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საქართველოს განათლების, მეცნიერებისა და ახალგაზრდობის სამინისტრო

საქართველოს ტექნიკური უნივერსიტეტი

ც. მირცხულავას სახელობის წყალთა მეურნეობის ინსტიტუტი

გარემოს დაცვის ეკოცენტრი

XI საერთაშორისო სამეცნიერო-ტექნიკური კონფერენცია "წყალთა მეურნეობის, გარემოს დაცვის, არქიტექტურისა და მშენებლობის თანამედროვე პრობლემები"

შრომების კრებული

12-16 ივლისი, 2024

ეძღვნება სტუ-ს ცოტნე მირცხულავას სახელობის წყალთა მეურნეობის ინსტიტუტის დაარსების 99 წლისთავს

MINISTRY OF EDUCATION, SCIENCE AND YOUTH OF GEORGIA
TSOTNE MIRTSKHULAVA WATER MANAGEMENT INSTITUTE OF GEORGIAN TECHNICAL UNIVERSITY
ECOCENTER FOR ENVIRONMENTAL PROTECTION

XI INTERNATIONAL SCIENTIFIC AND TECHNICAL CONFERENCE „MODERN PROBLEMS OF WATER MANAGEMENT, ENVIRONMENTAL PROTECTION, ARCHITECTURE AND CONSTRUCTION“

COLLECTED PAPERS

12 – 16 JULY, 2024

DEDICATED TO THE 99 ANNIVERSARY OF THE ESTABLISHMENT OF TSOTNE MIRTSKHULAVA WATER MANAGEMENT INSTITUTE OF GTU

თბილისი, საქართველო / **Tbilisi, Georgia**
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გარემოს დაცვის ეკოცენტრი

XI საერთაშორისო სამეცნიერო-ტექნიკური კონფერენცია „წყალთა მეურნეობის, გარემოს დაცვის, არქიტექტურისა და მშენებლობის თანამედროვე პრობლემები"

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2024

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ტირაჟი: 150

XI International Conference on

"MODERN PROBLEMS OF WATER MANAGEMENT, ENVIRONMENTAL PROTECTION, ARCHITECTURE AND CONSTRUCTION"

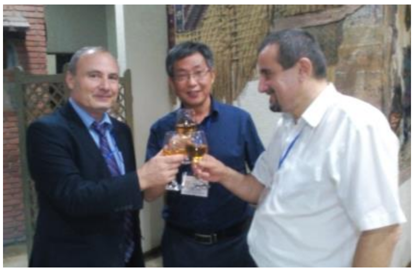
12 – 16 JULY, 2024, Tbilisi, GEORGIA

CONFERENCES	DATE	PLACE (LOCATION)
I	18-22 August, 2010	Qobuleti, GEORGIA
II	24-31 July, 2012	Qobuleti, GEORGIA
III	29 july – 4 August, 2013	Tbilisi – Borjomi, GEORGIA
IV	27 – 30 September, 2014	Tbilisi, GEORGIA
V	16 – 19 July, 2015	Tbilisi, GEORGIA
VI	22–25 September, 2016	Tbilisi – Telavi, GEORGIA
VII	25–27 August, 2017	Tbilisi, GEORGIA
VIII	1-5 November, 2018	Tbilisi, GEORGIA
IX	25 – 27 July, 2019	Tbilisi, GEORGIA
X	25 – 27 July, 2021	Tbilisi, GEORGIA

Scientific directions of the Conference

- Water management;
- Hydraulic engineering and irrigation;
- Hydrology and meteorology;
- Environmental protection;
- Safety and risk of hydraulic structures;
- Construction and architecture;
- Earth sciences.

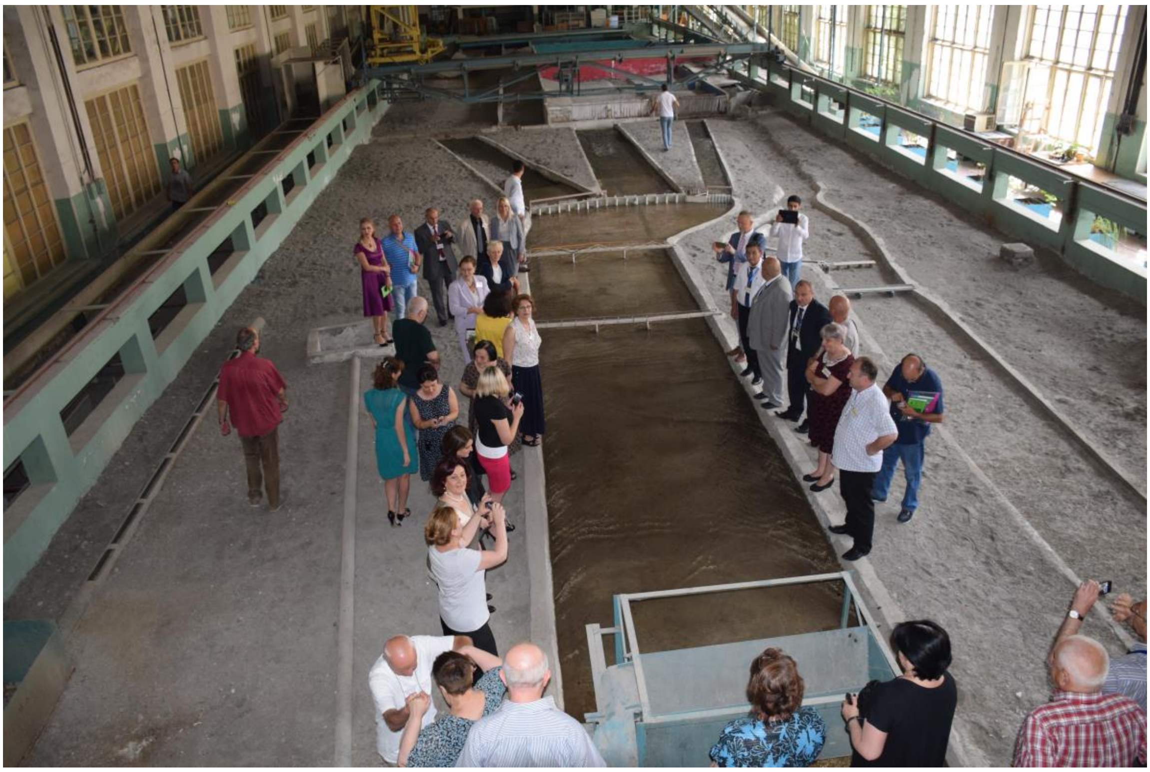
Photo gallery from the last International Conferences on "MODERN PROBLEMS OF WATER MANAGEMENT, ENVIRONMENTAL PROTECTION, ARCHITECTURE AND CONSTRUCTION"









<u>მილოცვა</u>

ცოტნე მირცხულავას სახელობის წყალთა მეურნეობის ინსტიტუტის დაარსების 99 წლისთავი

ინსტიტუტი, რომლის პირველი სახელწოდებაც იყო ამიერკავკასიის წყალთა მეურნეობის ინსტიტუტი, დაფუძნდა 1925 წლის 13 ივლისს, ხოლო 1929 წელს, როდესაც ფილიალები უკვე დაფუძნდა აზერბაიჯანსა და სომხეთში, ინსტიტუტს გადაერქვა სახელი და ეწოდა საქართველოს ჰიდროტექნიკისა და მელიორაციის სამეცნიერო-კვლევითი ინსტიტუტი. ორგანიზაცია საბჭოთა კავშირის დაშლამდე იყო საკავშირო დაქვემდებარებაში.

ფოტო. 1. ინსტიტუტის კორპუსების მშენებლობა, ქ. თბილისი, ი. ჭავჭავაძის გამზირი, 60 (ყოფილი ნ. მარისა და უნივერსიტეტის ქუჩა), 1935 წ.
Photo. 1. Construction of institute buildings, Tbilisi, I. 60 Chavchavadze Ave (former N. Mary and University Street), 1935

1992 წელს ინსტიტუტი შევიდა საქართველოს მეცნიერებათა ეროვნული აკადემიის სისტემაში და მას ეწოდა წყალთა მეურნეობისა და საინჟინრო ეკოლოგიის ინსტიტუტი.

საქართველოს მთავრობის გადაწყვეტილებით 2006 წელს ინსტიტუტი გამოვიდა საქართველოს მეცნიერებათა ეროვნული აკადემიის სისტემიდან და დაფუძნდა, როგორც სსიპ წყალთა მეურნეობის ინსტიტუტი.

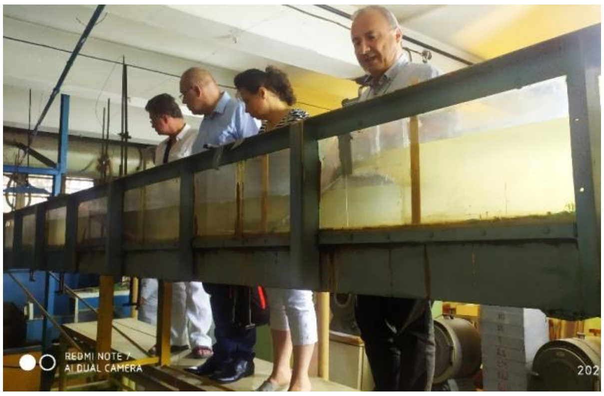
2011 წელს საქართველოს პრემიერ-მინისტრის განკარგულებით სსიპ წყალთა მეურნეობის ინსტიტუტი შეუერთდა საქართველოს ტექნიკურ უნივერსიტეტს, როგორც დამოუკიდებელი სამეცნიერო სტრუქტურული ერთეული და 2012 წლიდან ეწოდა საქართველოს ტექნიკური უნივერსიტეტის ცოტნე მირცხულავას სახელობის წყალთა მეურნეობის ინსტიტუტი.

აღსანიშნავია, რომ ინსტიტუტში არსებობს უნიკალური, ევროპის მასშტაბით ერთ-ერთი უდიდესი ჰიდროტექნიკური ლაბორატორია დაკომპლექტებული შესაბამისი დანადგარებითა და სატუმბი სადგურით.

2005 წელს ინსტიტუტი აღიარებულ იქნა, როგორც ევროპის საუკეთესო სამეცნიერო-კვლევითი ორგანიზაცია და ინსტიტუტის კოლექტივი მრავალი სამეცნიერო პროექტების,

კვლევებისა და მსოფლიოს ერთ-ერთი საუკეთესო ჰიდროტექნიკური ლაბორატორიის ფუნქციონირების გამო, სადაც საქართველოსათვის ესოდენ საჭირო მთელი რიგი წყალსამეურნეო, გარემოსდაცვითი და ეკოლოგიური ხასიათის ღონისძიებების მოდელირების ჩატარების საშუალებაა, დაჯილდოვდა შვეიცარიის დიპლომით «Century International Quality Era Award», ხოლო 2009 წლის 10 ნოემბერს საქართველოს მეცნიერებათა ეროვნული აკადემიის სხდომათა დარბაზში იუნესკოს გადაწყვეტილების შესაბამისად ინსტიტუტი დაჯილდოვდა სოფლის მეურნეობის მეცნიერებათა დარგში 2008, 2009 და 2010 წლებში ქვეყნის საუკეთესო სამეცნიერო-კვლევითი დაწესებულების დიპლომებით.


ფოტო 2 - 3. ჰიდროტექნიკური ლაბორატორია წყალდიდობების მოდელირებისას
Photo. 2 - 3. Hydrotechnical laboratory during flood modeling



ფოტო 4 - 5. ღვარცოფსარეგულაციო ელასტიკური ბარაჟის მოდელირებისას
Photo 4 - 5. **During the modeling of the debris flow regulation elastic barrage**


ფოტო. 6 - 7. ზღვის ტალღის ენერგიის ჩამქრობი მოწყობილობის მოდელირებისას
Photo. 6 - 7. During the modeling a sea wave energy quenching device

ინსტიტუტში ამჟამად მუშაობს 81 თანამშრომელი, აქედან 56% მეცნიერი თანამშრომელია, მათ შორის: 1 - საქართველოს მეცნიერებათა ეროვნული აკადემიის აკადემიკოსი, 4 - საინჟინრო აკადემიის წევრი, 5 - მეცნიერებათა დოქტორი, 28 - აკადემიური დოქტორი, 2 - დოქტორანტი და 19 - მაგისტრი.

ქვეყნის სტრატეგიული პრიორიტეტებიდან გამომდინარე, ინსტიტუტი ამჟამად მუშაობს შემდეგ სამეცნიერო მიმართულებებზე:

- წყლის წესურსების უსაფრთხოება და ინტეგრირებული მართვა კლიმატის ცვლილების გათვალისწინებით;
- ბუნებრივი კატასტროფების პროგნოზირება და კონტროლი;
- მელიორაციის თანამედროვე პრობლემების კვლევა;
- ზღვისა და წყალსაცავების პრობლემების პროგნოზი;
- ჰიდროტექნიკური ნაგებობების საიმედოობა და რისკი;
- სასოფლო-სამეურნეო სავარგულების ეროზიული პროცესების კვლევა.

ინსტიტუტში 2020-2025 წლებში მუშავდება პროგრამული დაფინანსების თემა - ,,წყლის რესურსების უსაფრთხოება და ინტეგრირებული მართვა კლიმატის ცვლილების გათვალისწინებით", რომელიც ეხმიანება UNESCO-ს საერთაშორისო მე-8 პროგრამის დირექტივებს. სამეცნიერო კვლევები ხორციელდება როგორც ინსტიტუტის ჰიდრავლიკურ და ჰიდროტექნიკურ ლაბორატორიებში, ასევე ბუნებრივ ლანდშაფტებში.

ინსტიტუტი 1934 წლიდან ყოველწლიურად გამოსცემს სამეცნიერო შრომათა კრებულებს, ხოლო 2011 წლიდან კი - ინსტიტუტის მიერ დაფუძნებული და ორგანიზებული ყოველწლიური საერთაშორისო კონფერენციის სამეცნიერო შრომათა კრებულებს, რომელთაც გააჩნიათ ISSN და DOI.

სამეცნიერო-კვლევითი მუშაობის ეფექტიანობის დასადგენად 1930 წლიდან ინსტიტუტი საქართველოს მთავრობის გადაწყვეტილებით ქვეყნის სხვადასხვა რეგიონებში აფუძნებს სამეცნიერო-კვლევით პუნქტებს:

- **ალაზნის საცდელ-სამელიორაციო ეკოლოგიური პუნქტი - 75 ჰა**
(ქ. სიღნაღი, სოფ. ხორნაბუჯი)

ალაზნის საცდელ-სამელიორაციო ეკოლოგიური პუნქტი ერთ-ერთი უძველესი სამეცნიერო ორგანიზაციაა, რომელიც დაარსდა 1948 წელს და მდებარეობს სიღნაღის რაიონში, წნორისწყლის დასახლებიდან აღმოსავლეთით 20 კმ-ზე, სოფ. ხორნაბუჯი.

დაარსებიდან 1977 წლამდე ალაზნის საცდელ-სამელიორაციო ეკოლოგიურ პუნქტს ხელმძღვანელობდნენ დირექტორები: დ. ყუფარაძე გ. აფხაზი, ვასილ სიხარულიძე, გიორგი ცომაია, ვიტალი ბრეგვაძე, უშანგი მოსულიშვილი, დავით მოსულიშვილი, ხოლო 2011 წლიდან დღემდე – გიორგი კაკაშვილი. პუნქტის თანამშრომელთა რაოდენობა შეადგენს 5-ს.

- **გორის საცდელ-სამელიორაციო ეკოლოგიური პუნქტი - 5 ჰა**
(გორის რ-ნი, სოფ. კარალეთი)

გორის საცდელ-სამელიორაციო ეკოლოგიური პუნქტი მდებარეობს გორი-ცხინვალის ავტომაგისტრალის მარჯვენა მხარეს, სოფ. კარალეთში. იგი გაიხსნა 1962 წელს აკადემიკოს

ცოტნე მირცხულავას განკარგულებითა და სოფლის მეურნეობის მეცნიერებათა კანდიდატის ვ. ბუაჩიძის ხელმძღვანელობით ქართლის რეგიონისთვის დამახასიათებელი სასოფლო-სამეურნეო კულტურების კვლევებისა და სოფლის მეორნეობის ორგანიზაციებისათვის რეკომენდაციების დამუშავების, კერძოდ კი, სასოფლო-სამეურნეო კულტურების წყალმოთხოვნილებისა და რწყვის რეჟიმის დადგენის მიზნით. პუნქტს მისი გახსნის დღიდან 2006 წლამდე ხელმძღვანელობს გამოცდილი აგრონომი არსენ მურადაშვილი, 2006 - 2021 წლებში - გურამ მურადაშვილი, ხოლო 2021 წლიდან დღემდე - ინსტიტუტის უფროსი მეცნიერი თანამშრომელი, ტექნ. აკად. დოქტორი, პროფ. **გიორგი ნატროშვილი.**

სამეცნიერო ბაზის მოდერნიზაციის მიზნით, ინსტიტუტის დირექტორის აკადემიკოს გივი გავარდაშვილის ინიციატივითა და ხელმძღვანელობით და შ. რუსთაველის საქართველოს ეროვნული სამეცნიერო ფონდის საგრანტო პროექტების (RIM) დაფინანსებით გორის სამეცნიერო ბაზის ტერიტორიის 2 ჰა ფართობზე 2023-2024 წლებში დარგულია 1650-ზე მეტი მრავალწლიანი ახალი ნერგი, დამონტაჟდა წვეთური მორწყვის სარწყავი სისტემა ფერტიგაციის გათვალისწინებით და შესყიდულ იქნა თანამედროვე ტიპის სასოფლო-სამურნეო ტექნიკა შესაბამისი გუთნით, ფრეზის და შესაწამლი აპარატით. აქვე დამონტაჟდა თანამედროვე ტიპის მინი მეტეოსადგური.

ვფიქრობთ, რომ ამ ბაზაზე სავსებით შესაძლებელია განხორციელდეს შესაბამისი სამეცნიერო-სასწავლო პროგრამები, არა მარტო ინსტიტუტის ახალგაზრდა მეცნიერების, ასევე საქართველოს ტექნიკური უნივერსიტეტის სხვადასხვა ფაკულტეტების ბაკალავრების, მაგის-ტრანტებისა და დოქტორანტებისათვის.

- **პროფ. ფრიდონ შატბერაშვილის სახელობის კოლხეთის (ფოთის) საცდელ-სამელიორაციო ეკოლოგიური პუნქტი (ქ. ფოთი, დ. თავდადებულის #10) - 0.5 ჰა**

პუნქტი შეიქმნა კოლხეთის დაჭაობებული ფართობების დაშრობითი ღონისძიებების დაწყებასთან დაკავშირებით 1932 წელს და არსებობს დღემდე. ამ ხნის განმავლობაში პუნქტის არცთუ მრავალრიცხოვანმა კოლექტივმა შეასრულა მთელი რიგი მნიშვნელოვანი კვლევები, რომლებიც წინ უსწრებდა კოლხეთის I და II რიგის ათვისების სამეცნიერო-კვლევით სამუშაოებს და საპროექტო დოკუმენტაციის შედგენას (ნიადაგების ფიზიკურ-მექანიკური შემადგენლობა, ფილტრაციის კოეფიციენტებისა და სხვა მახასიათებელი პარამეტრების დადგენა-შეფასება). პუნქტი განთავსებული იყო კოლხიდმშენის ადმინისტრაციულ შენობაში. 1982 წლიდან კოლხეთის საცდელ-სამელიორაციო პუნქტი გადავიდა ქ. ფოთის მალთაყვის ტერიტორიაზე, კეთილმოწყობილ ერთსართულიან შენობაში 315 მ^2 სასარგებლო ფართობითა და 0,5 ჰა ეზოთი, სადაც განთავსებულია სამუშაო ოთახები, ლაბორატორია, სასაწყობო მეურნეობა, ავტოსადგომები და სხვ. სამეცნიერო პუნქტს ხელმძღვანელობდნენ ტექნიკის მეცნიერებათა კანდიდატი შალვა დოლბაია, სოფლის მეურნეობის მეცნიერებათა კანდიდატი, გამოცდილი აგრონომი ოთარ გაგუა, ხოლო 2019 წლიდან დღემდე პუნქტის ხელმძღვანელია სპეციალობით მშენებელი, მაგისტრი, მეცნიერი თანამშრომელი – ჯემალ მიგინეიშვილი.

ნატოს პროექტის ,, შავი ზღვის უსაფრთხოებისა და დაბინძურების რისკების კონტროლი რიცხვითი მოდელების გამოყენებით" თანადირექტორის აკადემიკოს გივი გავარდაშვილის გადაწყვეტილებით კოლხეთის საცდელ-სამელიორაციო პუნქტის ლაბორატორიის შენობაში

პირველად საქართველოში დაგეგმილია შავი ზღვის ობსერვატორიის დაფუძნება ნატოს სტანდარტების გათვალისწინებით.

ნატოს პროექტში, რომლის დამუშავებაში მონაწილეობს მსოფლიოს 6 ქვეყნის (აშშ, საქართველო, უკრაინა, ბულგარეთი, რუმინეთი და თურქეთი) მეცნიერები, 2024-2026 წლებში პუნქტის ტერიტორიაზე გათვალისწინებულია სამეცნიერო-პრაქტიკული სამუშაოების განხორციელება.

ინსტიტუტის დირექტორი აკადემიკოსი გივი გავარდაშვილი ასევე აღნიშნავს, რომ 2024 წლის დასაწყისში მიღებულია ინფორმაცია ბრიუსელიდან, რომ ინსტიტუტი ევროპის ქვეყნებთან (ბულგარეთი, საქართველო, უკრაინა და საბერძნეთი) ერთად დაფინანსდა ევროკავშირის საგრანტო პროექტში - შავი ზღვის NEXT 2021-2027 პროგრამა (BSB00091) ,,წყალმცენარეების ენერგიის გამოყენება დაბინძურების შემცირებისა და "ლურჯი სტრატეგიის" განვითარებისთვის". ეს საერთაშორისო პროექტი განხორციელდება საქართველოს საზღვრებში შავი ზღვის აკვატორიაში, მათ შორის ინსტიტუტის კოლხეთის (ფოთის) საცდელ-სამელიორაციო ეკოლოგიურ პუნქტში.

- **სამგორის საცდელ-სამელიორაციო ეკოლოგიური პუნქტი - 5 ჰა**
(გარდაბნის რაიონი, სოფ. გამარჯვება)

პუნქტი გაიხსნა 1962 წელს აკადემიკოს ცოტნე მირცხულავას განკარგულებით, რომლის ხელმძღვანელად დაინიშნა სოფლის მეურნეობის მეცნიერებათა კანდიდატი ვერა ბუაჩიძე. ტერიტორიის ფართობი შეადგენს 4,5 ჰა-ს, დახრილია ჩრდილოეთიდან სამხრეთისაკენ და აქვს ქანობი 0,15; გაშენებულია მრავალწლიანი ნარგავები და ერთწლიანი კულტურები. რელიეფურმა პირობებმა მნიშვნელოვნად გაართულა რწყვის პროცესების ჩატარება, ამიტომ იქ ტრადიციული სარწყავი სისტემის პარალელურად კვლევები ხორციელდებოდა ნიადაგქვეშა სარწყავი სისტემებით, რომლის კოორდინატორიც იყო ტექნიკის მეცნიერებათა კანდიდატი ლადო ბოკერია. 2021 წლიდან დღემდე პუნქტს ხელმძღვანელობს მეცნიერ-თანამშრომელი, მაგისტრი გელა ვახტანგიშვილი.

- **არახვეთის სამთო-სამელიორაციო ეკოლოგიური პუნქტი - 0.5 ჰა**
(დუშეთის რ-ნი, სოფ. არახვეთი)

საქართველოში მიმდინარე ბუნებრივი ჰიდრომორფოლოგიური და, ნაწილობრივ, გეოლოგიური პროცესების ბუნებრივ პირობებში შესწავლის მიზნით საქართველოს მინისტრთა საბჭოს #270 დადგენილებით (25.05.1974) დამტკიცდა დუშეთის რაისაბჭოს 1974 წლის 15 თებერვლის #59 გადაწყვეტილება დუშეთის რაიონის სოფ. არახვეთში ინსტიტუტისათვის 0,5 ჰა მიწის ნაკვეთის გამოყოფისა და მასზე სამთო-სამელიორაციო ეკოლოგიური პუნქტის დაფუძნების შესახებ. პუნქტის ხელმძღვანელად დაინიშნა საქართველოს დამსახურებული ინჟინერი, ტექნ. მეცნ. კანდიდატი ლევან სულაქველიძე. ბატონი ლევანი გარდაცვალებამდე (01.02.1996) უანგაროდ ემსახურებოდა გარემოს დაცვის მეცნიერული და საინჟინრო საკითხების კვლევას.

1996-2005 წლებში არახვეთის სამთო-სამელიორაციო ეკოლოგიური პუნქტის ხელმძღვანელად დაინიშნა ტექნიკის მეცნიერებათა დოქტორი, პროფესორი გივი გავარდაშვილი, რომელიც პუნქტს ხელმძღვანელობდა ინსტიტუტის დირექტორად არჩევამდე (2005 წლამდე).

სამთო-სამელიორაციო ეკოლოგიური პუნქტი მისი დაარსებიდან დღემდე ემსახურება ბუნებრივი კატასტროფული მოვლენებით აქტიური საქართველოს სამხედრო გზისა და მისი მიმდებარე ტერიტორიების დაზიანების პრობლემების გადაწყვეტას.

2005 – 2021 წლებში სამთო ეკოლოგიურ პუნქტს ხელმძღვანელობდა გურამ ბურდული, ხოლო 2021 წლიდან დღემდე პუნქტს ხელმძღვანელობს – ნოდარ ბუქური.

სამწუხაროდ, საქართველოში 1990-92 წლებში ცნობილი პოლიტიკური არეულობების დროს პუნქტი გაიქურდა, ხოლო დიდთოვლობის გამო შენობის სახურავი ჩაინგრა და ნაგებობა მთლიანად გამოვიდა მწყობრიდან. ამჟამად ნაგებობა ექვემდებარება სრულ რეაბილიტაციას.

- **აფხაზეთის საცდელ-სამელიორაციო ეკოლოგიური პუნქტი - 0.5 ჰა**

აფხაზეთის საცდელ-სამელიორაციო ეკოლოგიური პუნქტი ამჟამად იკვლევს კოლხეთის დაბლობის ეკოლოგიურ პრობლემებს და ამუშავებს ფერმერებისათვის რეკომენდაციებს ტერიტორიის სასოფლო-სამეურნეო მიზნებისათვის გამოყენების შესახებ. ასევე, ახორციელებს საველე კვლევებს ნიადაგის დაშრობას ინოვაციური სამელიორაციო ღონისძიებებითა და დამშრობი სისტემების რაციონალური ექსპლუატაციის საშუალებით, ეროზიის საწინააღმდეგო კონსტრუქციებს და მდინარეების ჰიდროლოგიური რეჟიმების გამოკვლევას, მდ. კოდორის ნაპირსამაგრი მოწყობილობების დაპროექტებასა და მშენებლობას და სხვ.

- **ინსტიტუტის დირექტორები**

მიხეილ გაგოშიძე, პროფესორი

ცოტნე მირცხულავა, აკადემიკოსი

გივი გავარდაშვილი, აკადემიკოსი

ამიერკავკასიის წყალთა მეურნეობის ინსტიტუტს დაარსებიდან - 1925 წლიდან 1947 წლამდე ხელმძღვანელობდნენ დირექტორები: კ. მიხაილოვი, ე. გაბიევი, ნ. სოკოლოვსკი, დ. გალილოვი, შ. ბიტლაზარი, გ. ლარინი და პ. სოლოდი.

