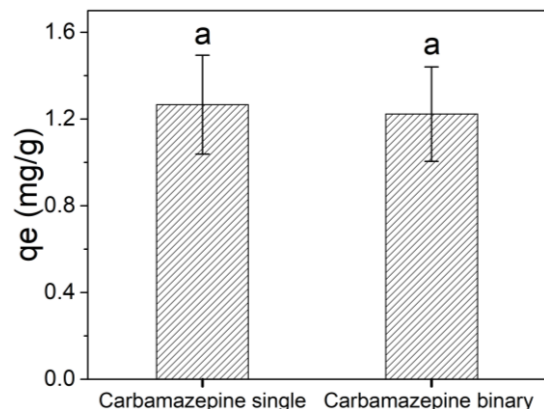


Fig. 6 The adsorption capacity of the MBC 1:2:1 composite for carbamazepine at pH 4.5 with Ishmi river water

4. Conclusions

The adsorption of naproxen and carbamazepine was tested over five different solution pH onto the low-cost MBC 1:2:1 composite. The highest adsorption for both compounds was achieved at solution pH of 2.5. The competition resulted to be higher at low pH conditions, mainly at 2.5 and 4.5. The sorption capacity of the composite for both compounds with simulated contaminated Ishmi river water was similar with that of simulated contaminated ultrapure water. These results demonstrate that even in real environment water conditions (river water), the sorption capacity of the prepared MBC 1:2:1 composite is efficient and applicable for naproxen and carbamazepine removal from water.

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6. Acknowledgements

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