- 1947-68 წლებში (21 წელი) ინსტიტუტს სათავეში ედგა პროფესორი **მიხეილ გაგოშიძე,** რომელმაც დიდი ღვაწლი დასდო მის განვითარებას.

საქართველოს პოლიტექნიკური ინსტიტუტი მიხეილ გაგოშიძემ დაამთავრა 1930 წელს. იყო ტექნიკის მეცნიერებათა დოქტორი (1955) და პროფესორი (1956). 1932–1947 წლებში მუშაობდა ამიერკავკასიის წყალთა მეურნეობის სამეცნიერო–კვლევით ინსტიტუტში სამთო მელიორაციის განყოფილების გამგედ, ხოლო 1947–1968 წლებში - საქართველოს ჰიდროტექნიკისა და მელიორაციის სამეცნიერო–კვლევითი ინსტიტუტის დირექტორად.

❖ **ორგანიზაციის, ასოციაციის ან ჯგუფის წევრობა**

- საქართველოს მინისტრთა საბჭოს მეცნიერებისა და ტექნიკის სახელმწიფო კომიტეტთან არსებული სამთო ეროზიის, ღვარცოფული ნაკადებისა და მათთან ბრძოლის ღონისძიებათა შემსწავლელი მუდმივი კომისიის თავმჯდომარე;
- მელიორაციისა და დრენაჟის საერთაშორისო კონგრესის ეროვნული კომიტეტის წევრი (1957);
- საკავშირო სოფლის მეურნეობის მეცნიერებათა აკადემიის (ამიერკავკასიის განყოფილება) წევრ–კორესპონდენტი.

❖ **ჯილდოები, პრემიები და პრიზები**

- საქართველოს მეცნიერებისა და ტექნიკის დამსახურებული მოღვაწე (1979)...

➢ 1968 - 2005 წლებში (38 წელი) ინსტიტუტს ხელმძღვანელობდა საქართველოს მეცნიერებათა ეროვნული აკადემიის აკადემიკოსი, რუსეთის სოფლის მეურნეობის მეცნიერებათა აკადემიის აკადემიკოსი **ცოტნე მირცხულავა,** რომელიც 2006 წლიდან 2010 წლამდე ინსტიტუტის მთავარი მეცნიერ-თანამშრომელი და სამეცნიერო საბჭოს თავმჯდომარე იყო, 2006 წელს მიიღო წლის საუკეთესო მეცნიერის წოდება და რომლის წვლილიც ინსტიტუტის მიღწევებსა და მისი ავტორიტეტის შექმნაში მეტად მნიშვნელოვანია.

საქართველოს სახელმწიფო პოლიტექნიკური ინსტიტუტის სამშენებლო ფაკულტეტი ბატონმა ცოტნე მირცხულავამ დაამთავრა 1942 წელს. 1942-1953 წლებში მუშაობდა "საქნავთის" სისტემაში, სადაც განვლო გზა ათისთავიდან ტრესტის მმართველის მოადგილის თანამდებობამდე; 1950-1997 წლებში იყო პოლიტექნიკური ინსტიტუტის დოცენტი; 1955-1968 წლებში - საქართველოს ჰიდროტექნიკისა და მელიორაციის სამეცნიერო–კვლევითი ინსტიტუტის ასპირანტი, განყოფილების გამგე, დირექტორის მოადგილე; ტექნიკის მეცნიერებათა დოქტორი, პროფესორი. 1968-2005 წლებში საქართველოს ჰიდროტექნიკისა და მელიორაციის სამეცნიერო–კვლევითი ინსტიტუტის დირექტორი. მისი შრომები ეხება მელიორაციისა და ჰიდროტექნიკურ ნაგებობათა საიმედოობის თეორიას, აგრეთვე მდინარეებისა და არხების კალაპოტის წარეცხვის საკითხებს. მან პირველმა დაადგინა სხვადასხვა გრუნტის წარეცხვის კანონზომიერებანი და მისი პროგნოზირების მეთოდი. ბმული გრუნტების წამრეცხი სიჩქარის დადგენის ანალიზური მეთოდი, ამ გრუნტის წარეცხვის მოდელირების ხერხი და წყლისმიერი ეროზიის ინტენსიურობის პროგნოზირების მეთოდი. გამოქვეყნებული აქვს 600-მდე მეცნიერული ნაშრომი, მათ შორის, 26 მონოგრაფია.

❖ **ორგანიზაციის, ასოციაციის ან ჯგუფის წევრობა**

- ირიგაციისა და დრენაჟის საერთაშორისო ორგანიზაციის წევრი;
- რუსეთის სოფლის მეურნეობის მეცნიერებათა აკადემიის წევრი;
- საქართველოს მეცნიერებათა ეროვნული აკადემიის აკადემიკოსი;

- ჰიდრავლიკური კვლევების ასოციაციის წევრი.

❖ ჯილდოები, პრემიები და პრიზები

- 2000 - საქართველოს სახელმწიფო პრემია მეცნიერებისა და ტექნიკის დარგში;
- 1999 - საქართველოს ღირსების ორდენი;
- 1980 - ხალხთა მეგობრობის ორდენი;
- 1977 - ლენინის ორდენი;
- 1974 - შრომის წითელი დროშის ორდენი;
- 1970 - საქართველოს მეცნიერებათა დამსახურებული მოღვაწე;
- საპატიო ნიშნის ორდენი (2 ორდენი).

➢ 2005 წლიდან დღემდე ინსტიტუტს სათავეში უდგას საქართველოს მეცნიერებათა ეროვნული აკადემიის აკადემიკოსი, ტექნიკის მეცნიერებათა დოქტორი, პროფესორი **გივი გავარდაშვილი**. ტექნიკის მეცნიერებათა დოქტორი (1996), პროფესორი (1998), საქართველოს მეცნიერებათა ეროვნული აკადემიის აკადემიკოსი (2022), საქართველოს დამსახურებული მშენებელი (2023), ცენტრალური ჩინეთის ნორმალის უნივერსიტეტის საპატიო პროფესორი (2015), კაუნასის (ლიეტუვა) გამოყენებითი მეცნიერებათა უნივერსიტეტის ევროკავშირის პროგრამის Erasumus+ პროფესორი (2017), მიწვეული პროფესორის სტატუსით: კალიფორნიის (აშშ) სახელმწიფო უნივერსიტეტში (1999), ჰესენის (გერმანია) უნივერსიტეტში (2006), ცენტრალური ჩინეთის ნორმალის უნივერსიტეტში (2007, 2011, 2015, 2024), მერილენდის (აშშ) უნივერსიტეტში (2011), მინსკის სახელმწიფო უნივერსიტეტსა და ბრესტის (ბელარუსია) ტექნიკურ უნივერსიტეტში (2015, 2016, 2017), ვარშავის (პოლონეთი) სიცოცხლის შემსწავლელ მეცნიერებათა უნივერსიტეტში (2018, 2019), ვარმია-მაზურის (პოლონეთი) ოლშტენის უნივერსიტეტში (2021, 2024).

აკადემიკოს გივი გავარდაშვილს საქართველოსა და საზღვარგარეთ გამოქვეყნებული აქვს 300-ზე მეტი სამეცნიერო ნაშრომი, მათ შორის - 18 მონოგრაფია მსოფლიოს 13 ენაზე, 8 მეთოდური მითითება, 6 სახელმძღვანელო, 26 გამოგონება (აქედან 10 საზღვარგარეთის პატენტი). გ. გავარდაშვილი იყო 200-ზე მეტი საგრანტო პროექტისა და ბიზნესის ხელშემწყობი პროექტის ავტორი, აქედან 40 პროექტის მთავარი ინჟინერი. ბუნებრივი კატასტროფების რეგულირების მიზნით საქართველოს მთის ლანდშაფტებში მისი ავტორობით აშენდა 13 გარემოსდამცავი ინოვაციური ნაგებობა.

გ. გავარდაშვილი იყო 8 დაცული სადოქტორო სადისერტაციო ნაშრომის სამეცნიერო ხელმძღვანელი, 4 მაგისტრისა და საქართველოს ტექნიკურ უნივერსიტეტში 5 აკადემიური დოქტორის ხელმძღვანელი. **გ. გავარდაშვილის** ხელმძღვანელობით შესრულებულია მრავალი საერთაშორისო საგრანტო პროექტი წყალთა მეურნეობის, სოფლის მეურნეობისა და გარემოს დაცვის მიმართულებით, რომლებიც დაფინანსდა საერთაშორისო ორგანიზაციების (**UNESCO, NATO, EU, SDC, ASCE, UN, FAO, WB, NUFFIC)** მიერ.

❖ ორგანიზაციის, ასოციაციის ან ჯგუფის წევრობა

- 2023 წ. - დღემდე - საქართველოს მეცნიერებათა ეროვნული აკადემიის ბუნებრივი კატასტროფების სამეცნიერო პრობლემების შემსწავლელი კომისიის თავმჯდომარე;
- 2019 წ. - დღემდე - ირიგაციისა და დრენაჟის საქართველოს ეროვნული კომისიის ვიცე-პრეზიდენტი;

- 2010 წ. - დღემდე - გაეროს სოციალურ-ეკონომიკური საბჭოს (ECOSOS) საკონსულტაციო სტატუსის მქონე ორგანიზაცია - ა(ა)იპ გარემოს დაცვის ეკოცენტრის დირექტორი;
- 2008-2010 წლებში - საქართველოში 2008 წლის აგვისტოს თვეში საომარი მოქმედებების შედეგად გარემოსთვის მიყენებული ზიანის შემფასებელი სახელმწიფო კომისიის წევრი;
- 2015 წ. - ქ. თბილისში 2015 წლის 13 ივნისს ბუნებრივი კატასტროფების შედეგად ვერეს ხეობის დაგეგმარების სახელმწიფო კომისიის წევრი.

❖ ჯილდოები და პრემიები, საპატიო წოდებები

- 2023 წ. - საქართველოს დამსახურებული მშენებელი;
- 2019 წ. - საქართველოს მეცნიერებათა ეროვნული აკადემიის დიპლომი, იუნესკოს მიერ დაწესებული მეცნიერების მსოფლიო დღესთან დაკავშირებით „ჰიდრომელიორაციის“ დარგში სამეცნიერო მიღწევებისათვის, თბილისი, საქართველო.
- 2018 წ. - უკრაინის სოფლის მეურნეობის მეცნიერებათა ეროვნული აკადემიის მედალი უკრაინულ-ქართულ მეცნიერებაში შეტანილი განსაკუთრებული წვლილისათვის (ქ. კიევი, უკრაინა);
- 2014 წ. - ცენტრალური ჩინეთის ნორმალის უნივერსიტეტის საპატიო პროფესორი (ქ. ვუჰანი, ჩინეთი);
- 2013 წ. - საქართველოს ღირსების ორდენი;
- 2012 წ. - ჩესტოხოვას პოლიტექნიკური უნივერსიტეტის დიპლომი და ვერცხლის მედალი (ქ. ჩესტოხოვა, პოლონეთი);
- 2011 წ. - ვროცლავის სიცოცხლის შემსწავლელი მეცნიერებათა უნივერსიტეტის დიპლომი და ვერცხლის მედალი (ქ. ვროცლავი, პოლონეთი).

❖ ინსტიტუტის სამეცნიერო საბჭო:

ედუარდ კუხალაშვილი (სამეცნიერო საბჭოს თავმჯდომარე, ტექნიკის მეცნიერებათა დოქტორი, პროფესორი), გივი გავარდაშვილი (ინსტიტუტის დირექტორი, საქართველოს მეცნიერებათა ეროვნული აკადემიის აკადემიკოსი, ტექნიკის მეცნიერებათა დოქტორი პროფესორი), მარინე მღებრიშვილი (სამეცნიერო საბჭოს სწავლული მდივანი, ტექნიკის აკადემიური დოქტორი), რობერტ დიაკონიძე (გეოგრაფიის აკადემიური დოქტორი), ირინე იორდანიშვილი (ტექნიკის მეცნიერებათა დოქტორი), შორენა კუპრეიშვილი (ტექნიკის აკადემიური დოქტორი), მარტინ ვართანოვი (ეკონომიკის მეცნიერებათა დოქტორი), ლევან იტრიაშვილი (ტექნიკის აკადემიური დოქტორი), ვლადიმერ შურღაია (ტექნიკის აკადემიური დოქტორი), თამაზ ოდილავაძე (ტექნიკის აკადემიური დოქტორი), ჯუმბერ ფანჩულიძე (ტექნიკის აკადემიური დოქტორი), ლევან წულუკიძე (ტექნიკის აკადემიური დოქტორი).

❖ სტრუქტურული ერთეულები

- ❖ ინოვაციური ჯგუფი - კოორდინატორი გივი გავარდაშვილი;
- ❖ ბუნებრივი საფრთხეებისა და გარემოს დაცვის განყოფილება - ხელმძღვანელი რობერტ დიაკონიძე;
- ❖ ზღვებისა და წყალსატევების განყოფილება - ხელმძღვანელი ირინე იორდანიშვილი;
- ❖ ირიგაციისა და დრენაჟის განყოფილება - ხელმძღვანელი შორენა კუპრეიშვილი.

ამჟამად ინსტიტუტში მუშავდება შემდეგი ადგილობრივი (შ. რუსთაველის საქართველოს ეროვნული სამეცნიერო ფონდის დაფინასებით) და საერთაშორისო მნიშვნელობის საგრანტო პროექტები:

- **შ. რუსთაველის საქართველოს ეროვნული სამეცნიერო ფონდის საგრანტო პროექტები:**

- ღვარცოფსარეგულაციო ელასტიკური ბარაჟი (AR18_1244). სამეცნიერო ხელმძღვანელი ტექნიკის მეცნიერებათა დოქტორი, პროფესორი ედუარდ კუხალაშვილი, პროექტის მენეჯერი - აკადემიკოსი გივი გავარდაშვილი;
- მთის წყალსაცავების საინჟინრო-ეკოლოგიური თავისებურებების სისტემური ანალიზი (FR_21_2942) - პროექტის ხელმძღვანელი - ტექნიკის მეცნიერებათა კანდიდატი კონსტანტინე იორდანიშვილი, პროექტის კოორდინატორი - ტექნიკის მეცნიერებათა კანდიდატი მარინა მღებრიშვილი.
- ჭიათურის მუნიციპალიტეტის ეკოსისტემებისა და სასურსათო პროდუქტების მანგანუმით დაბინძურებისა და სტიქიური მოვლენების რისკების მინიმიზაცია ნიადაგის დეგრადაციის შემცირების მიზნით (FR -23 – 6375). გივი გავარდაშვილი ძირითადი შემსრულებელი.

- **საერთაშორისო პროექტები:**

- შავი ზღვის უსაფრთხოებისა და დაბინძურების რისკების კონტროლი ციფრული მოდელების გამოყენებით (G6028), დამფინანსებელი NATO - პროექტის NPD დირექტორი - გივი გავარდაშვილი;
- წყალმცენარეების ენერგიის გამოყენება დაბინძურების შემცირებისა და "ლურჯი სტრატეგიის" განვითარებისათვის. ევროკავშირის საგრანტო პროექტი - შავი ზღვის NEXT 2021-2027 პროგრამა BSB00091. პროექტის თანადირექტორი - გივი გავარდაშვილი;
- საქართველო I2Q - ინოვაცია, ინკლუზიურობა და ხარისხი კონკურენტული ინოვაციის ფონდი (CIF) პროექტის ,,საქართველოს ტექნიკურ უნივერსიტეტში სამაგისტრო საგანმანათლებლო პროგრამის „მთიანი ტერიტორიების მდგრადი განვითარება" შექმნა მთის უნივერსიტეტთან (მილანის უნივერსიტეტის კვლევითი ცენტრი) თანამშრომლობით" 2024 – 2026 წწ. **გივი გავარდაშვილი** ძირითადი შემსრულებელი.

ინსტიტუტის მეცნიერ-თანამშრომლების აქტიური მუშაობით 2008-2023 წლებში შ. რუსთაველის საქართველოს ეროვნული სამეცნიერო ფონდის დაფინანსებით დამუშავებულია 40-ზე მეტი საგრანტო პროექტი, რაც ინსტიტუტის კოლექტივის დიდ წარმატებად ითვლება. ასევე ინსტიტუტში დამუშავებულია ინოვაციური მეცნიერული პროექტები, რომლებიც განხორციელდა ბუნებრივ ლანდშაფტებში, კერძოდ: გრუნტის წყლების რეგულირების მიზნით დიდ ჯიხაიში (სამტრედიის მუნიციპალიტეტში) 2018 წელს მოეწყო სამიარუსიანი კომბინირებული დრენაჟი; ღვარცოფების რეგულირების მიზნით სოფელ ქვემო მლეთაში (დუშეთის მუნიციპალიტეტი) მდინარე მლეთის ხევში 2022 წელს აშენდა ღვარცოფსარეგულაციო ელასტიკური ბარაჟი; ხოლო თოვლის ზვავების რეგულირების მიზნით, გუდაურის მიმდებარედ (ყაზბეგის მუნიციპალიტეტი), 2021 წელს აშენდა თოვლის ზვავის საწინააღმდეგო ლითონის კონსტრუქცია.

ინსტიტუტის მეცნიერებიდან თითქმის 30% ლექციებს კითხულობს საქართველოს ტექნიკური უნივერსიტეტის 3 ფაკულტეტზე, ინსტიტუტში 2012-2022 წლებში მომზადდა მრავალი სასწავლო პროგრამა და დამუშავდა 100-მდე სასწავლო სილაბუსი.

ვულოცავთ მშობლიურ ინსტიტუტს დაარსებიდან 99 წლის იუბილეს და თითოეულ მეცნიერ-თანამშრომელს ვუსურვებთ ნაყოფიერ მუშაობას ჩვენი ქვეყნის ევროსტანდარტების გათვალისწინებით წყლის რესურსების, წყალთა მეურნეობის, ჰიდრომელიორაციისა და გარემოს დაცვის მეცნიერული განვითარების საქმეში.

ინსტიტუტის დირექცია და სამეცნიერო საბჭო

Congretulation

99TH ANNIVERSARY OF THE ESTABLISHMENT OF THE TSOTNE MIRTSKHULAVA WATER MANAGEMENT INSTITUTE OF GEORGIAN TECHNICAL UNIVERSITY

The institute, whose first name was the Transcaucasian Institute of Water Management, was founded on July 13, 1925, and in 1929, when branches were already established in Azerbaijan and Armenia, the institute was renamed the Scientific Research Institute of Hydrotechnics and Reclamation of Georgia. The organization was under the Union until the collapse of the Soviet Union (Photo 1).

In 1992, the institute entered the system of the National Academy of Sciences of Georgia and was named the Institute of Aquaculture and Engineering Ecology.

According to the decision of the Government of Georgia in 2006, the Institute left the system of the National Academy of Sciences of Georgia and was established as the Water Management Institute of Georgia.

In 2011, by the decree of the Prime Minister of Georgia, the Water Management Institute of Georgia joined the Georgian Technical University as an independent scientific structural unit, and from 2012 it was named the Tsotne Mirtskhulava Water Management Institute of Georgian Technical University.

It should be noted that the institute has a unique hydrotechnical laboratory, one of the largest in Europe, equipped with appropriate equipment and a pumping station.

In 2005, the institute was recognized as the best scientific research organization in Europe, and the collective of the institute due to many scientific projects, research and operation of one of the best hydrotechnical laboratories in the world, where there is a way to model a number of water management, nature protection and ecological measures that are so necessary for Georgia, it was awarded the Swiss diploma «Century International Quality Era Award», and on November 10, 2009, in the meeting hall of the National Academy of Sciences of Georgia, in accordance with the decision of UNESCO, the institute was awarded the diploma of the best scientific and research institution of the country in the field of agricultural sciences in 2008 (Photo 2-7).

Currently, 81 employees work in the institute, 56% of them are scientific employees, including: 1 - Academician of the Georgian National Academy of Sciences, 4 - Member of the Engineering Academy, 5 - Doctor of Sciences, 28 - Academic Doctor, 2 - Doctoral student and 19 - Master.

Based on the country's strategic priorities, the institute is currently working on the following scientific directions:

- Water security and integrated management in light of climate change;
- prediction and control of natural disasters;
- Study of modern problems of land reclamation;
- Prediction of sea and reservoir problems;
- Reliability and risk of hydrotechnical structures;
- Research of erosive processes of agricultural fields.

In 2020-2025, the institute is working on the topic of program funding - "Water resources security and integrated management in view of climate change", which corresponds to the directives of UNESCO's international 8th program. Scientific research is carried out both in the institute's hydraulic and hydrotechnical laboratories, as well as in natural landscapes.

Since 1934, the institute has been publishing collections of scientific works every year, and since 2011 - collections of scientific works of the annual international conference founded and organized by the institute, which have ISSN and DOI.

In order to determine the effectiveness of scientific and research work, since 1930, the Institute has established scientific and research points in different regions of the country by the decision of the Government of Georgia:

- **Alazani experimental-reclamation ecological point - 75 ha (Sighnaghi town, Khornabuji village)**

Alazani experimental and reclamation ecological point is one of the oldest scientific organizations, which was founded in 1948 and is located in Sighnaghi district, 20 km east of Tsnoritskali settlement village in Khornabuji.

From its foundation to 1977, the Alazani experimental and reclamation ecological point was led by the directors: D. Kufaradze G. Abkhazi, V. Sikharulidze, G. Tsomaia, V. Bregvadze, U. Mosulishvili, D. Mosulishvili, and since 2011 - Giorgi Kakashvili. The number of employees of the point is 5.

- **Gori experimental and reclamation ecological point - 5 ha (Gori district, Karaleti village)**

Gori experimental and improvement ecological point is located on the right side of the Gori-Tskhinvali highway, village in Karaleti. It was opened in 1962 by the decree of academician Tsotne Mirtskhulava and under the leadership of candidate of agricultural sciences V. Buachidze, in order to research agricultural crops specific to the Kartli region and develop recommendations for rural agriculture organizations, in particular, determine the water requirements of agricultural crops and the irrigation regime. From the day of its opening until 2006, the point was headed by the experienced agronomist Arsen Muradashvili, from 2006 to 2021 by Guram Muradashvili, and since 2021 by the senior scientific employee of the institute, Acad. Doctor, Prof. **Giorgi Natroshvili.**

In order to modernize the scientific base, under the initiative and leadership of the director of the institute, Academician Givi Gavardashvili, with the financing of the Rustaveli National Science Foundation of Georgia grant projects (RIM), more than 1,650 new perennial seedlings were planted in 2023-2024 on an area of 2 ha of the territory of the Gori scientific base. A drip irrigation system was installed with fertigation and modern type of agricultural equipment with appropriate plow, milling and spraying equipment was purchased. A modern mini weather station was installed here.

We think that on this point it is quite possible to implement appropriate scientific-educational programs, not only for young scientists of the Institute, but also for bachelors, masters and doctoral students of various faculties of the Georgian Technical University.

- **Prof. Fridon Shatberashvili's Kolkheti (Poti) experimental-reclamation ecological point (Poti St., St. Tavdadeduli #10) - 0.5 ha**

The point was created in 1932 in connection with the initiation of measures to drain the swampy areas of Kolkheti and exists to this day. During this time, the not numerous collective of the point performed a number of important studies, which preceded the scientific-research works of utilization of Kolkheti I and II rows and drawing up project documentation (physical-mechanical composition of the soil, determination and evaluation of filtration coefficients and other characteristic parameters). The point was located in the administrative building of Kolkhidmshen. Since 1982, Kolkheti experimental-reclamation point has moved to St. In the Maltakvi area of Poti, in a well-furnished one-story building with a useful area of 315 m2 and a yard of 0.5 ha, where there are working rooms, a laboratory, a warehouse, parking lots, etc. The scientific station was headed by candidate of technical sciences Shalva Dolbaya, candidate of agricultural sciences, experienced agronomist Otar Gagua, and since 2019, the head of the station is Jemal Migineishvili, a construction specialist, master, scientific employee.

According to the decision of academician Givi Gavardashvili, co-director of the NATO project "Control of Black Sea Safety and Pollution Risks Using Numerical Models", it is planned for the first time in Georgia to establish a Black Sea observatory in accordance with NATO standards in the building of the Kolkheti experimental-reclamation point laboratory.

In the NATO project, in the development of which scientists from 6 countries of the world (USA, Georgia, Ukraine, Bulgaria, Romania and Turkey) participate, scientific-practical works are planned in the territory of the point in 2024-2026.

Academician Givi Gavardashvili, director of the institute, also notes that at the beginning of 2024, information was received from Brussels that the institute was financed together with European countries (Bulgaria, Georgia, Ukraine and Greece) in the EU grant project - the Black Sea NEXT 2021-2027 program (BSB00091), "Algae energy use". for the reduction of pollution and the development of the "blue strategy". This international project will be implemented within the borders of Georgia in the Black Sea water area, including the Kolkheti (Poti) experimental-reclamation ecological point of the institute.

- **Samgori reclamation ecological point - 5 ha**
  (Gardabni district, village Gamarjveba)

The point was opened in 1962 by the decree of academician Tsotne Mirtskhulava, whose head was appointed candidate of agricultural sciences Vera Buachidze. The area of the territory is 4.5 ha, it slopes from north to south and has a slope of 0.15; Perennial plants and annual crops are grown. The topographical conditions significantly complicated the irrigation processes, therefore, in parallel with the traditional irrigation system, research was carried out with subsoil irrigation systems, the coordinator of which was candidate of technical sciences Lado Bokeria. since 2021, the point is headed by a scientific worker, M.Sc. Gela Vakhtangishvili.

- **Arachveti mining and experimental ecological point - 0.5 ha**
  (Dusheti district, village Arahveti)

In order to study the natural hydromorphological and, partially, geological processes in Georgia under natural conditions, according to the Resolution #270 of the Council of Ministers of Georgia (25.05.1974), the decision #59 of the Dusheti Regional Council of February 15, 1974 was approved in the village of Dusheti district. About the allocation of 0.5 ha of land for the Institute in Arakheti and the establishment of a mining-reclamation ecological point on it. Honored Engineer of Georgia, Candidate Levan Sulakvelidze. Until his death (01.02.1996), Mr. Levan selflessly served the research of scientific and engineering issues of environmental protection.

In 1996-2005, Professor Givi Gavardashvili, Doctor of Technical Sciences, was appointed as the head of the Arakhveti mining-reclamation ecological point, who headed the point until he was elected as the director of the institute (until 2005).

From its establishment, the mining and reclamation ecological point has been serving to solve the problems of damage to the active Georgian military road and its surrounding areas caused by natural disasters.

From 2005 to 2021, Guram Burduli headed the mining ecological point, sice 2021, Nodar Bukuri heads the point.

Unfortunately, during the well-known political unrest in Georgia in 1990-92, the point collapsed, and due to heavy snowfall, the roof of the building collapsed and the structure was completely out of order. Currently, the building is subject to complete rehabilitation.

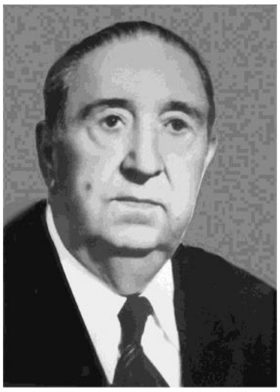
➢ Abkhazia experimental and reclamation ecological site - 0.5 ha (Sukhum, Abkhazia, currently operates at 60-b Chavchavadze Ave., Tbilisi)

Abkhazia's experimental-reclamation ecological station operated in St. in Sukhumi since 1982, the first head of which was candidate of technical sciences Roland Jgerenaya. In 1992, after the death of Roland Jgerenaia during the well-known hostilities in Abkhazia, Merab Sharangia was appointed as the head of the test-improvement ecological point.

In 2008, after the complete occupation of Abkhazia by Russia, the test-improvement ecological point was moved to St. in Tbilisi and the candidate of technical sciences, senior scientific employee Paata Sichinava was appointed as its head.

The Abkhazia experimental-reclamation ecological point is currently investigating the ecological problems of the Kolkheti lowland and developing recommendations for farmers on the use of the territory for agricultural purposes. Also, it carries out field studies on soil drying through innovative reclamation measures and rational exploitation of drying systems, anti-erosion constructions and investigation of hydrological regimes of rivers, Md. Designing and construction of Kodori mooring devices, etc.

❖ DIRECTORS OF INSTITUTE



Mikheil Gagoshidze, professor

Tsotne Mirtskhulava, Academician

Givi Gavardashvili, Academician

Transcaucasian Water Management Institute was headed by directors from 1925 to 1947: K. Mikhailov, E. Gabiev, N. Sokolovsky, D. Galilov, Sh. Bitlazar, G. Larin and P. Solo.

➢ In 1947-68 (21 years), the institute was headed by professor **Mikheil Gagoshidze**, who made a great contribution to its development.

Mikheil Gagoshidze graduated from the Polytechnic Institute of Georgia in 1930. He was a doctor of technical sciences (1955) and a professor (1956). In 1932-1947, he worked as the head of the mining reclamation department at the Transcaucasian Water Management Scientific Research Institute, and in 1947-1968 - as the director of the Georgian Hydrotechnics and Reclamation Scientific Research Institute.

❖ **Membership of an organization, association or group**

- Chairman of the permanent commission studying mining erosion, mudslides and measures to combat them under the State Committee of Science and Technology of the Council of Ministers of Georgia;
- Member of the National Committee of the International Congress of Reclamation and Drainage (1957);
- Member-correspondent of the All-Union Academy of Agricultural Sciences (Transcaucasia Section).

❖ **Awards, bonuses and prizes**

- Honored Worker of Science and Technology of Georgia (1979)...

➢ From 1968 to 2005 (38 years), the institute was headed by Academician of the National Academy of Sciences of Georgia, Academician of the Russian Academy of Agricultural Sciences **Tsotne Mirtskhulava,** who was the chief scientist-collaborator of the institute and the chairman of the scientific council from 2006 to 2010, in 2006 he received the title of the best scientist of the year and whose The contribution to the achievements of the institute and the creation of its authority is very important.

Mr. Tsotne Mirtskhulava graduated from the Faculty of Construction of the State Polytechnic Institute of Georgia in 1942. In 1942-1953, he worked in the "Saknavti" system, where he worked his way up to the position of deputy manager of the trust; In 1950-1997, he was a docent of the Polytechnic Institute; 1955-1968 - post-graduate student, head of the department, deputy director of the Scientific-Research Institute of Hydrotechnics and Reclamation of Georgia; Doctor of technical sciences, professor. In 1968-2005, he was the director of the Scientific Research Institute of Hydrotechnics and Reclamation of Georgia. His works relate to the theory of reclamation and the reliability of hydrotechnical structures, as well as to the issues of bed washing of rivers and canals. He was the first to establish the regularities of various soil erosion and the method of its prediction. Analytical method for determining the leaching rate of linked soils, the method of modeling this soil leaching and the method of predicting the intensity of water-borne erosion. He has published about 600 scientific works, including 26 monographs.

❖ **Membership of an organization, association or group**

- Member of International Organization of Irrigation and Drainage;
- Member of the Russian Academy of Agricultural Sciences;
- Academician of the National Academy of Sciences of Georgia;
- Member of the Hydraulic Research Association.

❖ **Awards, bonuses and prizes**

- 2000 - State Prize of Georgia in the field of science and technology;
- 1999 - Order of Honor of Georgia;
- 1980 - Order of Friendship of Peoples;
- 1977 - Order of Lenin;
- 1974 - Order of the Red Banner of Labor;
- 1970 - Honored Worker of Sciences of Georgia;
- Order of the badge of honor (2 orders).

➢ From 2005 to the present, the head of the institute is academician of the National Academy of Sciences of Georgia, doctor of technical sciences, professor **Givi Gavardashvili.** Doctor of Technical Sciences (1996), Professor (1998), Academician of the National Academy of Sciences of Georgia (2022), Honored Builder of Georgia (2023), Honorary Professor of Central China Normal University (2015), Professor of the EU Program Erasumus+ at Kaunas University of Applied Sciences (Lithuania) 2017), visiting professor at: California (USA) State University (1999), Hessen (Germany) University (2006), Central China Normal University (2007, 2011, 2015, 2024), Maryland (USA) University (2011), Minsk State University and Technical University of Brest (Belarus) (2015, 2016, 2017), University of Life Sciences in Warsaw (Poland) (2018, 2019), Olsztyn University of Warmia-Masur (Poland) (2021, 2024).

Academician Givi Gavardashvili has published more than 300 scientific works in Georgia and abroad, including 18 monographs in 13 languages, 8 methodological references, 6 manuals, 26 inventions (including 10 foreign patents). c. Gavardashvili was the author of more than 200 grant projects and business promotion projects, of which he was the chief engineer of 40 projects. In order to regulate natural disasters, 13 innovative environmental protection structures were built under his authorship in the mountain landscapes of Georgia.

G. Gavardashvili was the scientific supervisor of 8 protected doctoral theses, 4 master's and 5 academic doctorates at the Technical University of Georgia. c. Under the leadership of Gavardashvili, many international grant projects in the direction of water management, agriculture and environmental protection have been implemented, which were financed by international organizations (UNESCO, NATO, EU, SDC, ASCE, UN, FAO, WB, NUFFIC).

❖ Membership of an organization, association or group

- Since 2023 - Chairman of the Commission for Studying Scientific Problems of Natural Disasters of the National Academy of Sciences of Georgia;
- Since 2019 - the vice-president of the Georgian National Commission for Irrigation and Drainage;
- Since 2010 - an organization with a consultative status of the United Nations Socio-Economic Council (ECOSOS) - director of the Environmental Protection Ecocenter of A(A)IP;
- 2008-2010 - Member of the State Commission for Assessing the Damage to the Environment as a Result of Military Actions in August 2008 in Georgia;
- 2015 - st. As a result of natural disasters in Tbilisi on June 13, 2015, a member of the State Planning Commission of the Vere Gorge.

❖ Awards and prizes, honorary degrees

- 2023 - Honored Builder of Georgia;
- 2019 - Diploma of the National Academy of Sciences of Georgia, for scientific achievements in the field of "hydromelioration" established by UNESCO in connection with the World Science Day, Tbilisi, Georgia.
- 2018 - Medal of the National Academy of Agricultural Sciences of Ukraine for special contribution to Ukrainian-Georgian science (Kiev, Ukraine);
- 2014 - Honorary Professor of Central China Normal University (Wuhan, China);
- 2013 - Order of Honor of Georgia;
- 2012 - Diploma and silver medal of Czestochowa Polytechnic University (Czestochowa, Poland);
- 2011 - Diploma and silver medal of Wroclaw University of Life Sciences (Wroclaw, Poland).

❖ Scientific Council of the Institute:

Eduard Kukhalashvili (Chairman of the Scientific Council, Doctor of Technical Sciences, Professor), Givi Gavardashvili (Director of the Institute, Academician of the National Academy of Sciences of Georgia, Doctor of Technical Sciences, Professor), Marine Mghebrishvili (Learned Secretary of the Scientific Council, Academic Doctor of Technical Sciences), Robert Diakonidze (Academic of Geography Doctor), Irine Yordanishvili (Doctor of Technical Sciences), Shorena Kupreishvili (Academic Doctor of Engineering), Martin Vartanov (Doctor of Economic Sciences), Levan Itriashvili (Academic Doctor of Engineering), Vladimir Shurghaia (Academic Doctor of Engineering), Tamaz Odilavadze (Academic Doctor of Engineering), Jumber Fanchulidze (Academic Doctor of Engineering), Levan Tsulukidze (Academic Doctor of Engineering).

❖ structural units

- **I**nnovative group - coordinator Givi Gavardashvili;
- Department of Natural Hazards and Environmental Protection - Head Robert Diakonidze;
- Department of seas and waterways - head Irine Iordanishvili;
- Irrigation and drainage department - head Shorena Kupreishvili.

Currently, the following local (with funding from the Rustaveli National Science Foundation of Georgia) and international grant projects are being developed at the institute:

➢ **Grant projects of Sh. Rustaveli National Science Foundation of Georgia:**

- Debris flow regulation elastic barrage (AR18_1244). Scientific supervisor, Doctor of Technical Sciences, Professor Eduard Kukhalashvili, Project Manager - Academician Givi Gavardashvili;
- Systematic analysis of engineering-ecological features of mountain reservoirs (FR_21_2942) - project leader - candidate of technical sciences Konstantine Yordanishvili, project coordinator - candidate of technical sciences Marina Mghebrishvili.
- Minimizing the risks of manganese contamination and natural disasters of Chiaturi Municipality ecosystems and food products to reduce soil degradation (FR-23 – 6375). Givi Gavardashvili is the main performer.

➢ **International projects:**

- **C**ontrol of Black Sea Safety and Pollution Risks Using Digital Models (G6028), sponsored by NATO - Project NPD Director - Givi Gavardashvili;
- Algae energy use for pollution reduction and development of "blue strategy". EU grant project - Black Sea NEXT 2021-2027 program BSB00091. Co-director of the project - Givi Gavardashvili;
- Georgia I2Q - Innovation, Inclusivity and Quality Competitive Innovation Fund (CIF) project "Creation of the Master's Educational Program "Sustainable Development of Mountainous Areas" at the Technical University of Georgia in cooperation with the Mountain University (Research Center of the University of Milan)" 2024 - 2026. Givi Gavardashvili is the main performer.

With the active work of the scientific staff of the Institute in 2008-2023 Sh. More than 40 grant projects have been processed with the funding of the Rustaveli National Science Foundation of Georgia, which is considered a great success of the Institute's team. Innovative scientific projects implemented in natural landscapes have also been developed at the institute, namely: in 2018, in order to regulate groundwater, in Didi Jikhaish (Samtredia municipality), a three-way combined drainage was organized; In 2022, a flood regulation elastic dam was built in the gorge of the Mleti River in the village of Kvemo Mleta (Dusheti Municipality) for the purpose of flood regulation; And in order to regulate snow avalanches, in the vicinity of Gudauri (Kazbegi municipality), a metal structure against snow avalanches was built in 2021.

Almost 30% of the institute's scientists give lectures at 3 faculties of the Technical University of Georgia. In the period 2012-2022, the institute prepared many training programs and processed about 100 training syllabus.

We congratulate my native institute on the 99th anniversary of its establishment and I wish each scientist-collaborator fruitful work in the field of scientific development of water resources, water management, hydro melioration and environmental protection, taking into account the European standards of our country.

Directorate and Scientific Council of the Institute

Environmental protection

HISTORICAL ASPECTS OF ENVIRONMENTAL PROBLEM SOLVING

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Annotation. The work highlights the impact of negative factors on the environment. Anthropogenic changes in landscapes, the complication and expansion of international economic relations have led to increased interaction between humanity and the environment and an increase in the anthropogenic load on the human condition. It is noted that of particular interest is the study of the interaction of environmental science with other sciences in accordance with the requirements of the modern era, as well as the growing popularity of ecology in modern life. It is shown that the formation of ecology as a science, an in-depth study of its history of development can be considered one of the pressing problems of our time. In this aspect, in the world around us, full of contradictions, environmental science, like other sciences, has its roots and history.

The paper highlights the issues of the impact of negative factors on the environment. Anthropogenic changes in landscapes, complication and expansion of international economic relations have led to increased interaction of mankind with the environment and increased anthropogenic load on the human condition. It is noted that it is of special interest to study the interaction of ecological science with other sciences in accordance with the requirements of the modern era, as well as the growing popularity of ecology in modern life. It is shown that the formation of ecology as a science, in-depth study of its history of development can be considered one of the urgent problems of modernity. In this aspect, in the world around us, full of contradictions, ecological science, like other sciences, has its roots and history.

***Keywords**:* environmental science, natural resources, environmental protection, humanity, negative factors.

INTRODUCTION

Ecology was formed within the philosophical worldview of human society. The development of ecological science was influenced by generalized dialectical ideas of philosophical knowledge. In the history of ancient philosophical thought, the dialectical approaches of the pioneers played an important role in the development of ecological science. As a result of the logical connection between philosophical thinking and ecological scientific thinking, ancient environmental philosophers put forward different ideas about quantitative and qualitative changes in the material world. This led to the dialectical development of ecological scientific ideas and the emergence of scientific trends in subsequent periods. In the 5th and 4th centuries, Plato (427-347) put forward valuable ideas and measures to protect the hills of Attica in southeastern Greece from soil erosion and preserve their water resources, soil fertility, and to regulate population settlement.

In the third century B.C., the ancient Indian king Ashoka (268-232 B.C.) issued a decree prohibiting the killing of young and strangled animals for up to six months. In ancient times, measures were taken to protect water sources, caves of ancient settlements, valuable trees and areas rich in wildlife in Central Asia, the Mediterranean countries, and the Caucasus. In different historical periods, ecological views in ancient Rome and Greece were reflected in the scientific works of philosophers working in the field of natural sciences. In the 18th century, valuable ecological observations found in the works of such great philosophers as C. Linnaeus, J. Barfon, P. S. Pallas, I. I. Lipeichi, were reflected in botany and zoology. Since XI and XII centuries a number of practical measures were taken to prevent pollution of various water sources and air in the countries of Western Europe. Founded in France in the 14th century, a special enterprise called "Waters and Forests" was responsible for the efficient use and protection of water and forest resources. During the reign of the French King Charlemagne (742-814) and English King William (1027-1087), those who cut down forests and killed wild animals were severely punished [1-2].

MAIN PART

Degradation of the biological world as a result of anthropogenic and anthropogenic impacts annually leads to the destruction of a large number of plant and animal species, creating "dead zones" in one or another territory. At present, the environment is so polluted that the ecological crisis in localized areas continues to threaten the lives of living beings and people, and in recent years this process has accelerated. If this situation continues in the biosphere, serious threats to the life of living beings and humans may arise in the future.

At present, the influence of the human factor on the ecosystem has increased dramatically, as technogenic technologies used as a means of impacting nature have become virtually uncontrollable and anarchic, acquiring an almost human-independent status. As a result, global problems are arising that are troubling humanity and becoming increasingly intractable, and it is hard to say that they will not continue unabated. The direction and maintenance of the equilibrium established in nature depend on human economic activity, for this equilibrium determines the development of nature according to its own laws. Ecological crisis is not only pollution of air, water, soil and nutrients. Transformation and, in some cases, degradation of natural ecosystems as a result of anthropogenic impact leads to disruption of the biogeochemical cycle and, ultimately, ecological sustainability. This is reflected not only in negative environmental changes, but also in the structure of the human genome. The steady growth of hereditary diseases in all countries of the world is due to genetic changes.

This is primarily due to the fact that the health of the population is in direct dependence on environmental hazards. At the same time, it should be noted that in a number of cases, environmental changes during an ecological crisis are reflected both domestically and internationally. International cooperation in the field of environmental protection has further increased and has become global in nature [3-4]. There are two forms of such cooperation: intergovernmental agreements and conventions on environmental protection and national use of natural resources; participation in the work of international environmental organizations. Interstate agreements and conventions are concluded, first of all, between states that have similar physical-geographical conditions and common borders. The United Nations (UN) system is actively working on international cooperation in the field of environmental protection.

From the earliest days of the United Nations, environmental protection has been one of the practical objectives of the organization. In 1949, the first UN action in this field took place in Lake Saxe, USA. Although the techno-economic impact of man on nature and its resources to meet the material and cultural needs of the population was initially primitive, it has subsequently become more intensive as a result of the intervention of scientific and technological progress in our lives. The development of technical progress, meeting the need for means of production, consumer goods, cultural and household goods accelerates the use of natural resources, especially minerals [5-8]. Irrational use of natural resources prematurely depletes resources, slows down the process of self-recovery within natural processes, creates favorable conditions for the formation of ecological crises in the environment. High concentration of production leads to the emission of wastes considered harmful to the environment, which leads to the rapid growth of environmental tension in industrial centers.

Mechanized, chemicalized agricultural and industrial enterprises annually emit more than 1 million tons of soot, lead, zinc, sulfur, carbon monoxide and other substances into the air [9]. Until 1995, the country annually allocated about 170-180 million manats (previously) to protect the environment polluted by various industrial, transportation and household wastes. These funds do not account for even one percent of the damage to environmental, social and economic development in the process of nature management. It should also be noted that the volume of wastewater discharged into the Caspian Sea from large cities and towns of the Apsheron Peninsula exceeds the norm many times over. Pollution from natural sources is often of short duration. Pollutants are formed in production processes associated with human activity. This situation has led to a fundamental change in the composition of industrial waste and a new quality of air pollution. As a result, dust of heavy and rare elements and synthetic compounds has entered the atmosphere.

Earlier, during the development of Asian culture and the Middle Ages, mankind realized that the development and use of natural resources, in addition to obtaining material benefits, has a negative impact on the environment. A number of documents found during the development of ancient Babylon, Egypt, Rome, Central Asia, the Caucasus, and the Kiev-Russian culture mention restrictions on the use of biological resources. Many years ago, China and India fought against deforestation, and in China and Egypt, measures to control erosion of fertile land through governmental decisions and public initiatives were widely discussed. Human perception of ecology, careful attitude to certain natural resources stems from their general scientific knowledge, industrial, professional experience and needs. In this context, a number of valuable information can be found in ancient Egyptian, Indian and European writings.

In the Indian epics Mahabharata and Ramayana B.C., there are ideas about changing the quantity and quality of wild animals, and the prohibition of killing female animals [4]. These works contain interesting information about the way of life and habits of more than fifty different species of animals. Ancient authors were able to correctly explain the events that took place in nature, as well as the connections within the living world itself [10].

Mankind, as a living being, is inextricably linked to the material and energetic processes occurring in the biosphere of the geologic crust of the Earth. By mass of living very small part of the biosphere is about 0.25% [5] and is concentrated mainly on land, in water bodies and in the atmosphere as a thin layer (Fig.1).

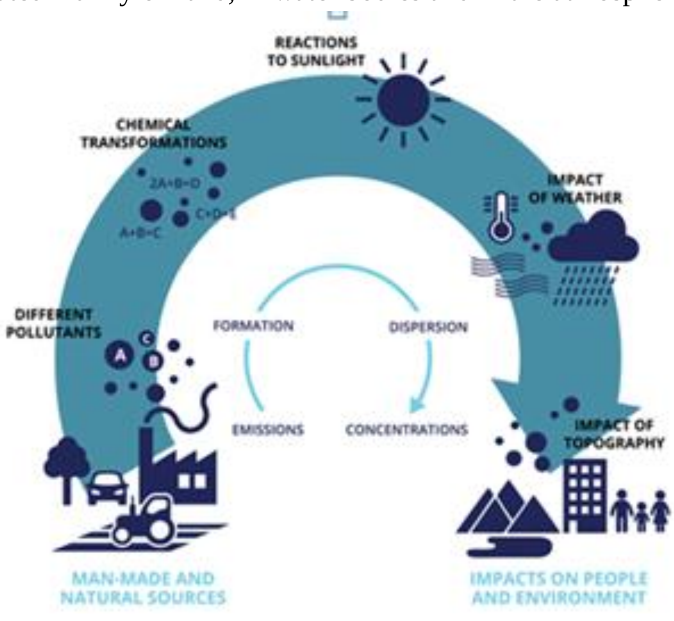

Fig. 1. Anthropogenic impact on the ecosphere

The process of evolution is applicable only to living organisms, since, according to V.I. Vernadsky, living organisms perform biogeochemical functions in the biosphere. The main purpose of environmental protection is to study the impact of various factors, primarily anthropogenic, on the elements of the biosphere. Mankind is increasingly convinced that the Earth is a unique creation with its own biosphere and living beings. At present, world science and mankind are watching with great excitement the dangerous events that may cause possible catastrophes for this unique creation of the planet Earth (Fig.2).

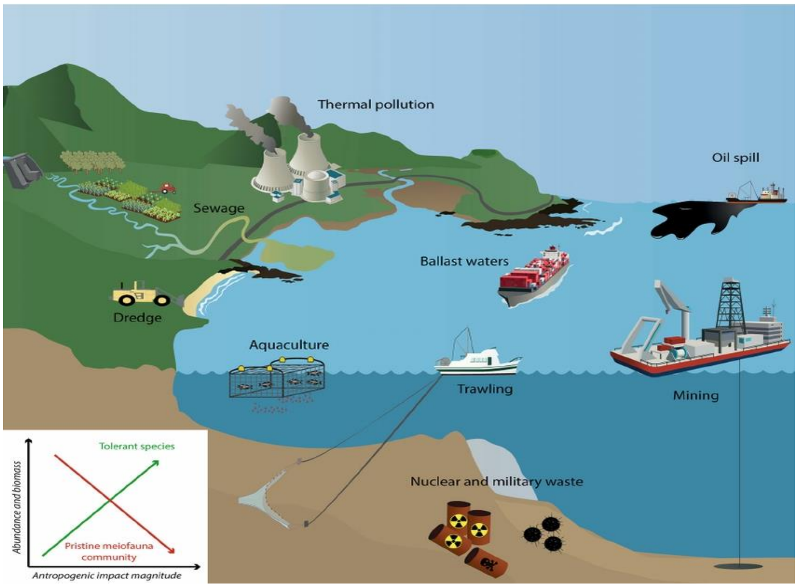

Fig. 2. Industrial pollution

These catastrophic events are due to profound changes in the industrial and agricultural activities of modern man. Human activities primarily have a strong impact on the atmosphere, which leads to catastrophic changes in ecosystems. The more polluted nature is, the less effective is the body's defense and preservation against xenobiotics. The science of genetics has proved that environmental pollution with toxic and harmful substances has an extremely negative impact on the genetic program of living beings, especially humans and leads to the development of the many diseases. For this reason, in further intensification of the "production" of bioproducts, priority should be given to environmental problems and the maintenance of optimal living conditions should be planned as much as possible. The attitude of human society towards nature has changed from time to time. In the beginning, nature was only a source of food for man, and man remained indifferent to the fate of nature. The scientific and cultural achievements of man during the period of 40-50 thousand years of civilization were taken from nature itself and all the shortcomings he has faced so far were the result of his cruel treatment of nature. Man is the only living being who tries to completely change the environment and all living things are subject to the laws of nature. However, man violates the laws of nature and tries to change them completely according to his infinite needs. It can be said that man's successes in this field actually turn into his failures. Man's irrepressible greed to alienate and conquer nature has led to a certain ecological collapse, which is more dangerous than nuclear weapons at this point in time (Fig.3).

Fig. 3. Chemical pollution

The main goals and objectives of ecology nowadays are the discovery of interactions and connections of anthropogenic ecosystems with nature, in this respect the study of ecosystem allows to determine the amount of metabolism and energy conversion. Artificial productive ecosystems are important compared to energy populations and biocenoses (Fig.4).

Fig. 4. Water pollution

In the conditions of modern development of science and technology, population growth, the interaction of nature and society has become a universal problem. Increasing material and cultural standard of living of people, increasing production of material goods raises the issue of efficient use of natural resources. The impact on nature as a result of human activity armed with technology and energy is so great that its negative factors can be compared to the strength of many impacts in geological periods. Efficient use of natural resources and environmental protection, have been in the center of attention of the world community for the last hundred years.

After the Second World War, under the influence of public opinion, many states have taken important measures and decisions in this regard. It should be noted that nature conservation has been an important issue since the beginning of the 20th century. The VII International Zoological Congress in Graz (Austria) in 1910 and the International Conference on Nature Conservation in Bern in 1913, in addition to issues of practical importance, set a number of important tasks to conserve and protect natural resources for future generations [6]. In the last fifty years, the global public exchange of opinions on environmental problems has become more and more extensive. At the suggestion of most countries, the International Conference on the Protection of the Biosphere and its Resources held in Paris in 1968 under the auspices of UNESCO, the Congress of the Economic Commission for Europe on Environmental Protection in Prague in 1971, and in recent years, the holding of the United Nations Conference on the Environment, have posed important challenges to society in the field of nature conservation. In developed countries, such as North America, Western Europe, Japan and a number of CIS countries, environmental protection is strictly controlled and important work has been done to combat pollution of transit rivers for clean environment along the borders of these countries.

The first international conference on nature conservation was held in 1913 in Bern, Switzerland [7, 8] . At the invitation of Switzerland, representatives of 17 countries participated in the conference: Austria, Germany, USA, Argentina, Belgium, Great Britain, Denmark, Sweden, Switzerland, Spain, Italy, Hungary, Netherlands, Norway, Portugal, Russia and France. The main focus of the conference was on the collection and publication of information on the use of natural resources and environmental protection. It should be noted that the activities of the seven UN specialized councils are directly related to environmental issues. They put forward plans and measures to eliminate a number of negative symptoms caused by the impact of people armed with technology on nature. Since its establishment, i.e. since 1945, UNESCO has been the most famous and advanced center for monitoring cooperation in the field of environmental protection and implementation of organizational measures [9, 10].

CONCLUSIONS

Based on the above, we can conclude that the historical role of ecology in human life is an undeniable fact from the moment of existence of the human race until the last moments of its existence. Thus, man has been interacting with the environment since the day of his existence in the world, and as a result of this interaction, his negative and positive (in most cases, this impact is considered the most negative) manifestation in any form in the environment. According to the results of the study, it should be noted that it is better to prevent the occurrence of environmental problems through preventive measures than to think about solving environmental problems caused by any anthropogenic activities in the field of environmental protection and rational use of natural resources.

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Water management

METHODS FOR CALCULATION AND DESIGN OF STRUCTURES REGULATING THE MOVEMENT OF RIVER SEDIMENTS IN RESERVOIRS

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Annotation. The article provides information about water resources and reservoirs of Uzbekistan. The results of field, theoretical and laboratory studies of reservoirs are presented . Methods are proposed for regulating the regime of river sediment movement in reservoirs, taking into account the fractional composition of pumps entering the thicket of the reservoir. A special sedimentation tank design is proposed for fractional regulation of the sediment regime in the reservoir. The design parameters of the settling tank are justified based on the hydrological and hydraulic characteristics of the reservoir. A methodology for calculating the distribution of sediment in a reservoir and methods for maintaining the usable volume of the reservoir are considered.

Keywords: *reservoirs, siltation of reservoirs, settling basin, river sediments, fractional composition of sediments, infrastructure, water resources.*

INTRODUCTION

Reservoirs constitute an essential component of the infrastructure in numerous nations, including Uzbekistan. This discussion delves into the condition of these water storage facilities within the country, highlighting both current challenges and potential strategies for enhanced management of water resources [1,2]. Given the imperative of judicious water utilization and regulation, Uzbekistan has established a network of reservoirs. Recent challenges have emerged due to global climate shifts and intermittent water scarcities, impacting various economic sectors. The Republic of Uzbekistan, situated in the Aral Sea basin, primarily draws its water from the Amu Darya, Syrdarya, and Zarafshan rivers, in addition to local rivers, also subterranean sources. The annual average water flow from these sources totals approximately 116.2 billion cubic meters, with over 67.4 percent originating from the Amu Darya basin and less than 32.6 percent from the Syrdarya basin. The nation's total groundwater reserves amount to 31.2 billion cubic meters, with 47.2 percent located in the Amu Darya basin and 52.8 percent in the Syrdarya basin [1,2]. The significant sediment load these rivers transport has substantial implications for the operational characteristics of the reservoirs.

In Uzbekistan, the distribution of natural water resources is markedly uneven throughout the year, necessitating efficient water resource management, flood and mudflow mitigation, and support for industrial and agricultural development [3,4]. Currently, the country utilizes reservoirs with a combined capacity of 19.93 billion cubic meters, with 5.93 billion cubic meters in the Syrdarya basin and 14.0 billion cubic meters in the Amu Darya basin [2,4]. The geographical diversity of the republic is mirrored in the variability of its reservoir locations, ranging from mountainous regions to foothills and plains [5-7].

Fig. 1. Main reservoirs of the Republic of Uzbekistan

The efficient utilization of reservoirs is contingent upon multiple factors [1-11]. A primary challenge is the siltation of reservoirs, which alters their morphometric parameters and disrupts the hydrobiological regime [1,3,19]. These alterations lead to a reduction in the reservoirs' effective volume and elevate water losses through mechanisms such as evaporation and filtration. Additionally, siltation adversely affects the ecological health of the region. Therefore, the management of sediment levels within reservoirs holds significant practical and theoretical value. Effectively controlling sediment accumulation not only aids in accurately determining the extent of siltation but also facilitates the utilization of river sediments as mineral-rich materials suitable for use as fertilizers [14].

Addressing and devising strategies to mitigate reservoir siltation involves a multifaceted approach. Various methodologies have been suggested to combat siltation, including reservoir flushing, curtailing sediment inflow, constructing ancillary structures on surrounding slopes, channeling sediments through outlets, and conducting dredging operations [1-14]. For each reservoir, tailored siltation management strategies should be devised, taking into account the local environmental conditions and supported by comprehensive feasibility studies. The objective of this study is to develop an effective siltation management strategy for the Chartak reservoir in the Republic of Uzbekistan, with a particular focus on the granular composition of the river sediments.

Materials and methods

The selection of a method to mitigate reservoir siltation should be grounded in comprehensive scientific research that examines the reservoir's current conditions. This choice is influenced by a technical and economic analysis, the capacity of the local energy infrastructure, the demands of water users, and other regional considerations. As sediments accumulate, the reservoir's operational characteristics are compromised, leading to the introduction of coarse sediments such as sands—into irrigation channels and culverts, thereby reducing the efficacy of the water distribution system. These and additional challenges underscore the necessity for predictive strategies and the development of solutions to manage the siltation of the reservoir's functional volume, utilizing data derived from extensive field research [1-7]. Notably, the Chartak reservoir has been the focus of several years of field studies employing advanced measurement technologies.

The accumulation of muddy sediments within a reservoir is influenced by its geographical location, the characteristics of its water source, and the geomorphology of its banks. An analysis of turbid sediment dynamics within the reservoir reveals that during flood events, sediment-laden flows follow the deeper channels of the riverbed. If the water discharge systems are operating at full capacity, it is possible for a proportion of these turbid particles to be expelled into the downstream basin [15,17]. However, satellite imagery of the riverbed at the upper entrance of the Chartak reservoir indicates that a substantial quantity of these sediments is deposited within the reservoir itself (Fig. 2).

Fig. 2. Chortoksoy reservoir

As the water level in the reservoir rises, the dynamics of the flood intensify the hydraulic processes within the stream, facilitating the dispersion of turbidity throughout the reservoir basin. It is noteworthy that turbid sediments undergo spatial sorting along the stream's length, settling initially with larger particulate fractions at the onset of the wetting zone. Positioned at the base of the Chotqal mountain ranges, the Chortok district experiences significant precipitation during the latter part of autumn and the early part of spring [18,19]. Consequently, substantial volumes of muddy sediments are carried into the reservoir along with natural water flows.

Results and Discussion

Increased precipitation enhances the flow into the Chortoksoy river basin, thereby augmenting the reservoir's water volume and precipitating floods. These conditions exacerbate riverbank erosion and other processes, increasing the proportion of muddy sediments. The turbid flow's composition can contain 15-20% of cloudy sediments, influenced by the duration and intensity of rainfall [6,9,15,17]. As these sediments enter the Chortok reservoir, the water's flow rate decreases, prompting the deposition of larger particles within the reservoir's usable volume.

In depth field studies have been conducted to assess the level of turbidity in the Chartak reservoir, focusing on the relationship between the turbidity and both the fractional (mechanical) composition of the sediments and the water throughput. The riverbed's water consumption plays a crucial role in the reservoir's silting. To this end, a longitudinal analysis of water consumption data entering the reservoir has been performed (Fig. 3).

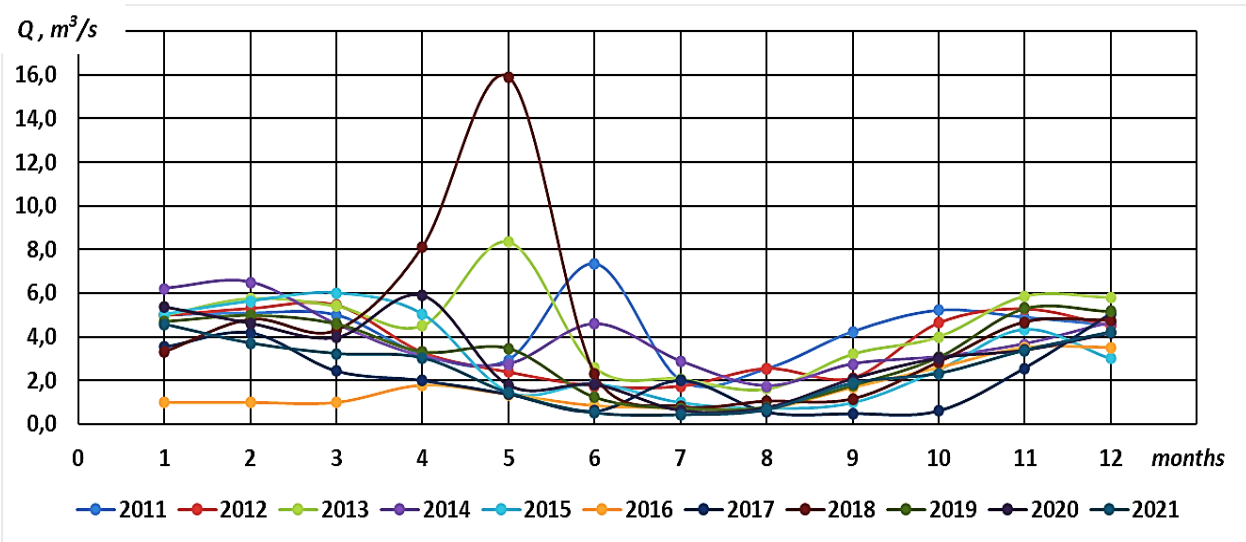

Fig. 3. Changes in Chortoksoy water consumption over the years

In the same study, the distribution of turbidity in the water reservoir was analyzed by streams (Fig. 4).

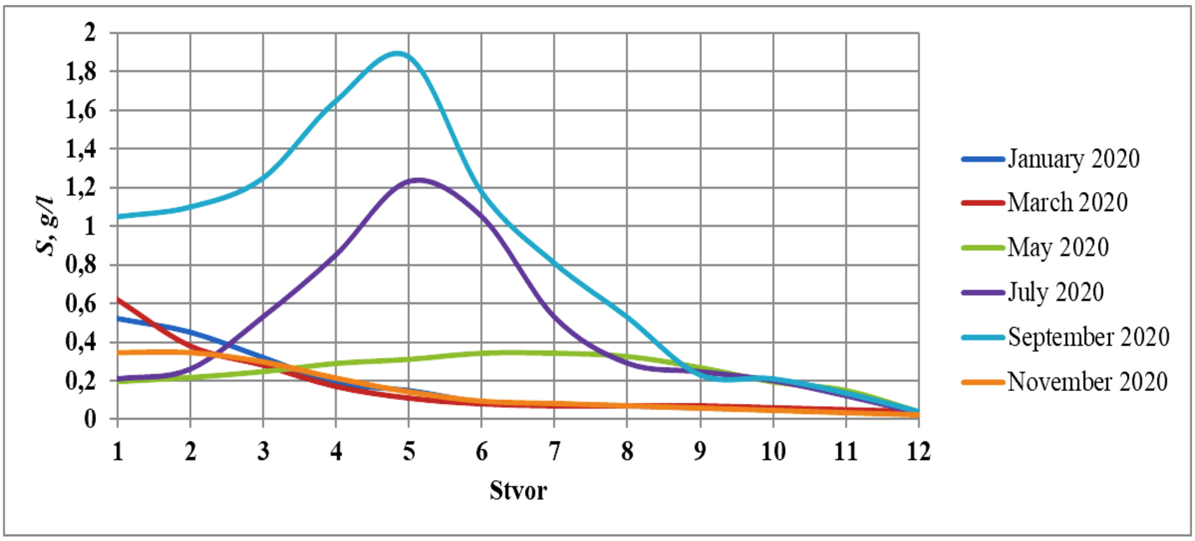

Fig. 4. Distribution of the amount of turbidity by walls

The data obtained from natural field studies were subsequently analyzed under laboratory conditions to ascertain the fractional composition of sediments along the walls of the Chortok reservoir (Fig. 5).

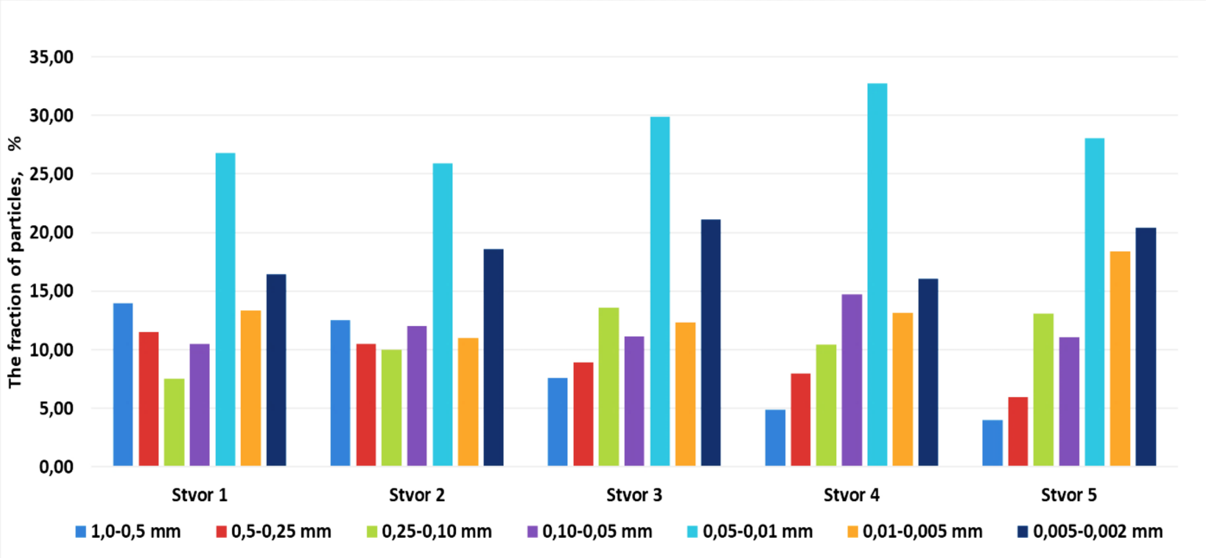

Fig. 5. The fractional composition of sediments

Field studies conducted on the Chartak reservoir refined the measurements of its useful volume. The survey utilized state-of-the-art equipment, including a SonTek-River Surveyor S5 doppler, a Leica electronic laser tachometer, and N-3 level geodetic tools. Originally designed with a capacity of 30 million cubic meters, the current operational volume of the Chartak reservoir was determined to be 20.72 million cubic meters. Through a comparison of the original design parameters with the empirical data, accompanied by statistical analysis and theoretical calculations, it was established that the reservoir contains approximately 9.28 million cubic meters of turbid sediments.

Theoretical and experimental research concluded that constructing a clarifier within the reservoir basin is a practical solution to diminish turbidity. To mitigate silt accumulation in the reservoir, the installation of a trapezoidal strainer at the reservoir's inlet was advised, and its design parameters were determined (Figure 3.4). Considering the granular makeup of both bottom and suspended particles in the water stream entering the reservoir, a trapezoidal filter design was suggested (Fig. 6).

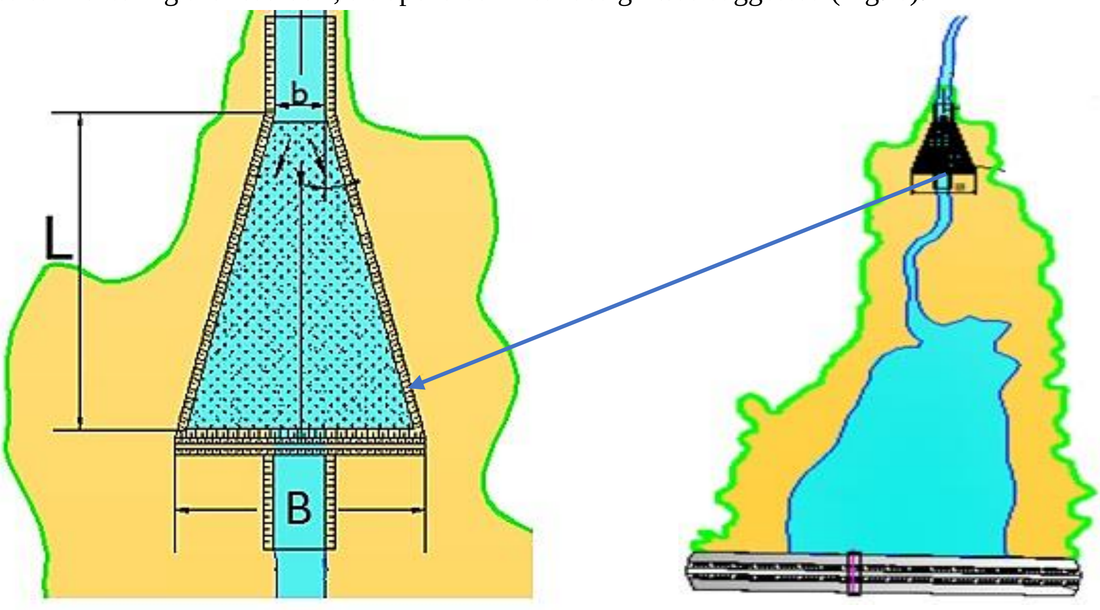

Fig. 6. Recommended water softener location

In order to optimize the economic efficiency of designing and constructing the clarifier, the annual average volume of turbid sediments entering the reservoir was calculated. It was found that approximately 170-180 thousand cubic meters of muddy sediments are carried into the reservoir annually through natural flow, which informed the proposed design parameters of the clarifier. The justification for these parameters was supported by using river discharge balance equations [6,12]. Specifically, the balance equation for discharge fractions can be formulated for a given length, L, of the reservoir*:*

$$dV_i = \frac{Q_i}{\gamma}\ dt = \frac{\rho\ w_i}{\gamma\ \omega_l}\frac{b_l}{}\left(V_l - V_{li}\right)dt \quad ; \qquad (1)$$

where: $V_i - L$- distance blur volume; $\omega_l - L$- the flow surface at a distance; $b_l - L$- the width of the stream at a distance; w_i –hydraulic largeness; $V_l - L$- the volume of the reservoir at a distance;

Inserting the following expression into the equation:

$$\frac{\rho\ w_i}{\gamma\ \omega_l}\frac{b_l}{} = \frac{1}{K} \quad ; \qquad (2)$$

After certain mathematical transformations, we get the following expression to determine the amount of blur at *L- distance:*

$$V_i = V_l\left(1 - e^{-\frac{t}{K}}\right); \qquad (3)$$

where: *K is* the turbidity characteristic, determined on the basis of field studies.

Using the given equation, we determine the length of the spacer as follows :

$$\frac{V_i}{V_l} = 1 - e^{-\frac{l}{\vartheta\ K}} \quad ; \qquad (4)$$

$$e^{-\frac{l}{\vartheta\ K}} = 1 - \frac{V_i}{V_l} \quad ; \qquad (5)$$

$$L\ = -w_i\ K \cdot \ln\left(1 - \frac{V_i}{V_l}\right) ; \qquad (6)$$

In this case, the depth of the spacer at the distance *"L"* is determined as follows:

$$h_l = \frac{w_i\left(V_l - V_i\right)}{Q} \quad ; \qquad (7)$$

where: Q is the average annual water consumption:

The design parameters of the cooler are determined by jointly solving equations (6) and (7) [13,21].

CONCLUSIONS

Water usage in Uzbekistan critically influences water supply maintenance. Various aspects were analyzed for the Chartak reservoir, including hydraulic and hydrological parameters, water consumption, long-term solid flow of the intake source, flow velocity, average flow depth, hydraulic dimensions, and the granular composition of turbid particles. Based on the hydraulic model previously mentioned and considering these parameters and the composition of the turbid sediments, the design parameters for an economically efficient clarifier were recommended to mitigate the reservoir's silting.

The design of the proposed clarifier is such that it will not negatively impact the management of upstream turbidity, sediment distribution, or the operational regimes of the reservoir. Instead, it will help reduce turbidity within the reservoirs. The operation involves turbid water entering the clarifier located in the upper basin, where the flow velocity significantly reduces, leading to the settlement of larger sediment particles. Smaller, suspended particles continue towards the end of the clarifier, settling gradually. Near the water outlet or tunnel, the smallest suspended particles settle and during the irrigation season, this sediment can be utilized on agricultural fields.

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Water management

A STUDY ON RAINWATER HARVESTING FOR ROOFTOP IN JORDAN

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Annotation. The great challenge for the coming decades will be the task of scarcity of water. The dependency on water for future development has become a critical constraint for development this paper presents the best way of utilizing the stored water.

Jordan is facing severe climate change risks and business as usual will no longer suffice in addressing the challenges the country faces to its development and growth. Jordan is one of the most water scarce countries in the world and climate change is further exacerbating aridity due to increasing temperatures and reduced more erratic rainfall patterns coupled with an unprecedented population increase. In addition, climate change induced hazards such as droughts, extreme temperatures and flash floods Such combination is having one of the most important roles in the variation on availability of water resources,

On the basis of these determinants the future of rainwater harvesting schemes will be assessed. Proposed Intervention four Governorates in the Dead Sea Basin have been selected for project interventions as these represent the areas that are considered as the most vulnerable Rainwater harvesting is considered as a best alternative to bridge the gap between the demand and supply.

Keywords: rain water harvesting, jordan south zone, rainfall, water demand, precipitation, every drop counts.

INTRODUCTION

Rainwater harvesting is a technology used to collect, convey and store rain for late use from relatively clean surface such as a roof, land surface or rock catchment. The water is generally stored in a rainwater tank or directed to recharge groundwater. Rainwater infiltration is another aspect of rainwater harvesting playing an important role in storm water management and in over 4000 years throughout the world, traditionally in arid and semi-arid areas, and has provided drinking water, domestic water and water for livestock and small irrigation. Today, rainwater harvesting has gained much on significance as a modern, water-saving and simple technology. The practice of collecting rainwater from rainfall events can be classified into two categories: surface runoff and rooftop rainwater harvesting. Surface runoff rainwater harvesting occurs when runoff from land surfaces is collected in furrow dikes, pond, tanks and reservoir. Rooftop rainwater harvesting refers to collecting rainwater runoff from roof surfaces which usually provides a much cleaner sources of water that can be also used for drinking.

Rainwater harvesting systems will also be installed in selected public buildings such as schools, mosques, municipalities for wider dissemination and awareness of the technology at the local community level and to also help address water scarcity in public buildings.

APLICATION AREA

The project will be implemented in 4 governorates of the Dead Sea Basin, which includes the areas that are most vulnerable to climate change. The main sub-basin is the Mujib basin that encompasses two main catchments - the Wadi Mujib and the Wadi Wala - and comprises an area of 6,727 km^2 of mainly plateau land to the east of the Dead Sea. The altitude level of the plateau ranges between approximately

700m and 1000m above sea level and drops to nearly 400m below sea level when entering the Dead Sea. The climate varies between Mediterranean in the western and northern areas to arid and semi-arid in the rest of the region and follows the same patterns as the national climate. Average rainfall can vary significantly and ranges from 300 mm in the eastern part of the basin to below 50 mm in the western part (Figure 1).

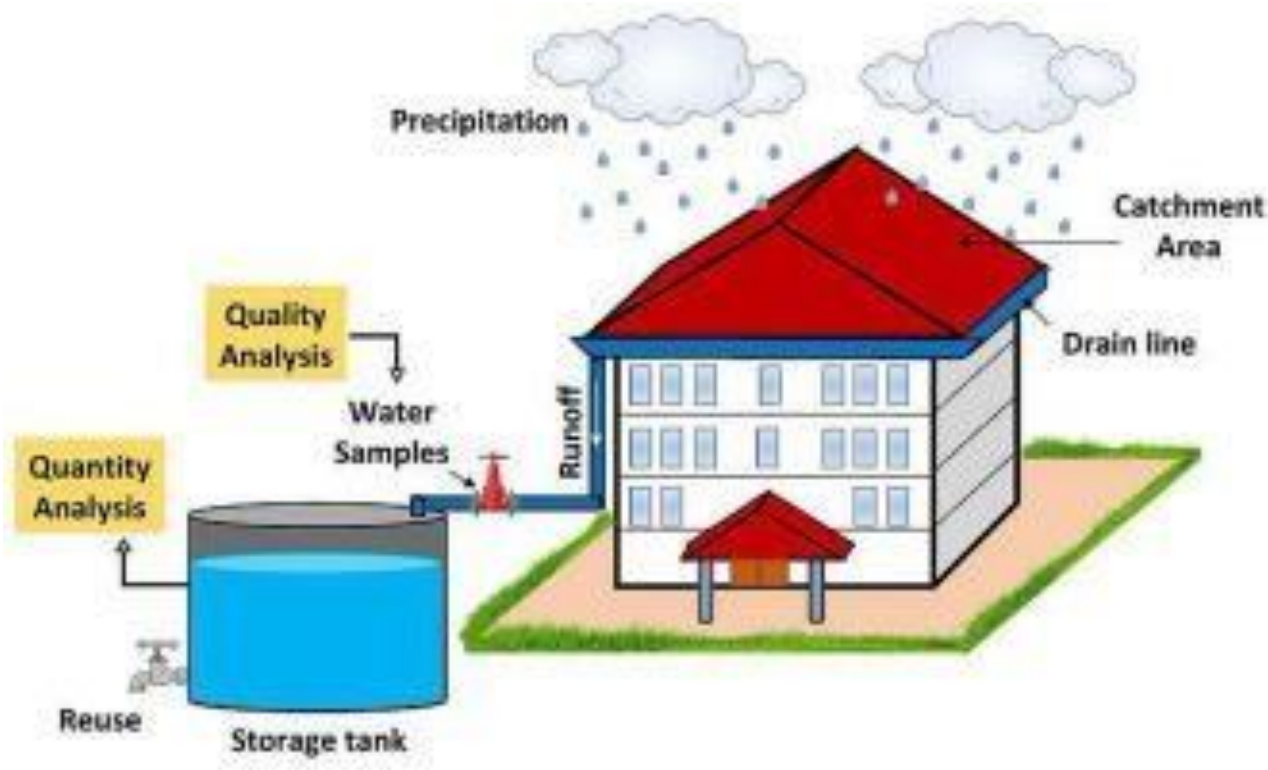

Fig. 1

Tafilah and The selected governorates are Madaba, Karak, Tafilah and Ma'an (Figure 2). These governorates cover an area of 9,839 km^2, or 72 percent of the area of the Dead Sea Basin. followed by Madaba, Ma'an and Tafilah, respectively.

Madaba, Karak, Maan have been selected according to the following criteria:

(I) areas included in the Dead Sea basin

(II) climate change exposure

(III) presence of large13 rural communities

(IV) vulnerability of communities and livelihood

(V) persistent water scarcity.

Rainwater harvesting system can be installed in both new and existing building and harvested rainwater used for different applications that do not require drinking water quality such as toilet flushing, garden watering, irrigation, cleaning and laundry washing. Harvested rainwater is also in many parts of the world as a drinking water source. As rainwater is very soft there is also less consumption of water and cleaning powder. With rainwater harvesting, the savings in potable water could amount up 30% of the total household consumption.

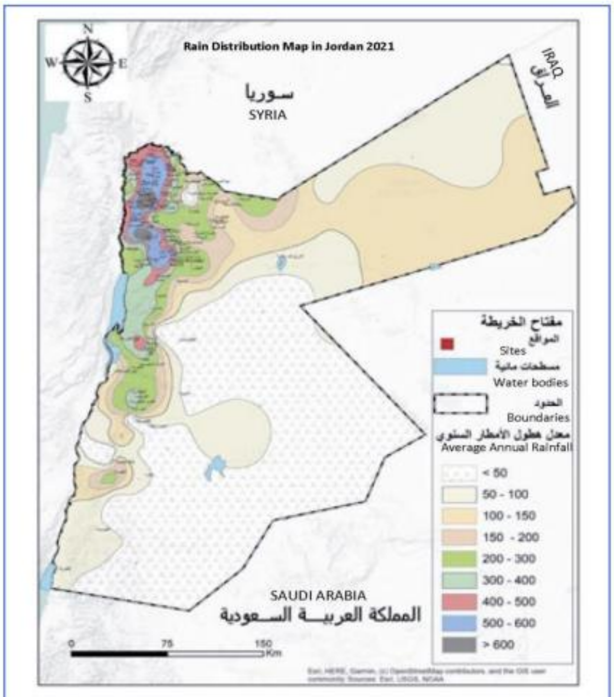

Figure 1- Rain distribution map in Jordan 2021 (Guidelines for harvesting rainwater in households and buildings. July 2022)

Figure 2. Project Area

OBJECTIVE

a. To meet the increasing demand of water.
b. To control wastage of rain water.
c. To avoid the flooding of roads.
d. To make the unit independent for water consumption.

BENEFITS OF RAINWATER HARVESTING

A - Advantages

Rainwater harvesting provides the independent water supply during regional water restrictions, and in developed countries, it is often used to supplement the main supply. It provides water when a drought occurs, can help mitigate flooding of low-lying areas, and reduces demand on wells which may enable groundwater levels to be sustained. Rainwater harvesting increases the availability of water during dry seasons by increasing the levels of dried borewells and wells. Surface water supply is readily available for various purposes thus reducing dependence on underground water. It improves the quality of ground by diluting salinity. It does not cause pollution and is environmentally friendly. It is cost-effective and easily affordable. It also helps in the availability of potable water, as rainwater is substantially free of salinity and other salts. Applications of rainwater harvesting in urban water system provides a substantial benefit for both water supply and wastewater subsystems by reducing the need for clean water in water distribution systems, less generated stormwater in sewer systems,[25] and a reduction in stormwater runoff polluting freshwater bodies.

A - large body of work has focused on the development of life cycle assessment and its costing methodologies to assess the level of environmental impacts and money that can be saved by implementing rainwater harvesting systems;

B - Independent water supply.

Rainwater harvesting provides an independent water supply during water restrictions. In areas where clean water is costly, or difficult to come by, rainwater harvesting is a critical source of clean water. In developed countries, rainwater is often harvested to be used as a supplemental source of water rather than the main source, but the harvesting of rainwater can also decrease a household's water costs or overall usage levels. Rainwater is safe to drink if the consumers do additional treatments before drinking. Boiling water helps to kill germs. Adding another supplement to the system such as a first flush diverter is also a common procedure to avoid contaminants of the water.

C-Supplemental in drought;

When drought occurs, rainwater harvested in past months can be used. If rain is scarce but also unpredictable, the use of a rainwater harvesting system can be critical to capturing the rain when it does fall. Many countries with arid environments, use rainwater harvesting as a cheap and reliable source of clean water. To enhance irrigation in arid environments, ridges of soil are constructed to trap and prevent rainwater from running downhills. Even in periods of low rainfall, enough water is collected for crops to grow. Water can be collected from roofs and tanks can be constructed to hold large quantities of rainwater.

In addition, rainwater harvesting decreases the demand for water from wells, enabling groundwater levels to be further sustained rather than depleted.

COMPONENT OF ROOFTOP SYSTEM

A. Catchment

The surface that receives directly is the catchment of rainwater harvesting system. It may be terrace, courtyard, or paved or unpaved open ground. The terrace may be flat RCC/stone roof or sloping roof. Therefore, the catchment is the area, which actually contributes rainwater to the harvesting system.

B. Conveyance

Conveyance system are required to transfer the rainwater collected on the rooftops to the storage tanks. This is usually accomplished by making connections to one or more down pipes connected to the rooftop gutters. When selecting a conveyance system, considerations should be given to the fact that, when it first starts to rain, dirt and debris from the rooftop and gutters will be washed into the down pipes.

C. Flush Separator

It's widely understood that the water collected from rooftop runoff sever a variety of potable and non-potable purpose. Yet it's important to remember roofs are not clean, and harvested water may accumulate because of this, it's recommended that rainwater be filtered before it moves into the storage tank.

D. Filtration

The filter is used to remove suspended pollutants from rainwater collected over roofs. A filter unit is a chamber filled with filtering media such as fiber coarse, sand and gravel layers to remove debris or recharge structure.

E. Storage

There are various options available for the construction of these tanks with respect to shape, size and the material of construction.

SHAPE:

Cylindrical, Rectangular, square.

USAGE

Rooftop rainwater harvested is a technique used for the conversion of water. In this technique, the rainwater that has fallen on the roof of houses or buildings is collected in storage or underground tanks through the helps of pipes. This also helps us recharge the groundwater levels.

GENERAL REQUIREMENTS FOR THE DESIGN AND INSTALLATION OF RAINWATER HARVESTING TANKS

Below are some of the general requirements for the design and installation of rainwater harvesting tanks:

1. All catchment areas, vertical spouts, gutters, fittings, valves, screens and tanks must be installed to be in compliance with the Jordan Uniform Plumbing Code.
2. In cases where a cistern is used, a maintenance vent should be provided with a minimum clearance of 100 mm above ground, or to be constructed in a manner that prevents flow of rainwater from the surrounding into the water tank.
3. The rainwater tank must be constructed in a way that enables emptying the tank for cleaning purposes.
4. An over flow pipe must be provided and must be designed to be consistent with the size of the vertical spout (inlet pipe). The over flow water must be discharged properly to be in compliance with local regulations.
5. Catchment surface or the rooftop should be an impervious roof made from smooth, clean non-toxic material.
6. Roof surface should always be kept clean and free from debris.
7. Rainwater collection tanks should be designed to protect the harvested water from any potential pollutants such as leaves, dust, insects and other pollutants.
8. Incoming water to the storage tank /cistern should be filtered or screened and allowed to settle prior to its use.
9. Taps or draw-off pipes shall be elevated above the tank /floor according to Jordan uniform plumbing code.
10. Collected rainwater inside tanks should not be exposed to direct sunlight to prevent algae growth.

METHODOLOGY

The Component provides technical assistance and water solutions to alleviate the impact of water scarcity in the Dead Sea Basin on the farming community through tapping for water resource substitutes and boosting water access for both household consumption level and drought-tolerant homestead crops without compromising the groundwater resources in the Dead Sea Basin.

Increasing sustainability in the water sector is aligned with the Jordanian Government`s Green Growth National Action Plan. Accordingly, rainwater harvesting is an important technological option to improve water supply. Rainwater harvesting from rooftops, roads, and parking lots can increase the overall water supply, creating resilience to local supply problems, and decreasing the liability on Jordan main water supply. New irrigation technologies are foreseen as water resilient solutions, such as rooftops rainwater harvesting (RWH) systems.

A public building is, among other forms, a municipal building, an institutional building (for example, hospital, nursing home, orphanage...), an educational building (for example, school, college, university, day care...), or a gathering building (where people gather for social, religious, recreational purposes).

Rainwater Harvesting technologies are a cost effective and technically easy method of conserving water and thereby providing additional water supplies to bridge dry spells. RWH is popular option at the household level as the water source is close to people, meaning it is convenient. Additionally, it requires a little to no energy to collect it (though pumping water from the collection tank will likely require electricity).

Rooftop water harvesting technology is standardized for Jordan by the Uniform Plumbing Code of Jordan approved by the Jordan National Building Council's technical committee in 2015. The Unified Plumbing Code establishes the type of rainwater harvesting tanks and technical specifications. The project will adhere to all official standards, guidelines and regulatory frameworks on rainwater harvesting structures. Where national standards are not available, international guidelines will be used.

How Much Rain Can Be Collected?

There are three major factors that influence the volume of water you are able to harvest:

- The size of the catchment area or roof. For roofs, this is calculated by finding the area of the building and adding the area of the roof's overhang.
- The size of the rainwater tank will determine the volume of water you're able to store.
- The annual rainfall and its distribution over the year.

If you'd like to work out an estimate of how much water you'd be able to capture and store, the following formula can be used to get an estimate:

Harvested water (liters) = catchment area (m^2) x rainfall depth (mm)

You can also find a helpful article about drainage and how to keep your home safe from moisture damage, whilst harvesting the most efficient amount of rainwater.

There are also economic requirements. The potential RWH amount is estimated using the following equation (Traboulsi, 2017):

(RWH) (**M**^{3}) = R (**MM/YEAR**) * A (**M**) * K

R: The average rainfall in the area.

A: The total catchment area.

K: The runoff coefficient.

The catchment areas for the micro or macro scale projects vary. These may be rooftops for houses or public buildings, green houses, courtyards, roads, parking areas, playgrounds, etc. The high runoff coefficient varies from 50-90% (70-80% for rooftops due to leakage and evaporation).

Results

From the experiment work carried out following results are listed below:

a. Rainwater harvesting is an important technological option to improve water supply.

b. The water which will be collected by the rain water harvesting system is of drinking quality.

c. So, we are successfully achieving the goal of the project.

Now a days water cost is rising as the population increase at rate so rainwater harvesting is beneficial to saveto money.

CONCLUSIONS AND RECOMMENDATION

a. In conclusion, rainwater harvesting for rooftop is a promising solution to water and can provide numerous benefits to household communities. It can significantly reduce water bills, help conserve water resources, and reduce the demand on municipal water supply;

b. The rooftop water harvesting system every year huge amount of water will be saved and huge expenditureon percentage of water will be reduced;

c. The huge amount of precipitation occurring on the ground can be harvested and utilized for different purpose, if proper collection system is provided. As so many parts of the world facing the problems of water crises, one must understand the importance of water, and should made optimum use of water and adopt efficient methods of collecting and saving rainwater.

d. Rainwater Harvesting technologies are a cost effective and technically easy method of conserving water and thereby providing additional water supplies to bridge dry spells. RWH is popular option at the household level as the water source is close to people, meaning it is convenient. Additionally, it requires a little to no energy to collect it (though pumping water from the collection tank will likely require electricity). An added advantage is that users own, maintain, and control their system without the need to rely on other members of the community or other stakeholders.

e. At the community level, rainwater harvesting reduces the volume of surface water discharged to drainage and may contribute to reducing flood risk and the load on combined sewer overflows (thus improving ambient water quality). Multiple studies show that installation of rooftop rainwater harvesting systems, especially in urbanized areas, can be an efficient contributor to reduced flood risk (Freni and Liuzzo, 2019).

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Earth sciences

RESEARCH ON SUSTAINABLE ECOLOGICAL AGRICULTURE MODEL OF THREE GORGES RESERVOIR AREA

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Annotation. Drawing on empirical insights from the land consolidation project in Yiling District of the Three Gorges Reservoir Area and following a comprehensive analysis of the region's ecological and socio-economic dynamics, this study proposes an approach to establish a sustainable ecological agriculture model in the Three Gorges Reservoir Area through three key steps: slope terracing, soil transfer and fertilization, and optimized agricultural planting patterns. This ecological agriculture model holds both theoretical and practical significance for fostering sustainable development in the agriculture sector of the Three Gorges Reservoir Area.

Keywords: slope terracing; soil transfer and fertilization; planting patterns; Three Gorges Reservoir Area

1. INTRODUCTION

The concept of "ecological agriculture" was originally proposed by the American soil scientist W. Albrech. In China, the term "ecological agriculture" was introduced by Professor Ma Shijun in the 1980s. It is an abbreviation of ecological engineering, specifically referring to an agricultural production system that integrates social, economic, and ecological benefits according to ecological principles and economic laws. Ecological agriculture simulates the principles of natural ecosystems and is based on bionics. Its fundamental principles are summarized by Professor Ma Shijun as "integrity, coordination, circulation, and regeneration." Thus, ecological agriculture represents the direction, while agricultural ecological engineering is the specific model and technical system.

Due to factors such as rising water levels and a large influx of immigrants, the agricultural ecological environment in the Three Gorges Reservoir Area has been damaged to varying degrees. Currently, the ecological agriculture system in this area faces several prominent issues: severe soil erosion, worsening climate conditions, significant geological disasters, destruction of forests and vegetation, rural poverty, human-land conflicts, overloading of the ecological environment capacity due to rural immigrants, and structural issues in traditional agriculture. These eight major issues pose significant safety hazards to the living and production conditions of the people in the reservoir area.

On April 22, 2006, Premier Wen Jiabao proposed the Soil Transfer and Fertilization Initiative during his inspection tour in Chongqing. To fundamentally address the coordinated and steady development of the ecological environment and agriculture in the reservoir area, it is necessary to build a modern Three Gorges from the perspective of sustainable agricultural ecology. The development of sustainable ecological agriculture will provide strong support for farmers to overcome poverty and achieve prosperity; facilitate the resettlement of rural immigrants; restore and protect the ecological environment; and ultimately achieve a virtuous cycle of sustainable agricultural development and ecological conservation in the Three Gorges Reservoir Area.

This paper explores ideas for establishing a sustainable agricultural ecological model by analyzing and addressing issues from various perspectives, including planning agricultural production conditions, improving soil fertility, and rationally arranging planting patterns.

2. RESEARCH ON AGRICULTURAL ECOLOGICAL MODELS

Due to the construction of the Three Gorges Hydropower Station, the water level has risen, resulting in the massive migration of residents. This has seriously affected the natural and socio-economic conditions of the Three Gorges Reservoir Area, particularly its agricultural ecology. What was once a naturally formed landscape that could not be easily excavated has now become a residential area.

After conducting an in-depth analysis of the current environment in the Three Gorges Reservoir Area and recognizing the need to develop sustainable agricultural ecology, it is proposed to establish a new sustainable ecological agricultural model through three steps: slope terracing, soil transfer and fertilization, and optimized agricultural planting patterns.

In light of China's gradual reduction of cultivated land resources, Soil Transfer and Fertilization is seen as an effective way to protect valuable land resources. The implementation of this project not only serves as a good demonstration for Soil Transfer and Fertilization but also provides first-hand data and valuable experience on preventing soil and water loss from sloping farmland during and after project implementation.

Through comprehensive analysis of a typical case study—namely the Soil Transfer and Fertilization project planning in the Three Gorges Reservoir Area—a comparison of different schemes is conducted based on regional characteristics. This will provide new ideas for exploring ways to improve production capacity while preventing soil erosion on construction-occupied land.

2.1 Converting Slopes into Terraces

Converting slopes into terraces is a typical and effective measure for improving sloping farmland, particularly suitable for areas with severe soil erosion and poor basic production conditions. This method can quickly and effectively reduce the slope gradient and length of the sloping farmland, creating a gentle and suitable surface for agricultural production. The conversion process is often accompanied by the construction of slope water systems with functions such as intercepting, draining, irrigating, and storing water. These systems facilitate agricultural production, improve production conditions, and enhance the sustainability of agricultural development. The target for converting slopes into terraces is existing farmland with a slope gradient between 10 and 25 degrees. Any long-term cultivated slopes with a gradient below 25 degrees, deep soil layers, moderate or above fertility, and irrigation capability should be converted into terraces to construct basic farmland.

2.1.1. Horizontal Terrace Design

The primary focus of designing horizontal terraces is to analyze and determine the appropriate layout of terraces under various conditions. The width of the field surface, the height of the ridge, and the slope of the field are three key elements in determining the terrace layout. It is essential to configure these elements appropriately to ensure safety and stability, facilitate cultivation and irrigation, minimize labor requirements, and optimize land usage.

Field width: The optimal width of a terrace should be determined based on a comprehensive assessment of factors such as terrain, slope, soil depth, crop types, and level of mechanization. It is important to avoid excessively narrow or wide fields, typically ranging from 60 to 120 meters.

Ridge height: The height of a ridge is influenced by both field width and the original ground slope. A wider field surface generally requires a higher ridge, while a narrower field calls for a lower one. Typically, ridge heights range from 0.5 to 2 meters.

Slope: A gentler slope enhances safety and stability but increases land occupation and labor requirements. Conversely, steeper slopes reduce land occupation and labor demands but compromise safety and stability. Therefore, it is crucial to determine an optimal slope that ensures stable terracing while minimizing land use—usually around 75 degrees.

Overall, the design considerations for horizontal terraces involve balancing multiple factors to achieve an optimal configuration that meets safety standards, facilitates efficient cultivation practices, and maximizes land utilization efficiency.

2.1.2. Design of Supporting Water Storage Facilities for Terraces

The water storage tank is designed in a square shape with a typical capacity of 30 cubic meters. It is constructed using rubble stone, and the lining ditch is jointed with M10 cement mortar and coated with waterproof mortar.

2.1.3. Design of Slope Water System Engineering

The primary function of drainage and irrigation channels is to intercept slope runoff, divert water for irrigation, prevent erosion, and reduce sediment accumulation in ponds. These channels are typically laid in fruit orchards. It is important to plan drainage and irrigation ditches on slopes simultaneously with farming roads, cisterns, and sand sinks. By integrating ditches and roads as the framework, interception ditches, drainage ditches, diversion canals, irrigation canals, sand sinks, and water reservoirs should be reasonably arranged to form a complete defense and utilization system.

Ditches, terraces, farming roads, reservoirs, sand sinks, and other projects should be planned simultaneously with a reasonable layout to form a complete defense and utilization system. For slope soil and water conservation projects with a large amount of water coming from the upper part of the slope, horizontal flood drainage trenches should be arranged in the inflow area close to the soil and water conservation agency. Additionally, storage tanks can be constructed at relatively gentle places by layers to facilitate flood storage, drainage, and irrigation.

2.1.4. Design of Field Production Roads

To facilitate the field operations of farmers and the management and maintenance of soil and water conservation projects, it is necessary to construct field roads within the terraced area. These roads can be categorized into pedestrian paths and tractor roads based on their specifications. The design width of the field road is 2.5 meters, arranged in a zigzag pattern and connected to major roads. The road surface is paved with 15-centimeter-thick mud-bound gravel.

In contrast, the production road is a stepped cement road with a width of 1.0 meter, positioned perpendicular to the terrace ridge. This layout facilitates soil transportation for the Soil Transfer and Fertilization project as well as tea harvesting by farmers.

2.2. Move soil for fertilizer cultivation

There are 686,300 hectares of cultivated land in the Three Gorges Reservoir area, with 480,000 hectares classified as medium and low-yield fields. Once the water level of the Three Gorges Dam reaches 175 meters, a significant portion of this cultivated land will be submerged. Most of these fields consist of alluvial soil situated on valley terraces, featuring flat terrain, fertile soil, favorable production conditions, and high yields. The timely preservation of these land resources before inundation will make a substantial contribution to agriculture in the reservoir area.

In the early stages of the Three Gorges Project, farmers in the reservoir area practiced agricultural production and water storage. They implemented a "slope change" technique to transform barren slopes into arable soil. However, the soil quality was poor, prompting a beneficial relocation effort to improve the tilled layer. The Soil Transfer and Fertilization Project involved stripping and transferring fertile soil from high-quality farmland and gardens in the soon-to-be-submerged areas of the Three Gorges Reservoir to barren farmland and gardens located above 182 meters in altitude and within 5 kilometers of the reservoir bank. Additionally, land consolidation and related engineering projects were implemented to rescue and rationally utilize the fertile soil layer. This was done to improve the quality and comprehensive production capacity of barren farmland and gardens above the flooding line, as well as to enhance the ecological environment of the reservoir area.

In the implementation of the Soil Transfer and Fertilization Project, the immigrants in the reservoir area, especially the farmers, are not only the subjects of implementation but also the direct beneficiaries. Research indicates that by removing 10 centimeters of barren cultivated land and implementing slope modification and irrigation and water conservancy facilities, the soil layer can be increased, leading to a 30% increase in production on existing cultivated land. Furthermore, if the mature soil layer thickens to 25 centimeters, production can increase by 40%. The Soil Transfer and Fertilization Project not only holds practical significance but will also play an immeasurable role in the future sustainable development of agriculture in the reservoir area.

2.3. Discussion on agricultural planting mode

The structural problems in traditional agricultural planting are highly evident and contradictory. The current "grain-based" agricultural production structure and the "grain-pig" agricultural economic structure are unable to meet the demands of agricultural development in the Three Gorges region. This incompatibility primarily stems from resource-based constraints within agriculture. Firstly, farmers have limited opportunities to enhance agricultural efficiency through increasing yield per unit area due to fragmented land management. Secondly, locally distinctive economic crops such as tea, oranges, and chestnuts have not been fully utilized or given sufficient attention. Thirdly, with the rapid increase in rural labor force density in resettlement areas, there is no means to improve agricultural labor productivity without transferring labor out of agriculture. Fourthly, frequent natural disasters and a severe lack of basic agricultural facilities have resulted in significant fluctuations in food production and sluggish income growth. Fifthly, traditional agriculture's emphasis on self-sufficiency sharply conflicts with necessary structural adjustments within agriculture. The large-scale return of farmland to forests is at odds with stable income and income growth for farmers, leading to prominent conflicts between food crops, economic crops, and forestry.

In response to these issues, considering the specific geographical location and environmental characteristics of the Three Gorges Reservoir area, the following planting patterns should be implemented:

1. Aquatic plants will be introduced in the lakeshore areas with an elevation below 175 meters.

2. A protective forest belt will be planted along the Yangtze River in areas with an elevation ranging from 175 to 200 meters. Tree species with well-developed and fast-growing roots, such as dawn redwood, will be carefully selected to utilize their root systems for stabilizing the soil and reducing surface runoff. This approach aims to prevent soil erosion and large-scale bank collapses at the landslide front.

3. The primary areas for fertilization are those situated at an elevation of 200 to 500 meters. In these regions, soils of superior quality and higher fertility are chosen for the cultivation of crops such as corn, interspersed with economic crops like sesame. However, due to the relatively poor fertility of the original sliding soil or the thin soil layer of the imported fill soil, water conditions are relatively poor. As a result, potatoes and other tuber crops are preferred choices for planting in these areas.

4. In regions with an elevation ranging from 500 to 700 meters, tea cultivation is influenced by its growth environment as an evergreen shrub with strong adaptability. Altitude plays a crucial role in determining the quality of tea. High-mountain tea surpasses that grown on flat land due to the presence of cloud and mist cover, ample humidity, low air pressure, and prolonged sunshine. These factors contribute to tender tea buds and increased aromatic substances, resulting in a smooth taste without bitterness. Furthermore, the abundant ultraviolet light significantly impacts the color and germination of the tea.

5. In areas with an elevation ranging from 700 to 800 meters, artificial coniferous forests will be planted to conserve water sources and prevent soil erosion. These forests also serve to isolate rockfall areas from the lower terraced fields, ensuring the safety of crops, tea gardens, and orange orchards. In steep slope areas without vegetation coverage in the terraced fields, it is recommended that economically valuable fruit trees with well-developed roots, such as chestnut trees, be sparingly planted to provide direct protection for the terraces.

After implementing agricultural ecological design, a "protective-productive" soil ecosystem has been established. The terraced fields serve as the central production area, while the surrounding forest belts and fruit orchards act as protective belts.

3. CONCLUSIONS

In conclusion, the engineering and technical measures mentioned above will significantly enhance and sustainably develop the agricultural ecological environment in the Three Gorges Reservoir Area. Specifically, this is evidenced by a substantial increase in vegetation coverage, which contributes to water resource conservation, soil erosion prevention, and the reduction of natural disasters such as landslides and mudslides. Additionally, it mitigates eutrophication pollution of the Yangtze River caused by excessive organic matter from original farmland due to rising water levels, facilitating positive evolution of the ecological environment. Moreover, it expands the effective agricultural land area and improves yield per unit, particularly benefiting special economic crops in terms of yield and quality. This brings about various economic benefits for people and promotes efficient agriculture. The implementation of Soil Transfer and Fertilization plays a crucial role in safeguarding national land resources and enforcing land management regulations.

This sustainable agricultural ecological model plays a significant role in the construction and protection of the ecological environment in the Three Gorges region. It not only brings economically sustainable and steadily increasing benefits to people but also provides valuable references for land consolidation, ecological construction, and new rural development throughout the entire Three Gorges region.

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Water management

STUDY OF AZERBAIJAN'S WATER RESOURCES: ANALYSIS OF CLIMATE CHANGE FOR AVAILABILITY AND SUSTAINABILITY

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Annotation. This article examines the impact of climate change on Azerbaijan's water resources, focusing on their availability and sustainability. The Republic of Azerbaijan, known for its complex hydrological profile, is highly dependent on its surface and groundwater resources. These resources are crucial for agriculture, which dominates the rural economy and relies heavily on irrigation. The study explores several key areas: the overview of water resources, trans-boundary water management challenges due to shared resources with neighboring countries, and the implications of climate change on water quality and supply. It discusses governmental initiatives, international cooperation, and the incorporation of technological innovations and policy reforms to enhance water management. The article also highlights the need for modernizing the water sector and engaging stakeholders to improve resilience to climate-related challenges and ensure sustainable water use for future generations.

Keywords: Azerbaijan, water resources, climate change, sustainable water management, irrigation, trans-boundary water conflicts.

1. INTRODUCTION

The Republic of Azerbaijan, a country with a complex hydrological profile, relies heavily on both surface and ground water resources. The management and distribution of these resources are influenced by geographical, political, and environmental factors.

Water Resources Overview

Azerbaijan's water resources are primarily composed of river waters, groundwater, and a small percentage from freshwater lakes. The country's total renewable water resources are estimated to be around 30.5 km^3 per year. Of this, surface water makes up about 28.5 to 30.5 km^3, with rivers contributing the majority. Groundwater resources, which include annual recharge and baseflow from rivers, add approximately 6.51 km^3[1].

Trans-boundary Water Management

A significant challenge for Azerbaijan is the management of trans-boundary waters. The country shares several rivers with neighboring states, such as Georgia, Iran, and Russia. Notably, the Kur and Araz rivers are crucial for the region's water supply but are managed through bilateral agreements rather than comprehensive intergovernmental treaties. This arrangement necessitates frequent negotiations to address usage and conservation issues[2].

[1] Mammadzadeh, I. (n.d.). Water Resources Management in the Republic of Azerbaijan: Overview and Outlook. Country Report. Global Water Partnership. Retrieved from https://www.gwp.org/globalassets/global/gwp-cacena_files/en/pdf/azerbaijan.pdf

[2] Axundov, A., Van der Ruyt, M., & Sultanov, E. (2012, February). Management of Water Resources in Azerbaijan. Baku: State Agency for Water Resources, Ministry of Emergency Situations of the Republic of Azerbaijan, DELTARES. Retrieved from https://www.gwp.org/globalassets/global/gwp-cacena_files/en/pdf/azerbaijan.pdf

Irrigation and Agriculture

Azerbaijan is historically an agricultural land, with approximately 1.88 million hectares of arable land, of which around 1.45 million hectares are irrigated. The irrigation system supports the agriculture that dominates the rural economy, with agricultural crops covering about 77% of the irrigated land. However, political conflicts have led to the occupation of some agricultural lands, notably affecting the water storage capacity and maintenance of infrastructures like the Sarsang reservoir.

Water Quality and Environmental Concerns

Water quality in Azerbaijan faces threats from industrial pollution, inadequate waste management, and the impacts of climate change. Efforts are underway to enhance the ecological monitoring of water bodies and to implement ameliorative measures to prevent degradation of water quality and ensure sustainable use.

Government Initiatives and International Cooperation

The Ministry of Ecology and Natural Resources of Azerbaijan is actively involved in hydrological and meteorological monitoring. It also manages the national water cadastre, which is essential for planning and managing the country's water resources effectively. Furthermore, Azerbaijan participates in several international water organizations to align with global water management standards and practices.

Enhancing Water Resources Management in Azerbaijan

The impact of climate change on water resources in Azerbaijan presents significant challenges but also potential areas for strategic adaptation and mitigation. The country is experiencing a range of climate-related pressures on its water resources, including rising temperatures, increased variability in precipitation, and a higher frequency of extreme weather events such as floods and droughts. These changes are expected to exacerbate existing issues of water scarcity, water quality, and water management.

One of the major concerns is the increased stress on agricultural water supply due to higher temperatures and unpredictable rainfall patterns. Agriculture, a critical sector in Azerbaijan's non-oil economy, is highly dependent on consistent water availability, making it vulnerable to these changes. The country is also grappling with environmental challenges such as severe air and water pollution, soil degradation, and loss of biodiversity, which are compounded by the impacts of climate change[3].

Despite these challenges, there are prospects for improving water resource management through technological innovation and policy reform. Azerbaijan's approach includes enhancing its infrastructural capacity to manage water more efficiently and adopting more sustainable agricultural practices to cope with the decreased water availability. The use of advanced irrigation systems and the implementation of water-saving technologies are critical steps toward adapting to the changing climate.

Furthermore, strategic planning and international cooperation are essential, given that a significant portion of Azerbaijan's freshwater comes from transboundary water sources. The country's National Adaptation Plan highlights efforts to integrate medium-to-long-term climate adaptation needs into national development planning, focusing on water, agriculture, and coastal areas.

Overall, addressing these challenges requires a comprehensive approach that combines local action with global cooperation, aimed at both mitigating the immediate impacts of climate change on water resources and building long-term resilience.

Modernization and Stakeholder Engagement

Recent initiatives in Azerbaijan highlight a significant shift toward modernizing the water sector through comprehensive stakeholder engagement. In collaboration with the Food and Agriculture

[3] Climate Risk Profile: Azerbaijan [Electronic resource]. January 31, 2017. URL: https://www.climatelinks.org/resources/climate-risk-profile-azerbaijan

Organization (FAO) of the United Nations, the Azerbaijani government has conducted surveys to assess perceptions and identify challenges in water governance. This process involved a wide range of participants, indicating a concerted effort to refine policy and management strategies in response to evolving environmental and climate-related challenges[4].

Research on water resources in Azerbaijan highlights the significant impact of climate change on water accessibility and sustainability. The country is taking proactive steps to address these challenges through initiatives like the National Adaptation Plan, which aims to improve resilience to climate change across key sectors including water, agriculture, and coastal areas. This project, supported by the UNDP and funded by the Green Climate Fund, focuses on enhancing institutional, technical, and financial capacities to integrate climate adaptation into national development planning[5].

The global context of water resource management also emphasizes adaptive strategies such as increasing water storage capacities and employing managed aquifer recharge (MAR) techniques. These approaches help buffer against seasonal water variability and improve overall water supply reliability, especially in agricultural areas that are heavily impacted by water shortages due to climate change[6].

Furthermore, the importance of addressing both water quality and quantity is evident, as climate change continues to exacerbate water scarcity and pollution. Effective water management policies must therefore consider sector-specific pollution controls and integrated water resource management to ensure sustainable water use and availability[7].

Overall, these efforts are crucial for Azerbaijan and similar regions facing increased water stress due to climate change, emphasizing the need for comprehensive and adaptive water management strategies to sustain water resources for future generations.

Challenges and Future Outlook

Despite these advancements, Azerbaijan continues to face significant challenges in water management. These include dealing with trans-boundary water conflicts, adapting to the impacts of climate change, and overcoming institutional and financial constraints. The need for continued investment in infrastructure, enhanced stakeholder engagement, and comprehensive policy reforms are essential to address these challenges effectively.

The ongoing efforts to engage various stakeholders and modernize water management practices are crucial steps toward ensuring that Azerbaijan can manage its water resources more effectively. Continued focus on these areas will be vital for securing water sustainability for future generations.

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Environmental protection

INNOVATIVE MEASURES FOR SAFETY OF MOUNTAIN LANDSCAPE

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Annotation. According to the origin of debris flows and their negative effect, the South Caucasus region is one of the most sensitive areas among the world's mountainous countries, because the Central Caucasus Range is located in this region, which belongs to a young mountain system.

Considering the climate change, snow avalanches and erosion-debris flow processes are intensified in this region, which is of great interest to scientists. It should be noted that during the last 21st century, debris flow processes not only cause great economic damage to all three republics of the South Caucasus (Georgia, Azerbaijan, Armenia), but also often cause human casualties.

The presented article deals with the solution of the above-mentioned problems, in particular, the physical process of moving the alluvial mass accumulated in erosive banks is discussed, taking into account the tense state of the eroded mass.

***Keywords*:** snow avalanches, mudflow, wave motion, rheology, Safety.

INTRODUCTION

Among the hazards affecting the infrastructure in the mountainous regions of Georgia, snow avalanches are the most dangerous ones, having a particular frequency to the extent of the consequences of the damage incurred and they have been increased geometrically in the last ten years in terms of the climate change in the world.

Mtskheta-Mtianeti region is taken as the survey target, it is located in the northern part of Eastern Georgia and its area constitutes 8.3% of the total country. The region has the most significant strategic purpose for our country.

As scientific studies have shown, the most avalanche-prone regions in Georgia are Racha-Lechkhumi and Kvemo Svaneti (74%), followed by Mtskheta-Mtianeti and Adjara (26%). It is interesting that Mtskheta-Mtianeti is the leader in the high-risk avalanching sites, which was probably expectable, taking into consideration great absolute altitudes, slope inclination, forest cover, etc. (Salukvadze M.E. (2018)).

According to the data of the National Environment Agency, there are more than 5,000 identified avalanche catchments in Georgia. Updatable data constantly, almost automatically allows the changes in nature to be quickly reflected in the database, processed and thousands of avalanches to be quickly mapped (Sukhishvili L., Megrelidze I. (2011).

Figure 1 presents the risk map of snow avalanching sites of Georgia according to the relevant classification (Abdushelishvili K.L., Kaldani L.A., Salukvadze M.E. (1979).

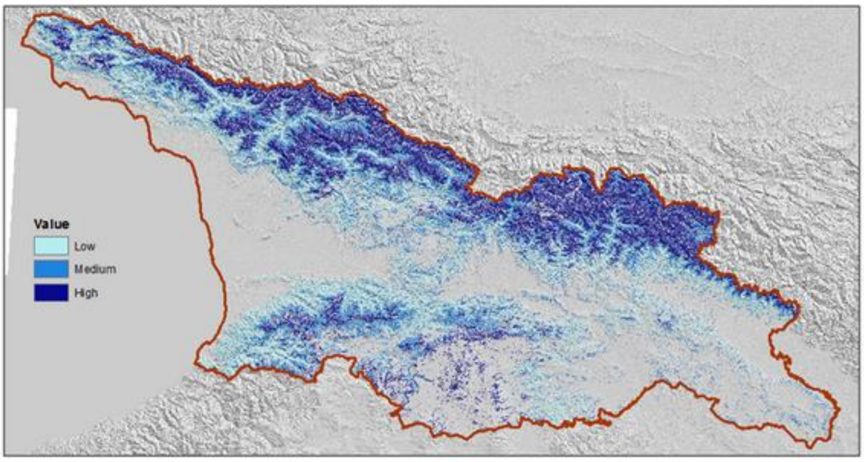

Fig. 1. Avalanche risk map of Georgia (Scale 1:2000000)

If in Georgia, until the last decades of the XX century, the extremes of activation of the debris flow processes mostly had certain cyclicity and depending on the geological and climatic terms, repeated once in 3-5 or 8-11 years, since the 1990s, the activation of the same processes over the average background value is seen almost every year, while the intervals of their extreme manifestation are much reduced. More and more new areas, settlements, engineering-economic structures, etc. come under the negative impact of the said processes [4,5].

In recent years, based on the information obtained about the landslides, debris flow and rock avalanches, approximately 350 formerly unknown debris flow hearths were identified. However, this number is quite small compared to the total number of processes seen in the last decades. In this period, approximately 53 thousand landslide-gravitational sites and up to 3000 debris flow-transforming erosive streams of water and processes in dynamics, located in the hazardous zones, were identified on the territory of Georgia, with up to 3000 settled areas located in their hazard risk area (See Fig. 2).

As the Information Bulletins of the geological outcomes of the National Environmental Agency of the Ministry of the Environment Protection state, the manifestation of natural geological processes in the geodynamical stressed regions exceeded the background value almost every year and consequently, the economic damage inflicted by them is significant (See Table 1), [5,8 - 10].

Fig. 2. Map of the debris flow zones in Georgia

Table 1

Statistics of The Damage Inflicted by The Debris Flows [4,5]

No.	Years	Number of debris flows	Approximate direct damage (mln. GEL)	Human victim	Total damage (mln. GEL)
1	1995	320	96	12	228
2	1996	162	27	5	107.3
3	1997	335	44	7	146
4	1998	173	20	6	87
5	1999	27	4.5	-	16.5
6	2000	23	3.0	-	16
7	2001	26	4.0	-	19
8	2002	23	2.5	2	16.3
9	2003	28	4.0	-	18.5
10	2004	258	28	2	175
11	2005	155	9.0	4	105
12	2006	63	9.0	-	79.5
13	2007	104	11.5	-	32
14	2008	126	15	8	63
15	2009	193	16.5	3	80
16	2015	85	35	23	45,8

Note: 1 USD = 2.9980 GEL (2023)

As for the modern methods used in recent years to combat debris flows, the construction of new reliable obstructing engineering-ecological facilities in the riverbeds, construction of coast-protecting weirs, terracing and foresting the slopes in erosive-debris flow hearths and landslide zones, cleaning the debris flow masses in detrital cones, etc. are worthwhile.

STRUCTURAL SOLUTION FOR AN INNOVATIVE MOUNTAIN SLOPE AVALANCHE-REGULATING BUILDING IN RELATION TO LOCATION TOPOGRAPHY

Due to the wide-scale of snow avalanches, notwithstanding the existing models and control measures, it is not possible to avoid catastrophic consequences. Snow avalanches are a terrifying phenomenon among natural disasters and the creation of innovative types of regulating buildings is linked to their genesis and dynamics.

The structural solution of the regulating structures used on it's force-feed surface often does not allow the transformation of the moving mass and the redistribution of the impact force. The innovation of avalanche-regulating buildings lies in the fact that it is reliable, durable and resistant to flexible avalanche impact force, has increased elasticity and reduced rigidity.

The anti-avalanche building (Fig. 3) presented in the project (Georgian Patent # 278) consists of secondary metal stands of different heights (1) attached to the slope, in which the metal elastic ropes (3) with the vehicle amortized tires on their top (2) are placed into sections, and a metal crossbar (4) is rigidly attached to the top of the stand, the distance of which from the ground is increasing in the direction of snow avalanche movement. Figure 4 shows the snow avalanche building in axonometry (Gavardashvili G.V., Pasikashvili M.G., Tskhovrebadze A.G. (1996)).

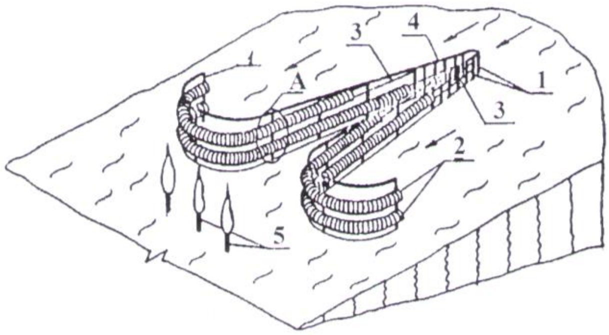

Fig. 3. Anti-snow Avalanche Building: 1 - Secondary metal stands; 2 - Vehicle Amortized tires; 3 - Metal Elastic Ropes; 4 - Metal Crossbar; 5 - Green Plants

LOADS AND IMPACTS CONSIDERED WHEN CALCULATING THE STRUCTURE

- **Constant load**

  - ***Net weight of structures;***

The net weight of steel and reinforced concrete structures is generated automatically. Reset coefficient - for steel structures $\gamma = 1.05$ (kg.f/m^3); For reinforced concrete structures - $\gamma = 1.10$ (kg.f / m^3).

  - ***Temporary load***

Snow avalanche pressure in the event of a enclosing on a building is calculated according to the following dependence (Samuel C. Colbeck, (1980)):

$$P_b = C_d\,(\rho_{av} V^2_{av} /2), \qquad (\text{kg.f/m}^3) \tag{1}$$

$$P_b = 1{,}5 \cdot (450 \cdot 4{,}43^2 / 2) = 6623{,}4 \ \ (\text{kg.f/m}^3) \tag{2}$$

Where:

ρ_{av} - snow avalanche stream solidity and $\rho_{av} = 450$ (kg / m3);

C_d – resistance coefficient of snow avalanche enclosing on the building, the numerical indicators of which are given in Table 2.

Table 2

Snow Avalanche Resistance Coefficient Cd in case of enclosing on the building

The shape of enclosing the building	Values of the coefficient of resistance C_d	
	If dry snow	If wet snow
Circle	1,5	3 - 5
Rectangle	2,0	4 - 6
Wedge-shaped	1,5	3 - 6

Snow avalanche stream velocity is calculated according to the following dependence (Gavardashvili G.V., Kukhalashvili E.G., Iremashvili I.R. (2021[a]):

$$V = (2gZ)^{0,5}\ (m/s) = (2 \times 9{,}81 \times 1{,}0)^{0,5} = 19{,}62^{\,0,5} = 4{,}43\ (m/s); \tag{3}$$

where,

$$Z = h_B – (H/L)\ l_B \ \ (m) \tag{4}$$

$$L = 800 \times \cos 24^0 = 800 \times 0{,}91 = 728{,}0\ (m) \tag{5}$$

Snow mass sliding can occur at a slower pace and by interacting with the nets on the structure, a natural "wall" can be created, which will distribute the loads according to the "wall" area :

$$P = P_b \cdot b_0 = 6{,}623 \cdot 1{,}9 = 11{,}86\ (\text{t/m}^2) \tag{6}$$

- **Dynamic load of snow avalanche**

Determining the dynamic impact (F) of snow avalanches [2,4]:

$$F = K\rho\omega V^2 \quad (\text{kg.f/m}^2), \tag{7}$$

where: ρ – Snow avalanche stream solidity; $\rho = 450$ (kg.f/m^3); ω – Distribution area (m2);
V– Avalanche stream velocity; $V = 4.43$ (m/s); K – Coefficient, K = 1.5.

Because the structure of the building is permeable, under the dynamic impact of a snow avalanche, part of the snow avalanche stream stops at the nets while the other part continues to move at a reduced velocity. Therefore, the dynamic load of snow is considered on the profile of the columns (column size Ø245 mm).

$$F = 1{,}5 \cdot 0{,}450 \cdot 0{,}245 \cdot 4{,}43^2 = 3{,}25\ (t/m^2) \tag{8}$$

- **Seismic load**

According to the relevant conclusions obtained as a result of seismic zoning and engineering-geological surveys of the territory of Georgia, it is established that the construction site is located in a 9-point seismic hazard zone according to MSK 64 scale (A = 0.40); Soil category according to seismic properties - II.

According to the calculation scheme of the anti-snow avalanche building, the structure is calculated for horizontal and vertical seismic impacts. According to the current norm PN 01.01-09 applicable in Georgia for anti-snow avalanche building, the calculated static loads are multiplied by the following coordination coefficients (Gavardashvili G., Kukhalashvili E., Iremashvili I., Gavardashvili N. (2021[b]):

Constant - 0,9; Temporary - 0,8. Initial data of seismic impact, according to PN 01.01-09; Soil Category II, Table 1; Soil acceleration A = 0.40 (c);

Reinforced concrete frame. $K_1 = 0.25$; Position 8. $K_2 = 1.0$; Position 1. $K_3 = 1.4$; Position 3. $K_\psi = 1{,}0$. A special algorithm was developed and the structure was calculated using a finite-difference scheme with the help of a computer. The results of the report are given in Table 3.

Table 3

The calculation was performed by matching the forces

Load №	**Name of the load**	**Type of the load**	**Variation of load signs**	**Mutual exclusion of the load**	**Reliability coefficient**	**Load duration share**
1	Constant	Constant **(C)**	+		1,000	1,000
2	Short	Temporary **(T)**	+		1,000	0,350
3	Special	Special **(S_s)**	+		1,000	0,000
4	Seismolog. - X	Seismic **(S_x)**	+/-	1	1,000	1,000
5	Seismolog. - Y	Seismic **(S_y)**	+/-	1	1,000	1,000

After entering the initial data into the computer by means of an algorithm, the design dimensions of the innovative anti-avalanche structure are given in Fig. 4.

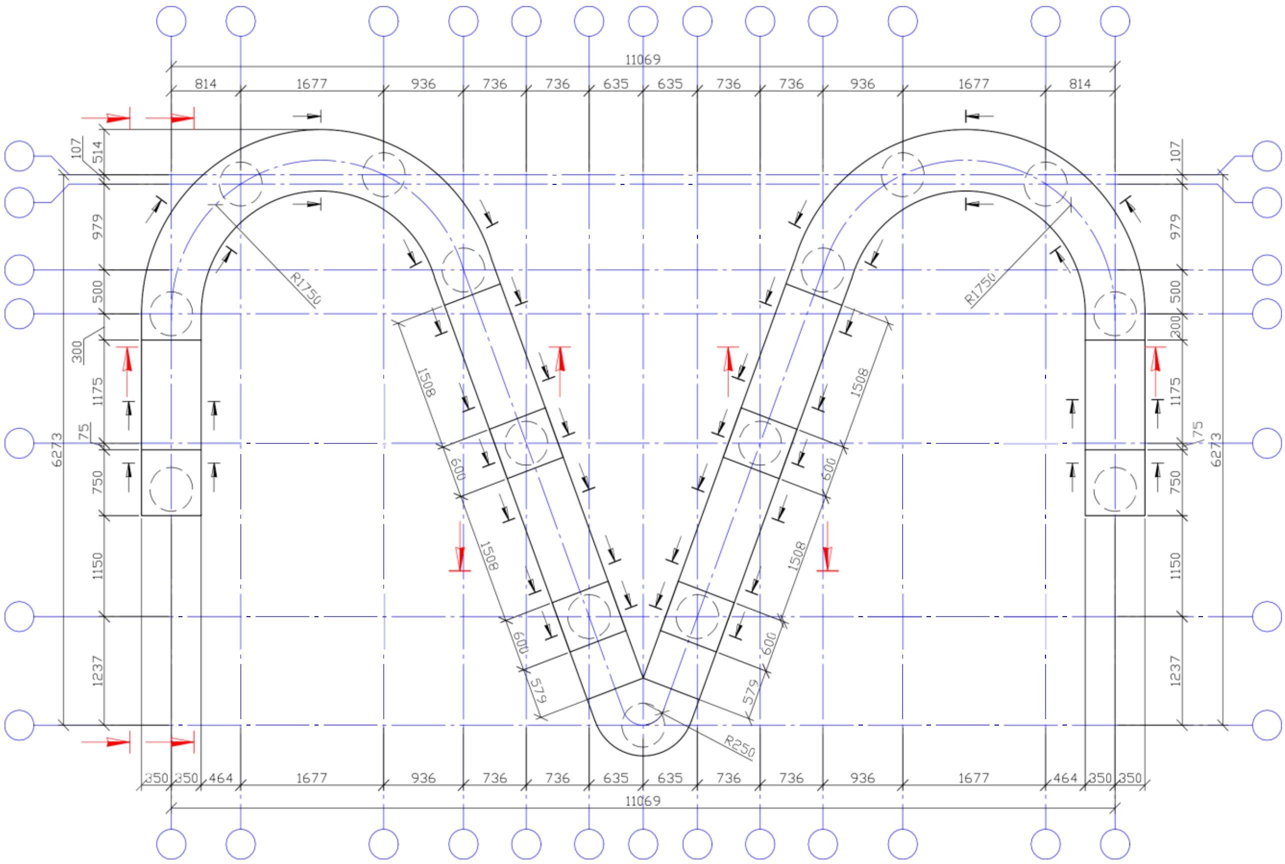

Fig. 4. Construction Frostwork plan

Innovative snow avalanche structure on the Kobi-Gudauri alpine area of the Georgian military road at 2338 m above sea level has been calculated, designed and built in accordance with the presented recommendations, the general view of which is given in fig. 5.

Fig 5. An Overview of Innovative Snow Avalanche Construction Georgian Military Road in Kobi-Gudauri alpine zone (2238 m above sea level)

STRUCTURAL DESCRIPTION OF THE ELASTIC DEBRIS FLOW-REGULATING BARRAGE

Natural anomalies, debris flows in particular, are of a particular importance for designing efficient engineering solutions. Debris flow is a terrible phenomenon of the natural calamities and the regulation measures are associated with their genesis and dynamics.

The rigidity and structural solutions of the barrages used in practice fail to transform the flow on the pressure surface or redistribute the dynamic force.

By considering the above-mentioned, an innovative structure of the elastic debris flow-regulating barrage was designed by the joint efforts of the scientific workers of Ts. Mirtskhulava Water Management Institute of Georgian Technical University and NGO Ecocenter for Environmental Protection, with its Know-How approved by the Patent License of Georgia [2].

The sections of the elastic debris flow-regulating barrage are made of triangular prisms of the same height inserted in the bed, tight packed with their side faces. The base heights of the prisms increase along the debris flow current and form a springboard. The structure's top is directed against the current and there are elastic ropes stretched between the edges above the prisms connected with one another with the lateral ropes forming pockets between the edges to receive the debris flow mass. This type of barrage allows receiving debris flow smoothly (See Fig. 6).

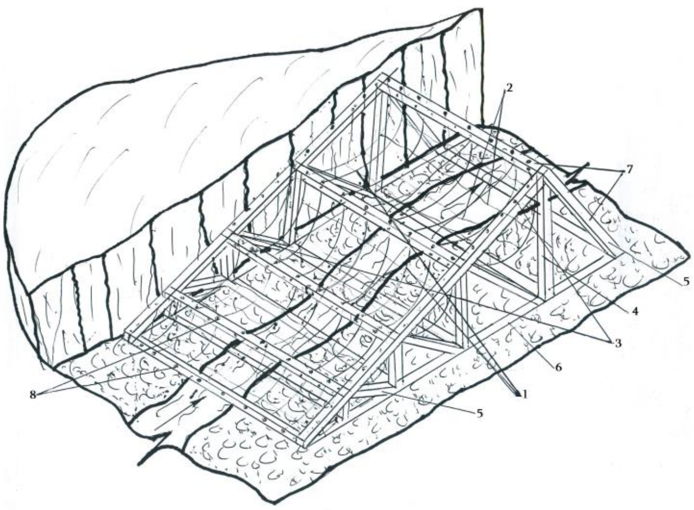

Fig. 6. General view of the elastic debris flow-regulating barrage

Elastic debris flow-regulating barrage (1) is made of sections connected to one another, which are made of triangular prisms of equal heights (2); the sections with side faces (3) are inserted in the bed in close sequence. The base heights of the prisms (4) increase in the debris flow direction and form a springboard. The top of the facility is directed against the current. The upper edges of the prisms have holes (5) or clamps to stretch elastic ropes (6) between them, while there are lateral ropes (7) stretched across the elastic ropes forming pockets between the sections to receive the debris flow mass. The ropes are attached at the bases with the openings (8) to fasten the ropes.

The sizes of the elastic debris flow-regulating barrage are calculated by considering the expected strength of debris flow and topographical properties of the location. When the structure is used as an elastic debris flow-regulating barrage, the current flows up the elastic surface and the impact force is distributed along its length as follows:

As the debris flow moves, the debris flow-retaining pockets in the first section of the facility receive the major dynamic impact force at the time of the flow passage, while the energy is further damped on the surface of the springboard, gradually and smoothly under the action of the elastic surface. The sizes of the network of the debris flow-retaining pockets are designed by considering the diameters of the stones drifted by the expected debris flow.

The technical-economic advantage of the existing structures is the opportunity of removing the ropes of the facility and cleaning the facility making it possible to use it for many times.

Besides, the construction elements with less complex shapes are used to build the facility thus reducing the cost of construction. In addition to the above-mentioned, the technical-economic efficiency of the structure is high due to its trouble-free and long operation making it possible to avoid additional operational costs.

DEBRIS FLOW REGULATION ELASTIC BARRAGE TO REGULATE THE MOVEMENT OF SOLID FRACTIONS IN THE RIVERBED

In order to regulate the movement of solid fractions in mountain rivers, an innovative debris-flow regulation elastic barrage was designed in the Tsotne Mirtskhulava Water Management Institute of Georgian Technical University. The priority of the scientific and technical of this innovation is certified by Georgian Patent (Georgian Patent No. GE P 2020 7068).

In order to work out the design methods for the structure, a large-scale laboratory simulation of the laboratory model of the debris flow regulation elastic barrage was carried out at the above-mentioned scientific-research institute, when the flow loaded with sediment was moving inside a hydraulic channel. The laboratory experiments will be conducted for the turbulent flow movement inside the hydraulic channel.

Fig. 7 shows the debris flow regulation elastic barrage during the laboratory tests, with the following modeling similarity parameters taken into account: dynamic similarity ($Fr = ident$), geometrical similarity (bed slope $i = ident$), sediment movement ($V_{water} / V_{sediments} = ident$), bed resistance coefficient (Chezy coefficient $C = ident$).

Fig. 7. Debris flow regulation elastic barrage during the laboratory tests

The dynamic impact of the flow on the innovative debris flow control structure is calculated with the following dependence:

$$P_1 = \frac{\gamma \omega V^2}{g} \sin \psi \ f(m) , \quad (\mathrm{N/m^2}) \tag{9}$$

Where γ is the volume weight of the debris flow (N/m^3); ω is the area of the effective cross-section (m^2); V is the flow velocity (m/s); ψ is the gradient angle to the structure base (^{0}); ψ is the internal friction coefficient and equals to:

$$\psi = tg^2\left(45^0 - \frac{8}{2}\right); \tag{10}$$

Where h_0 is the equivalent depth of cohesiveness (m); H is the depth of current (m); a is the coefficient $(1-h_0/H)\psi$. $f(m)$ is the coefficient and depends on the rheological properties of the debris flow:

$$f(m) = \frac{16-\left(\alpha^3+4\alpha\sqrt{\alpha}\right)\left(2+\sqrt{\alpha}\right)^2}{\left(\alpha^3+4\alpha\sqrt{\alpha}\right)\left(2+\sqrt{\alpha}\right)^2} \tag{11}$$

The innovative debris flow control structure is a bearing frame of a metal structure with steel details. Considering the technical characteristics of the structure, a point foundation was selected for it, and waterproof concrete W8, Class B25, made with Portland cement was used for the foundations. The structure, which is in contact with the ground and the river filtration current, is waterproofed with up-to-date insulating materials. The bearing structure of the anti-debris flow control barrage, as a single spatial system, is designed for permanent and temporary dynamic loads. The calculation was performed with software „Lira Sapr 2019” (License Number 1/7165).

The detail project is developed in accordance with normative documents effective in the territory of Georgia: Concrete and reinforced concrete structures (03.01.-09); Building Foundations (DN 02.01-08); Building climatology (DN 01.05-08); SNiP 2.01.07.85 Loads and Impacts; SNiP II-23-81: Steel structures; SNiP 2.03.11-85: Protection of structures against corrosion. The calculation results are given in Figure 8.

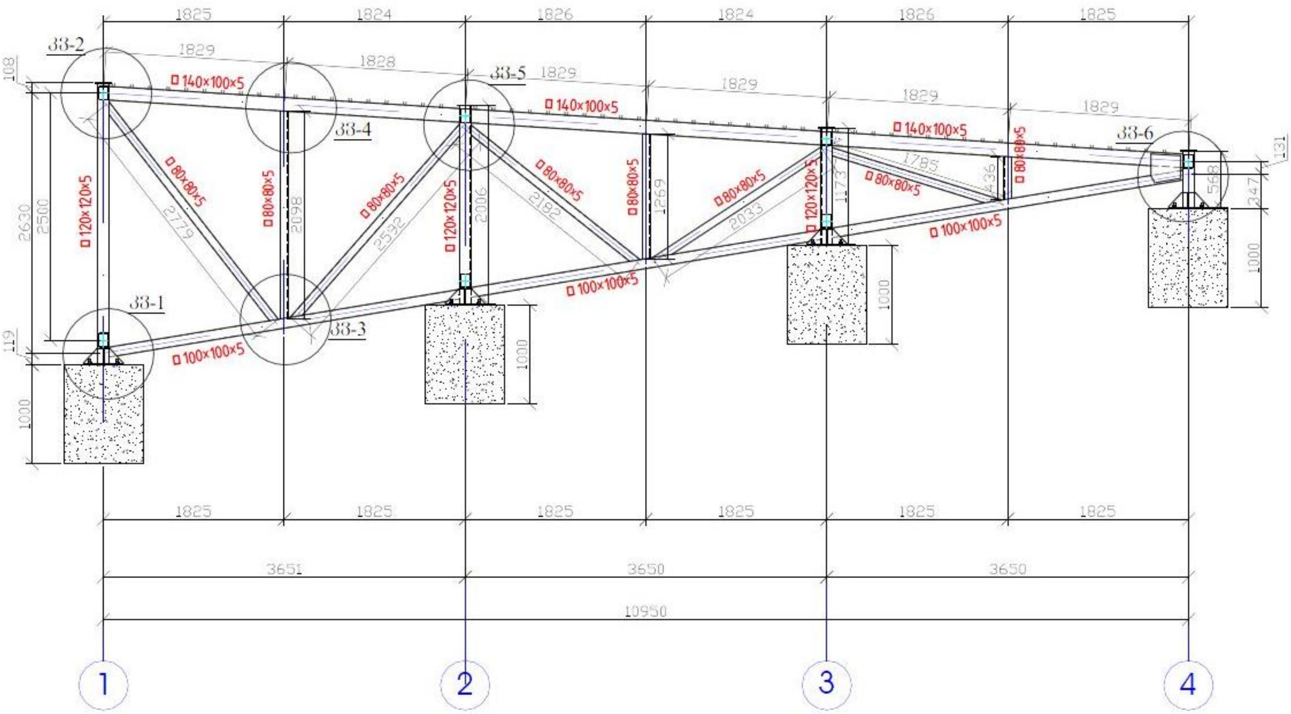

Fig. 8. Longitudinal section of the debris flow regulation structure

The volume of solid fractions accumulated in the headrace of the debris flow regulation elastic barrage is calculated as a function of time according to the following dependence:

$$W_t/W_T = \left[0{,}90 + 0{,}10\left(\bar{d}/\Delta\right)^{1{,}51}\right]\ (t/T)^{2{,}34}, \tag{12}$$

Where W_t is the volume of solid fractions retained by the structure at a given moment of time (m^3), W_T is the total volume of fractions retained at the headrace of the structure (m^3), Δ is the permeability factor of the structure, t is the elementary time period (min), T is the time of complete filling of the structure with sediments in its headrace (min).

Based on the conducted theoretical, laboratory and field studies, in order to regulate the solid fractions in the Mleta riverbed at 1600 m asl, in October of 2022 an experimental model of the debris flow regulation elastic barrage was built by us, and the debris flow formed in May of 2023 filled the first step of the structure with solid fractions. The general view is given in Figure 9.

View of the structure before the debris flow passage

View of the structure after the debris flow passage

Fig. 9. General view of the debris flow regulation elastic barrage regulating solid fractions

CONCLUSIONS

Based on the theoretical, laboratory and field scientific studies conducted under the financial support of the grant project of the Shota Rustaveli National Science Foundation of Georgia: Grant Project CARYS - 19 – 305 "Innovative Complex Measure against Snow Avalanche" Funded by the World Bank and Grant Project # AR-18-1244 "Elastic debris flow-regulating barrage" in 2018 – 2023, the following basic conclusions can be made:

➢ **Snow Avalanche Construction:**

- Field-reconnaissance surveys were conducted at the Kobi-Gudauri section of the Georgian military road to design an innovative snow avalanche design. A scientific methodology was developed and an innovative construction was designed on the mountain slope of the study area taking into account the dynamic and statistical loads of the avalanche;
- In order to regulate snow avalanches, on November 17, 2021, an innovative snow avalanche construction was organized on the Kobi-Gudauri alpine section of the Georgian military road at an altitude of 2238 m above sea level.

- **Elastic debris flow-regulating barrage:**

- An innovative design of an debris flow regulation elastic barrage has been developed;
- Laboratory modelling were conducted;
- Methodology for design of the debris flow regulation elastic barrage was developed;
- Four Doctoral Degree Dissertation defended at the faculty of civil engineering of Georgian Technical University;
- Debris flow regulation elastic barrage was constructed in the Mleta riverbed in September and October of 2022;
- In May 2023, turbulent debris flow was formed in the Mleta River gorge bed, and affected the experimental model. The structure did not collapse and is operable to date proving its reliability.

ACKNOWLEDGMENT

The research was financial supported by Shota Rustaveli National Science Foundation of Georgia, Grant Project CARYS - 19 – 305 "Innovative Complex Measure against Snow Avalanche" Funded by the World Bank and Grant Project # AR-18-1244 "Elastic debris flow-regulating barrage"

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Construction

MODERN DESIGNS OF RETAINING WALLS FOR DIFFICULT TERRAIN

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„We shape our buildings and afterwards our buildings shope us"
Winston Churchill

Annotation. A significant part of the territory of Georgia is difficult for the development of urban planning due to relief conditions and difficult geophysical conditions [1,2]. In this regard, the city of Tbilisi especially stands out with its complex terrain, because... In conditions of land shortage, today it is disadvantaged areas that are attractive to construction companies and investors.

A retaining wall is a structure that keeps the soil behind it from collapsing and sliding on slopes (slopes, slopes, convexities, etc.).

Structural solutions for traditional retaining walls are built strictly vertical. Relatively recently, thin-walled reinforced concrete retaining walls began to be used, which are an engineering structure of complex shapes inclined at an angle to the horizon.

Keywords: Retaining wall, complex shapes different, architectural form, multi-purpose support, providing protection.

RELEVANCE OF THE PROBLEM

A significant part of the territory of Georgia is difficult for the development of urban planning due to relief conditions and difficult geophysical conditions [1,2]. In this regard, the city of Tbilisi especially stands out with its complex terrain, because... In conditions of land shortage, today it is disadvantaged areas that are attractive to construction companies and investors.

A retaining wall is a structure that keeps the soil behind it from collapsing and sliding on slopes (slopes, slopes, convexities, etc.).

Structural solutions for traditional retaining walls are built strictly vertical. Relatively recently, thin-walled reinforced concrete retaining walls began to be used, which are an engineering structure of complex shapes inclined at an angle to the horizon.

The purpose of this work is to highlight the current state and determine the theoretical and methodological foundations for the formation of a living environment, ensuring the possibility of using areas of complex terrain with large slopes (60% and above) for mass housing construction, which until now were considered unsuitable for this purpose.

Novelty

Compared with the well-known and traditional gravity walls [3,4], the thin-walled dressing or pressure retaining wall [5], are made of reinforced concrete and have the following advantages:

1. The construction of thin-walled walls of complex shape is possible for any configuration and height of the relief;
2. The consumption of materials for constructing such a wall is more rational;
3. To construct such a wall, a large "dead" space is not required;
4. Provides specialists with ample opportunities to create unique architectural forms along the entire length of the workspace and the opportunity to use modern structures and materials;

5. Provides the opportunity to create a variety of architectural and structural forms of multifunctional retaining walls.

Traditional retaining walls

Retaining walls are usually erected in areas where it is necessary to strengthen vertical or different forms of the landscape and connect different areas with contrasting topography.

It is known that the diagram of soil pressure on a vertical retaining wall has the shape of a trapezoid. The resultant pressure applied at the center of gravity of the diagram is **G=½γ(H2+Hh) tan2(450-½φ)** [3].

A vertical thin-walled retaining wall on a pile foundation can be calculated as follows: The joint work of the pile and soil is modeled along the lateral surface using the bed coefficient **Cz=K*z/ϒc** [4,5].

In mountainous areas with complex terrain, thin-walled reinforced concrete retaining walls, vertical or inclined, with or without pile or combined foundations, but with anchors, are often used.

Sloped, dressing and lattice retaining walls

The structures of leaning and dressing retaining walls, designed to keep the soil mass from collapsing and sliding, erected on steep slopes, landslide areas, were designed, tested and effectively used by us in different regions of Georgia on the basis of monolithic reinforced concrete and special anchors.

Leaning and covering walls are a rational and simple type of structure that protects the rock of slopes and relief formations from destruction. The advantage of dressing walls is that their construction does not require the construction of complex pits and foundations and does not affect the earth mass with its underground networks and collectors.

The design and construction of multifunctional retaining walls of various shapes, taking into account the complex terrain, as well as the construction of low-rise buildings (usually 2-3 floors) on steep terrain and the specificity of its volumetric planning structure are the development of national traditions in Georgian housing construction, allowing to preserve the architectural appearance of the inhabited places and cities have a leading importance to the natural landscape.

In conditions of land shortage, the emergence of new technologies and increasing demand for environmentally friendly, safe, spacious and cost-effective designs of modern retaining walls, they are often used to develop complex terrain.

One of the most difficult tasks that is solved during the construction of such structures on complex terrain is to ensure their stability, strength, reliability, and durability, taking into account unfavorable environments for foundation construction and seismic effects.

The complexity of calculations and production of walls of complex shape lies in the need to take into account many different factors:

• actual soil stratification and foundation loading sequence;

• complex geometry of the construction site of already erected (existing) buildings and terrain;

• nonlinear properties of foundation soils (they often operate beyond the linear stage: slipping between layers, deformations under large pulling loads, etc.);

• assessment of the forces arising in structures during uneven settlements;

• selection, comparison of options and creation of rational structural forms of such retaining walls.

Below are several examples of thin-walled retaining walls we have completed in different regions of Georgia (Fig. 1, 2).

Landscaping of relief formations includes: an element of improvement and landscape organization of the territory with the effective development of slopes using dressing and lattice (pressure) retaining walls, ensuring the formation of a green formation environment with the active use of plant components, as well as maintaining a previously created or originally existing natural environment on territories of landscape formation. Stationary landscaping of complex terrain can be carried out using dressing (pressing) retaining walls when designing new or reconstructing existing buildings and structures (buildings) on slopes (or nearby) with a slope of more than 12 degrees.

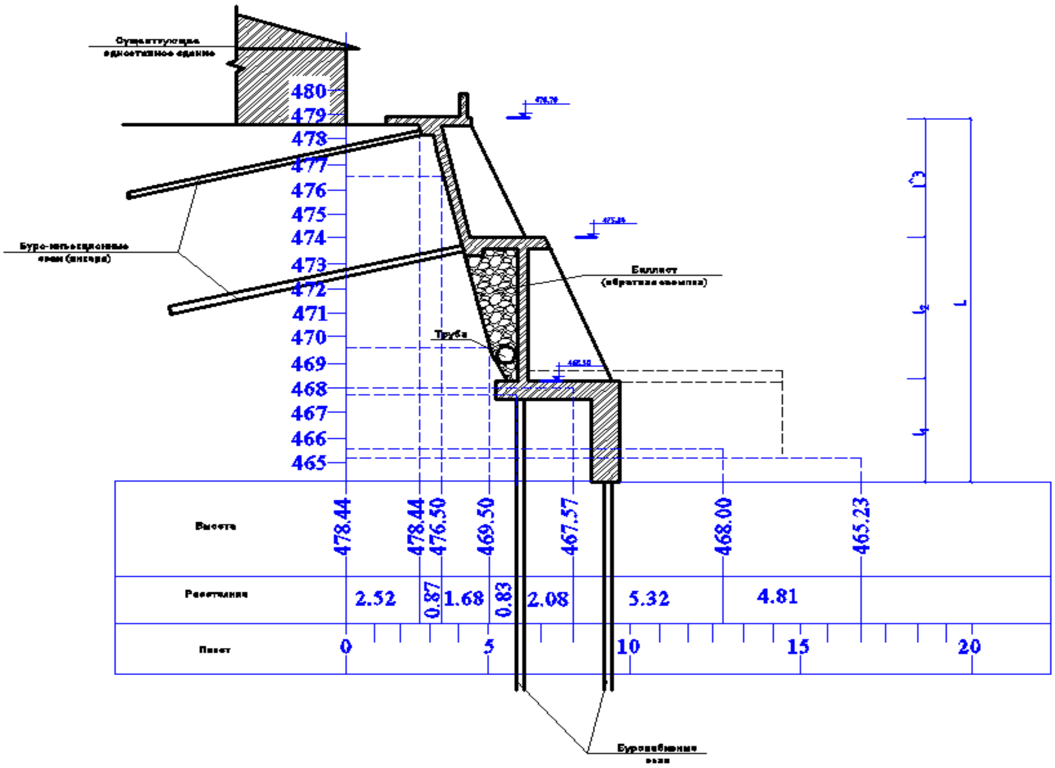

Fig. 1. Cross section of thin-walled retaining walls pressed against the terrain

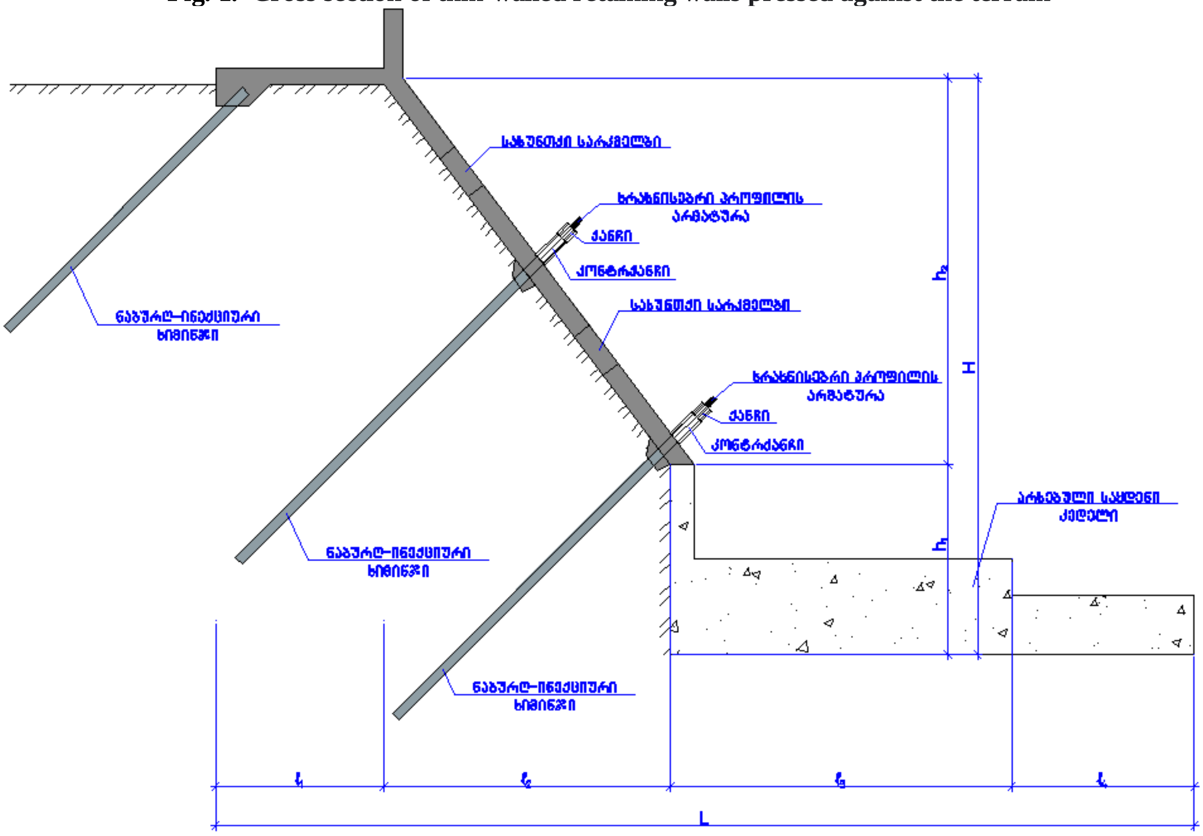

Fig. 2. Cross section of thin-walled retaining walls pressed against the terrain

The choice of the optimal design solution for dressing (clamping) retaining walls is possible only on the basis of computer modeling and careful calculations, taking into account the existing geotechnical foundation conditions and geometric shapes for the construction of such structures (Fig. 3, 4).

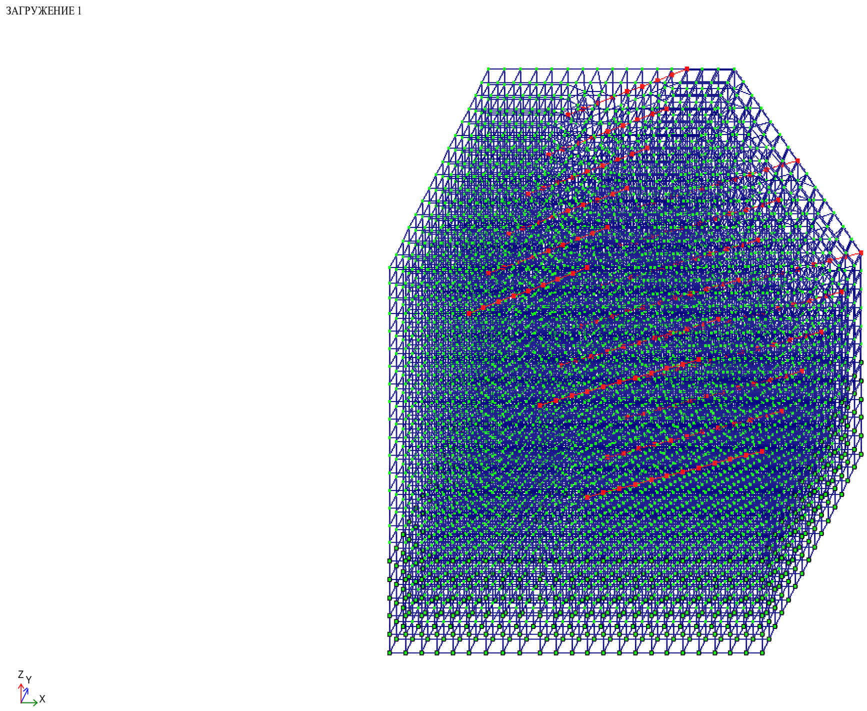

Fig. 3. Calculated spatial model based on the use of LIRA CAD

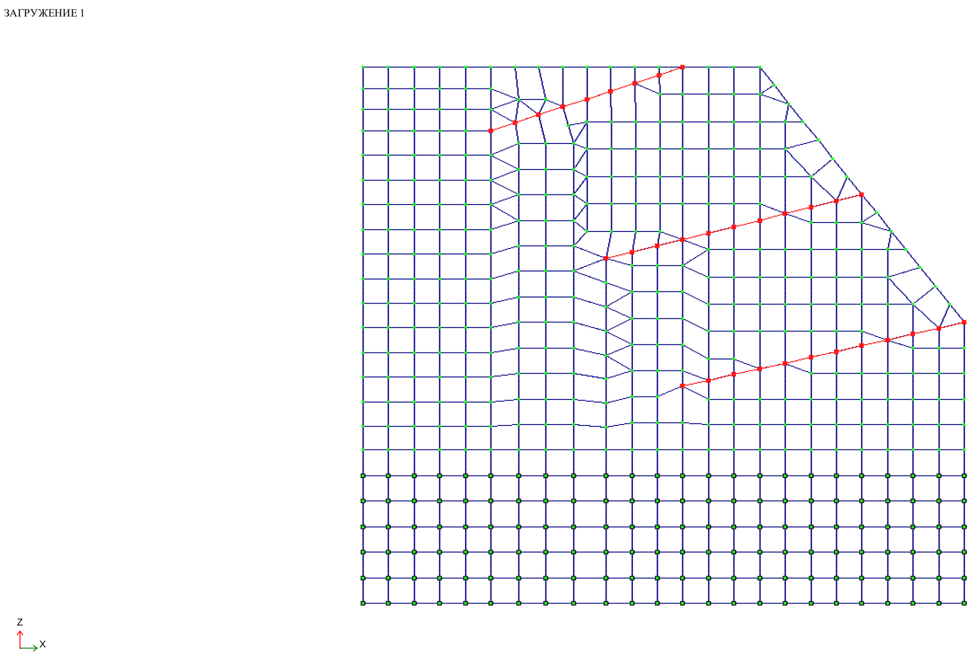

Fig. 4. Calculated spatial model based on the use of LILA CAD in section with anchors

Urban greening, making maximum use of existing slopes, is very beneficial in a variety of ways.

The use of the proposed technology of dressing retaining walls for mountainous regions can make it possible to restore the ecological balance in a relatively short time.

The operation of thin-walled and dressing retaining walls of an anchor structure using screw-profile reinforcement with a coupling is based on the principle of pressing structures against stable soils, using anchors located below the surface of a sliding prism, which must absorb landslide pressure.

Along with construction technologies, methods and styles of landscape gardening in areas of complex terrain are being improved (Fig. 5).

Fig. 5. An example of landscaping of relief formations of multi-tiered retaining walls with an inclined elevator and pedestrian roads. Arch. M. Jeiranashvili

CONCLUSIONS

1. It is necessary to identify uniform types of zones of complex terrain, where the effective use of uniform and multifunctional retaining walls is possible;
2. Numerical analysis of the joint operation of structures of enclosing retaining walls using anchors made of reinforcement with a screw profile and a tension coupling makes it possible to design optimal structures in terms of bearing capacity for any seismic zones and regions;
3. The structures of inclined or lattice retaining walls can be made of monolithic reinforced concrete, prefabricated or prefabricated monolithic (combined), and from metal or modern composite materials and structures;
4. The consumption of materials for the construction of dressing retaining walls in replacement of traditional gravity ones is more rational;
5. The installation of dressing retaining walls does not require a large "dead" space;
6. Provides specialists with ample opportunities to create unique architectural forms along the entire length and height of the working space.

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Earth sciences

ABOUT THE DEFINITIONS OF PARAMETERS OF CURVES OF RIVER FLOW MEANDRING AREAES

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Annotation. Climatic factors in the formation of runoff, the geomorphological structure of the territory and the nature of the constituent rocks, soil and vegetation cover, modern tectonic movements and fluctuations in erosion base marks - these are the main natural factors of channel processes that determine differences in their forms, intensity and direction of manifestation. All other things being equal, the greater the relative magnitude of changes in runoff, the greater the instability of the river bed topography. In high-water years, the intensity of channel deformations increases. The high-water flow processes the forms of the channel relief created during the low-water period, and the low-water flow processes the forms created during the high-water period.

Keywords: water, river, channel, formation process.

INTRODUCTION

Channels and rivers are in close interactions. During the stream movement there is a mutual relation and dependence between the characteristic of lengths, depths and curve of the channel, the flow criteria and ground grain measure.

Bed processes in rivers are continuous. Channel processes arise under a combination of conditions on which the water content of rivers and their regime, longitudinal slope, sediment size and concentration, rock erosion, as well as all the main elements that determine the intensity and features of the development of channel processes depend [9]. It follows that channel processes depend on the geographic environment and on the specific features characterizing the landscape of the catchment.

Channel formation process is in constant connection with the geological, topographical, climatic, water and other factors of the area and taking into consideration the influence of the latter on channel processes is difficult. Even if only the hydrodynamic part of the event is regarded, however, serious difficulties occur connected with its mathematical modeling. V.G. Sanoyan [1,2] had worked out the method of scrolling movement of the stream, using thus his theory of stream bandwidth and hydrological descriptions. The water flows along the channel in deep places and shallows next to each other. In the part of curves, by the grooved banks, as a result of wide circulation of water which is directed to down, speeds fasten. The lengths speeds of the stream are added to them, so the flooding of the stream incurving bank increases more [4]. Here the grooves of the curves are more abrupt, and the depths of the stream are bigger. As a beginning of the meander the narrowest segment of the channel is considered to be. On the meander line the channel widens, reaches its maximum size, then gradually it narrows. Passing from one meander to another the incurving center passes from one bank to another, i.e. the fracture center between two meanders is the twist for meander groove. In the end of meander, the widths of the channel is bigger than in the beginning. The length of the widening part of the curve is about 1,5 times bigger than that of narrowing part. The narrowing parts are situated in the curves of the channel, and widening parts are comparatively vertical.

Currently, there are about 30 competing explanations for the causes of river meandering: general denudation of the earth's surface, neotectonics, geology, Coriolis acceleration, the presence of random obstacles, the principle of minimum energy dissipation, the concept of entropy, structural turbulence, transverse circulation, wandering of the dynamic axis of the flow, "the property of the flow to meander." ", etc. None of these hypotheses have been fully confirmed [10].

For the first time, an attempt has been made to explain the causes of floods in the lower reaches of the Kura by processes of bank erosion and sediment accumulation in the river bed. Similar problems occur in such transboundary rivers as Tisza (Romania, Hungary, Slovakia, Ukraine, Serbia and Montenegro), Merij (Bulgaria, Turkey and Greece), Dniester (Moldova and Ukraine), Nistru and Prut (Moldova, Romania and Ukraine) and Northern Don (Russia and Ukraine) [11].

The reasons of occurring the meanders are presented by different researchers differently [7,8]. We point out some of them:

1. The principle of minimum dissipation of energy
2. The wide gyre of the water in the river
3. The turbulence
4. The fluctuation of water vertical movement to harmonic stimulations
5. Entropy
6. The geological reasons
7. Speed of Koriol's
8. Accidental resistance
9. Bandwidth of liquid
10. Denudation of Earth's crust

Meandering is mainly considered as a process that depends on the dynamics of the flow and its hydraulic characteristics: water flow, flow speed, and slope of the water surface. There are very few works that pay attention to the influence of natural factors and features of the hydrological regime of rivers on the development of bends. Streams with the same hydraulic characteristics can create different channel forms in different natural conditions, and, in turn, outwardly identical channel formations can arise under the influence of completely different hydraulic processes [12].

Identifying the regional specifics of the free meandering of rivers is not only an important scientific, but also a practical problem, the solution of which is associated with increasing the efficiency and reliability of measures to regulate river channels. In addition, the issues of the emergence of bends, stages of development and conditions for their straightening, transformation of shape and hydrological-morphological dependencies during the evolution of bends, with changes in water content and other characteristics of rivers, remain poorly studied.

MAIN PART

The characteristics of meander rivers are the clause and the amplitude. For any characteristic of channel deformation we can determine the dependence upon the three main characteristics of channel process [5]. Particularly, we can determine for the clause and amplitude of meander the following [6].

$$\frac{t}{d} = \alpha_1 \lambda^{x_1} \quad \text{and} \quad \frac{a}{d} = \alpha_2 \lambda^{x_2}, \tag{1}$$

where t – is the clause of curves, a - is amplitude, λ - is Lokhtin number.

The coefficients and thermometers in the [1] formula can be determined on the basis of the results of the united processing of original data by the method of the small squares [5].

$$t = 10{,}5d\left(\frac{Q}{d^2\sqrt{gdi}}\right)^{0{,}38}, \quad a = 2{,}3d\left(\frac{Q}{d^2\sqrt{gdi}}\right)^{0{,}42}, \tag{2}$$

where Q - is channel forming exit, *i* - is the slope of free surface in the circle of curve, *q* - is the speed of gravity, *d* -is middle equalized diameter of the grain.

The resulting relations show that in the same conditions the growth of exits results in both clause and curve amplitude increase. The decrease of curve results in increasing of curve characteristics. In the highland and lowland rivers the curves decrease according to the elimination of flows, which, due to [2] formula, results in the increase of frequency and amplitude of meanders down the stream. In the relations given the influence of channel grain diameters is expressed weakly.

Relation (2) gives us opportunity to define the width of river meander line in the layout. During the permanent slope of the river the meander line width is also stable, and during the constant decreasing of channel curve the width of meander line has widening shape down the stream. The position of the buffer in the layout is defined by the width of meander with increase of certain supply.

CONCLUSION

The clauses and amplitudes of the curves are defined by relations dependent on main factors which form the channel. The width of the meander line can be defined by the relations given above.

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Water Management

HYDROLOGICAL CALCULATIONS FOR RESERVOIR DESIGN: A CASE STUDY OF THE ALIJANCHAY RESERVOIR IN AZERBAIJAN

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Annotation. Since approximately half of Azerbaijan's territory is characterized by an arid climate, its water resources are limited, and two-thirds of surface water resources come from transboundary rivers. Under climate change conditions, these resources have decreased by 10-15%. Currently, new reservoirs are being designed to effectively use surface water resources. The article is devoted to calculating the main characteristics of river flow, assessing the amount of river sediment and the environmental flow of the Alijanchay River, on which the reservoir will be built. The statistical structure of runoff series (homogeneity, stationarity, autocorrelation coefficient) was analyzed, and the values of annual, seasonal, monthly, maximum and minimum river flow corresponding to different return periods were determined. The calculations also took into account a possible decrease in river flow in the future as a result of climate change. The volume of environmental flow of the river below the reservoir dam was calculated using different methods. For the reservoir project, the volume of environmental flow (27.7% of the annual flow) was proposed, calculated using a holistic method.

Keywords: Alijanchay river, water reservoirs, irrigation, water discharge, annual flow, suspended load, bed load, ecological flow, climate change.

INTRODUCTION

The development strategy of the Republic of Azerbaijan is to minimize the country's dependence on oil and natural gas exports by developing a number of priority areas of the economy. One of such priorities is the development of agriculture and thus improving the food supply of the population. The total area of agricultural land in Azerbaijan is 4.2 million hectares (48.8% of the country's territory), of which 1.45 million hectares are arable lands. The arable lands are mainly in the plains, which are characterized by arid climatic conditions, and therefore the cultivation of crops is possible only through irrigation. At present, there is a potential to grow crops on an additional 200,000 hectares, but this work is delayed due to the shortage of water resources (Akhmedzade & Gashimov, 2006). Azerbaijan is among the countries with limited water resources. Transboundary rivers account for 67% of total surface water resources, and local water resources are unevenly distributed throughout the area (Rustamov & Kashgai, 1989). Due to climate change, the country's water resources have decreased by 10-15% (Taghiyeva & Verdiyev, 2020). According to local and international organizations, the negative impact of climate change on water resources will continue at least until the middle of the 21st century (UNDP, 2011; ENVSEC, 2016; UNESCO, UN-Water, 2020). Thus, water resources have become one of the key factors in the country's sustainable development.

There are about 140 reservoirs in Azerbaijan and their total volume is 22 billion m^3 (Akhmedzade & Gashimov, 2006). According to the National Action Plan for the Rational Use of Water Resources, 10 more reservoirs are planned to be built on local rivers in the coming years. One of these reservoirs will be built on the Alichanchay.

With a total capacity of 108 million m^3 and an active capacity of 100 million m^3, the reservoir will improve the water supply of 5,000 hectares of land in the river basin. With the construction of this reservoir, it will be possible to grow agricultural products (walnuts, almonds and olives) on a new 38,000 hectares. Only water-saving irrigation technologies will be applied in these new lands. The new lands are located outside the Alichanchay basin and water will be transported to this area via a main canal.
This article is about the calculation of the main flow characteristics and ecological flow of Alijançay, where the reservoir will be built.

Characteristics of Alijanchay and its basin

Alichanchay is the left tributary of the Kura River, the largest river in the Caucasus region (Figure 1). The source of the river is located at elevation 3500 m, and the mouth is located at elevation 13 m. Its length is 98 km, the catchment area is 1210 km^2.

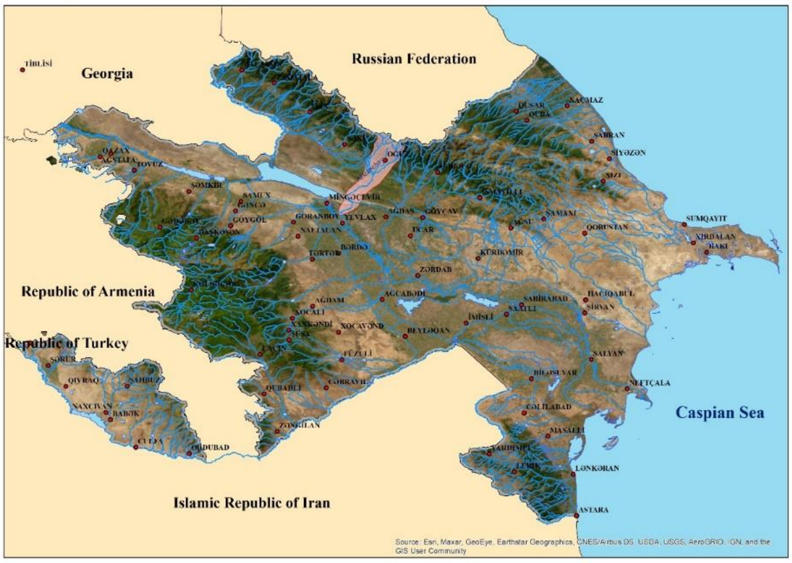

Fig. 1. Geographical position of Alijanchay basin

Both geological and geomorphological features of the mountainous and plain parts of the basin differ sharply from each other. In the mountains there are Jurassic and Cretaceous rocks of the Mesozoic era, and in the plains there are Neogene and Paleogene rocks of the Third Cenozoic era, as well as Quaternary rocks. Strong denudation and intensive erosion occur in mountainous areas. The river formed a alluvial deposits in the plain area. Large gravel is collected in the upper part of the alluvial deposits, gravel and sand in the middle part, and sand, fine sand and finer sediments in the foothills.

Due to the large range of elevations in the Alijanchay basin, five different climate types have been formed here: semi-desert and dry steppe climate types; temperate climate type with dry winters; temperate climate type with even distribution of precipitation; cold climate type with even distribution of precipitation; mountain tundra climate type. The amount of precipitation in the upper part of the river basin before the dam is 757 mm, and total evaporation is 519 mm. Precipitation is unevenly distributed by seasons and months. Two maximum precipitation are observed during the year: spring and autumn. Precipitation is low in July-August and winter.

In the Alijanchay basin, soil types (six main types) are distributed according to the altitude zone and are mainly fertile soils.

There are 6 natural landscape zones in the river basin: lowland semi-deserts, mountain steppes, plain forests, broad-leaved mountain forests, mountain meadows, subnival and nival landscapes.

However, certain parts of the first 4 landscapes have changed as a result of human activities and turned into anthropogenic landscapes (gardens, fields, cities and villages, etc.) (Museyibov, 1998).

Hydrological observations have been made on it in 4 stations in different years. The location of the reservoir dam coincides with the position of one of these stations (Gayabashi). Observations at this observation station were made in 1959-2013 and the station was closed in 2014.

The maximum regime phase in Alinjanchay lasts from late March to June. Spring rains form floods. Minimum water discharge is observed in July-August. However, torrential rains cause floods during the dry season phase (Figure 2).

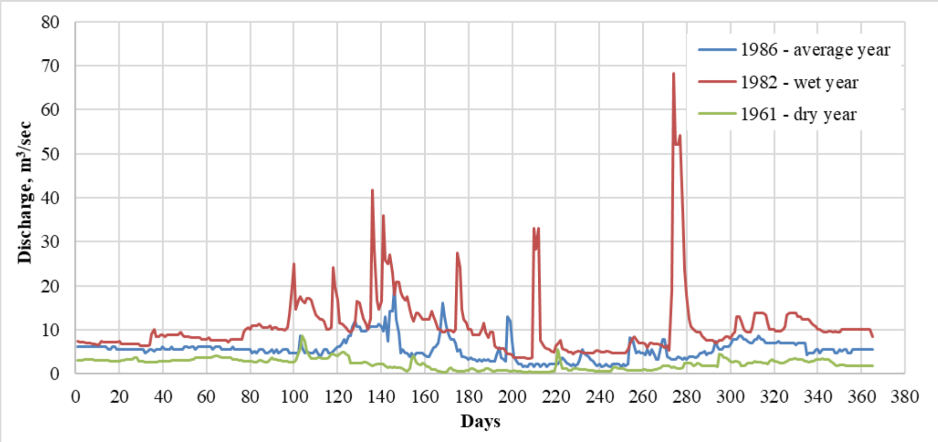

Fig. 2. Observed hydrograpfs of Alijanchay for the defined years (Gayabashi gauge)

The average water discharge at Gayabashi gauging station is 5.52 m^3/s. The amount share of groundwater, rain and snow water in the annual flow is 43%, 36% and 21%, respectively.

Materials and research methods

The main database of the study is hydrological observation data for 1959-2013 at the Gayabashi station of Alijanchay. Based on these observations, the average annual, maximum daily and minimum monthly water discharge series were compiled, and their genetic and statistical analysis was performed. The series of observations involved in the analysis are representative, since their minimum length is 55 years and they contain several wet and dry periods.

The analysis of synchronous fluctuations of discharge series was carried out using the difference integral curves. To assess linear trends in series of water discharge, the criterion of significance of sample correlation coefficient (R) was used at a significance level of $2\alpha = 5\%$ (t-test) for the dependences $Q = f(t)$. The Student and Fisher tests were used to check the series for homogeneity. The Pearson Type III distribution curves was used to calculate the probability values of annual runoff, Gumbel distribution of maximum runoff and Weibull distribution of minimum runoff. The statistical parameters of the observation series were evaluated by the L-moments method.

When assessing the impact of climate change on river flow, 1961-1990 was taken as the main base period for information on air temperature, precipitation and water discharge, and a comparative method was used.

The ecological flow of the Alijanchay was assessed according to a method based on various hydrological methods and a holistic approach. The holistic method was developed as part of the Kura II Project funded by the United Nations Development Program and the Global Environment Facility for 2017-2021 and used the results of field research on the hydrological regime and hydromorphology of the river, physical and chemical indicators of river water, river fauna species and water use.

DİSCUSSİON OF RESULTS

Taking into account the Gayabashi station on Alijanchay was closed in 2014 and a severe drought was observed in the country in 2011-2021, attempts were made to extend the annual, seasonal, monthly, maximum and minimum water discharge series of the river by using the hydrological analogy method. However, it was not possible to extend the existing series because the correlation coefficients of the relationship between this water discharge and the corresponding water discharge of neighboring rivers are small. For this reason, the homogeneity, stationarity, parameters of distribution functions and the quantities of different iterations of water discharge of the river were assessed according to the observations performed until 2014.

Figure 3 shows the difference integral curve of the average annual water discharge of the river.

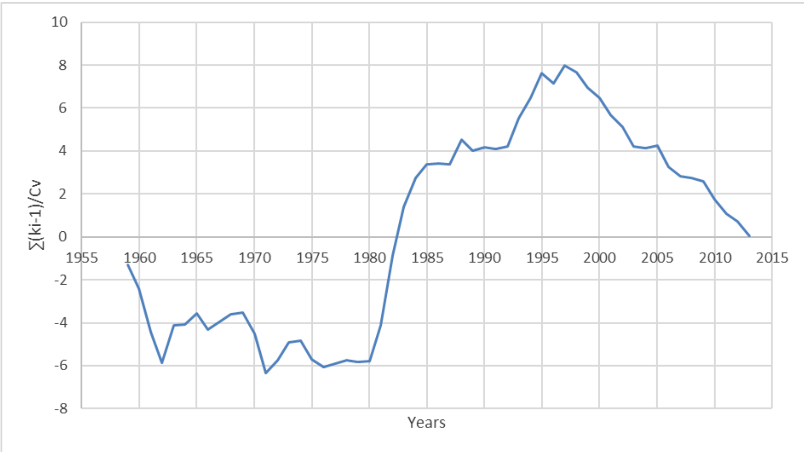

Fig3. The difference integral curve of the average annual water discharge of the river

In this graph, three different periods are clearly distinguished:

1959-1980 - medium periods (average annual water discharge 5.06 m^3 / s (160 million m^3));

1981-1997 – wet periods (average annual water discharge 6.82 m^3 / s (278 million m^3));

1998-2013 – dry periods (average annual water discharge is 4.73 m^3 / s (149 million m^3)) (Table 1).

Table 1

Statistical parameters of different periods (Alijanchay - Gayabashi)

Parameters	1959-1980	1981-1997	1998-2013	1959-2013
Number of years of observation	20	17	16	53
Mean of annual water discharge	5.06 m^3/s	6.82 m^3/s	4.73 m^3/s	5.52
Relative error of mean	6.9 %	5.6 %	2.8 %	4.0 %
Standard deviation	1.56 m^3/s	1.6 m^3/s	0.52 m^3/s	1.59 m^3/s
Coefficient of variation	0.31	0.23	0.11	0.29
Relative error of the coefficient of variation	16.6 %	17.6 %	17.8 %	10.1 %

According to the existing standards adopted in Azerbaijan, the mean of the observation series and the relative error of the coefficient of variation (or standart deviation) should be less than 10% and 15%, respectively (Determination...2004; Sikan, 2007). As can be seen from Table 1, both requirements are met for a complete observation series. This means that the mean annual water discharge of Alijanchay (Gayabashi gauge) can be considered as representative.

The relative error of mean for each of the different periods is 2.8-6.9% and less than 10%. The relative error of the standart deviation varies between 16.6-17.8%. This is explained by the multiplicity of fluctuations in the series of hydrological observations.

The criterion of significance of the sample correlation coefficient *(R)* for the dependences $Q = f(t)$ was used to assess linear trends in the series of water discharges. The hypothesis of the absence of a trend was not refuted if the term was given by

$$|R| < t_{2\alpha}\sigma_R, \quad (1)$$

where

$t_{2\alpha}$ – theoretical value of Student's statistic at significance level $2\alpha = 5\%$;

σ_R – standard error of the correlation coefficient, calculated by the formula:

$$\sigma_R = \sqrt{\frac{1-R^2}{n-2}}, \quad (2)$$

The linear trend of average annual water discharge of Alijanchay (Gayabashi gauge) is shown in Figure 4.

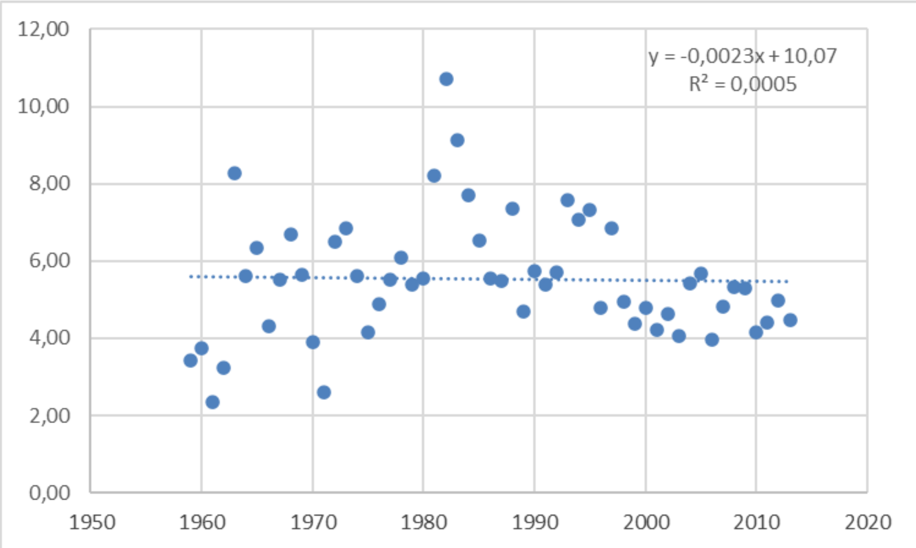

Fig. 4. Linear trend of average annual water discharge of Alijanchay (Gayabashi station)

The results of the assessment of the stationarity and homogeneity of the series are given in Table 2. As can be seen from this table, the homogeneity of the series of maximum water discharge is rejected by both the average and the dispersion, and the series is non-stationary.

Table 2

Cases of rejection of the hypothesis about the homogeneity and stationarity of the series of the runoff (rejection is marked with a "+" sign)

Flow characteristics	Criterion		
	Significance of the trend	Student's test	Fisher's test
Annual flow	-	+	-
Maximum flow	+	-	-
Minimum flow	-	+	+

The statistical parameters of the observation series were evaluated by the L-moments method (Hosking, 1990) and the results obtained are given in Table 3.

Table 3

Statistical parameters of water discharge series of Alijanchay (Gayabashi station)

Flow characteristics	**Statistical parameters**			
	Mean annual water discharge, m^3/s	**Standart deviation, m^3/s**	**Coefficient of variation**	**Skewness**
Average annual water discharges	5.52	1.59	0.29	0.80
Maximum daily water discharges	26.4	21.5	0.82	3.81
Minimum daily water discharges	1.63	1.14	0.70	0.87

Various distribution functions were used to smooth and extrapolate the empirical probability curves: Pearson type III distribution for average annual water discharge; Gumbel distribution for maximum water discharge and Weibull distribution for minimum water discharge (David A. Chin, 2006).

Figure 5 shows the empirical and analytical probability curves of average annual water discharge.

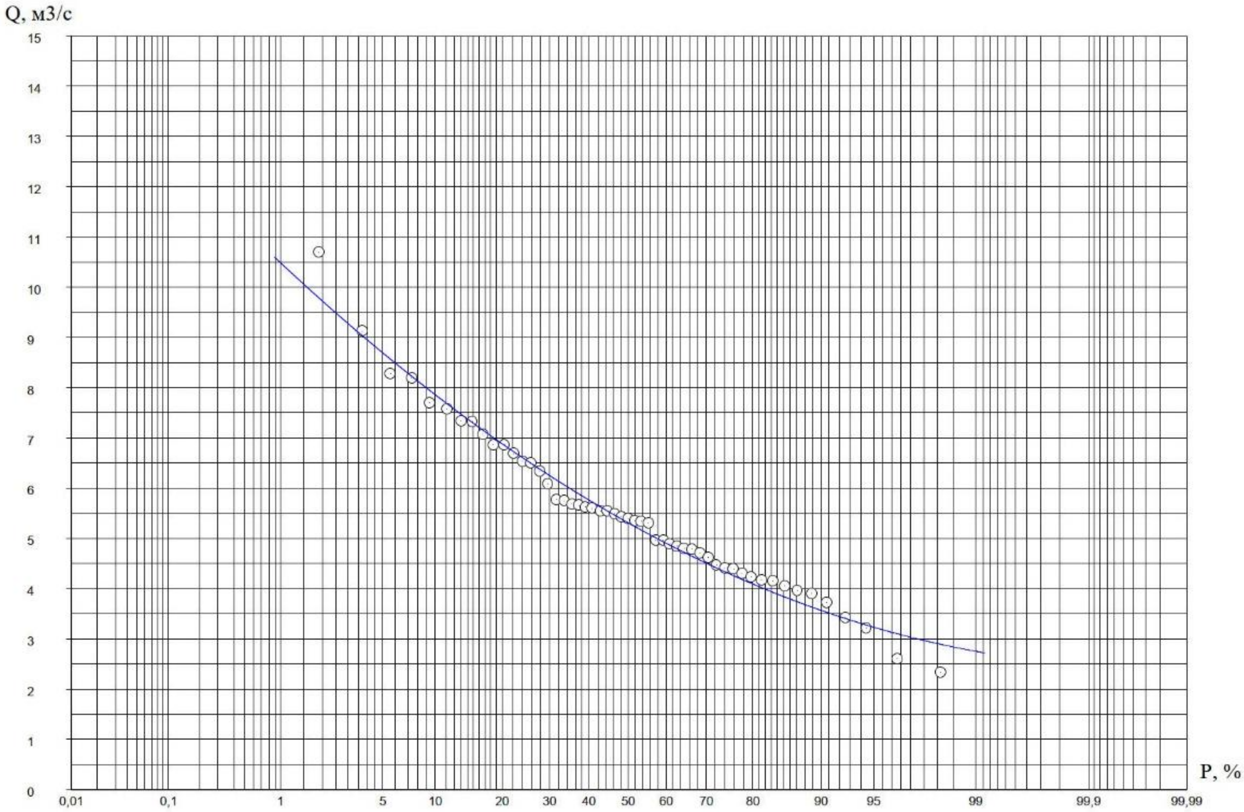

Fig. 5. Empirical and Analytical Probability Curves of average annual discharge

The diffrent probability values were given in Table 4.

Table 4

The different probability values of discharges

Flow characteristics	Exceedance probability, %											
	0.01	**0.1**	**1**	**2**	**5**	**10**	**20**	**50**	**75**	**90**	**95**	**99**
Annual water discharge, m^3/s	-	-	10,5	9.75	8,70	7,90	6,90	5,40	4,30	3,60	3,10	2,80
Maximum water discharge, m^3/s	317	193	158	87.1	66.0	53.0	34.3	19.8	15.8	10.6	6.60	5.20
Minimum daily water discharge, m^3/s	-	-	5,60	4,80	4,15	3.14	2.60	1,40	0.75	0.35	0.20	0.12

The average monthly water discharge and flow volumes of the Alicanchay for the long-term period were also calculated (Table 5).

Table 5

Average monthly water discharges and flow volumes of Alicanchay for long-term period

Flow characteristics	Months												Total annual
	X	**XI**	**XII**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	
Water discharge, m^3/s	5,08	4,95	4,47	4,12	4,45	5,54	7,35	8,05	7,67	5,04	4,51	5,02	5,52
Flow volume, mln m^3	13,61	12,84	11,99	11,04	10,77	14,85	19,04	21,57	19,89	13,49	12,08	13,00	174

The main part of the annual flow of the river passes in April-June. For the remaining months, the river flow is approximately evenly distributed.

All of the above results are based on observed water discharge. However, recently the climate in Azerbaijan has been changing. Over the last 28 years (1991-2018), the average annual temperature in the country increased by 0.9-1.1°C compared to the base period (1961-1990), and the amount of precipitation decreased by an average of 4.4% (Taghiyeva & Verdiyev, 2020).

According to the Oghuz meteorological station located in the Alijanchay basin, the temperature increased in all seasons, the largest increase was recorded in the summer (1.5°C), and the average annual temperature increase was 1.0°C. Precipitation, on the other hand, decreased in all seasons, and the annual precipitation decreased by 14.5%.

As a result of changes in temperature and precipitation, the annual flow of the river decreased by 11.26% in 1991-2013 compared to 1961-1990. In 2020-2070, the annual flow of rivers in the Greater Caucasus region, where the Alijanchay basin is located, is projected to decrease by 10-15% (Taghiyeva & Verdiyev, 2020).

Observations on the suspended load at the Gayabashi point of the river were made only in 1962. In that year, the average annual water discharge of the river was 3.22 m^3/s, and the suspended load discharge was 1.80 kg/s. Taking into account that the average long-term water discharge is 5.52 m^3/s, the average long-term value of the suspended load flow was calculated according to the ratio method and was determined to be 3.09 kg/s or 97.4 thousand tons.

The main part of the sediment flow in the rivers of Azerbaijan is the suspended load. Bed load dischage in Alijanchay has never been measured. However, recent studies of other rivers in the region where this river basin is located have shown that bed load flow is 35% of the suspended load flow (Akhundov, 1978). Taking this into account, the average long-term sediment flow is 131.5 thousand tons (97.4 thousand tons of suspended and 34.1 thousand tons of bed load).

Particular attention was paid to the calculation of the ecological flow to be discharged from the reservoir to downstream. Thus, inefficient use of water resources has a negative impact on the ecological condition of rivers, disrupts the metabolism and energy in river ecosystems. Changes in the hydrological regime of the river are ultimately reflected in the biotic characteristics of the ecosystem (Ecological flows.... 2015; Imanov and et al., 2017). The ultimate goal in ensuring ecological flow is to improve the river's environmental condition (the "ecological status" of the river according to the EU Water Framework Directive) by minimizing the negative effects of river water changes (EU Water..., 2000).

At present, there is no normative document in Azerbaijan to assess the ecological flow of rivers. Taking this into account, the ecological flow of the river was determined by six hydrological methods (Montana method, 7Q10, Q95%, etc.) and one holistic method. Hydrological methods are widely used in international practice due to their simplicity (only hydrological data are required) and low cost (no need for field research) (Ecological flows.... 2015).

The Kura II Project ("Advancing Integrated Water Resource Management (IWRM) across the Kura river basin through implementation of the transboundary agreed actions and national plans") funded by the United Nations Development Program and the Global Environment Facility was implemented in Azerbaijan and Georgia in 2017-2021. Within the framework of this project, a method based on a holistic approach was developed to assess the ecological flow in the Alijanchay basin. According to this method, the regime of ecological flow is determined by three components:

1. Survival flow. This flow volume is accepted to be equal to the minimum daily water discharge observed in the driest years (Q95% or Q350);
2. Low flows. This amount of flow is necessary to ensure the types of biological indicators and their living conditions, environmental processes, as well as important social and cultural functions. The duration of low water period is one to six months (Q75% or Q270);
3. High flows (Maximum discharge with at least 5 days duration). These water uses to support the morphology of the river bed and the ecosystems of the river basin (Q8% or Q30).

The values of these components for Alicanchay (Gayabashi point) are 1.11, 2.60 and 8.90 m^3 /s, respectively (Figure 6).

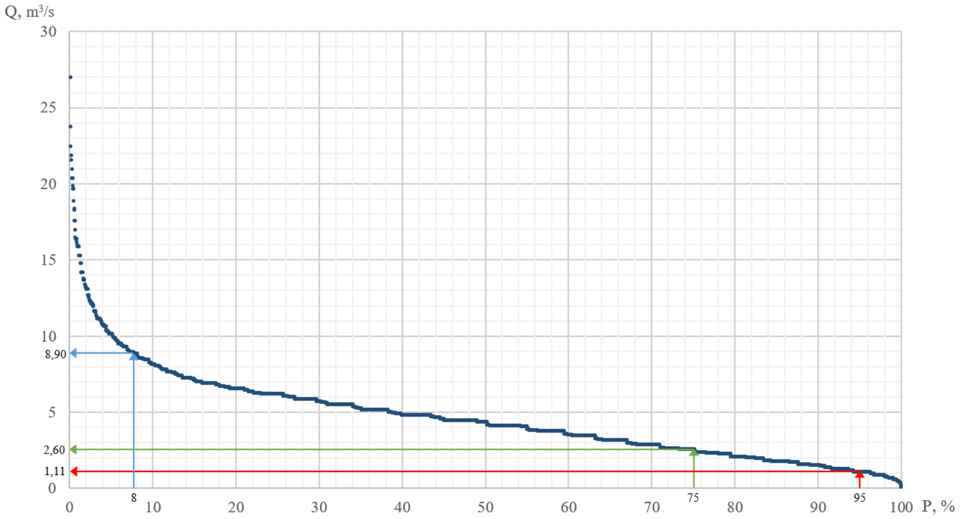

Fig. 6. Flow-duration curve of daily water discharges (Alijanchay - Gayabashi)

It was determined that the values of ecological flow calculated by various methods vary between 23.7-57.0 million m^3 or 13.6-32.9% of the annual flow. The amount of ecological flow determined by the holistic method (27.7% of the annual flow) was proposed for the reservoir project. However, taking into account that the annual flow of the river will be reduced by 10-15% during the operation of the reservoir to be built on the Alijanchay, the amount of ecological flow should be reduced accordingly.

CONCLUSIONS

As a result of the study, it was determined that the average long-term flow of the Alijanchay is 174 million m^3. The average annual temperature in the river basin has recently increased by 1.0°C, and annual precipitation has decreased by 14.5%. Due to climate change, the annual flow of the river decreased by 11.26% in 1991-2013 compared to 1961-1990, and the homogeneity and stationaryness of the range of maximum water discharge was broken. The main part of the annual flow of the river passes in April-June. The average annual sediment flow is about 131.5 thousand tons. The amount of ecological flow was calculated by different methods, and its quantity was proposed according to the holistic method for the design of the reservoir. Based on the calculations made and taking into account that the annual flow of the Alijanchay will decrease by 10-15% in 2020-2070, the main parameters of the reservoir to be built on the river and the amount of ecological flow have been determined.

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Earth sciences

ANALYTICAL HIERARCHY PROCESS (AHP) FOR RESEARCH OF LANDSLIDE HOTSPOT ON THE TERRITORY OF TSAGERI MUNICIPALITY (RACHA-LECHKHUMI AND KVEMO SVANETI REGION, GEORGIA)

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Annotation. The Analytic Hierarchy Process (AHP) using geographic information systems (GIS) and remote sensing technologies is often used to assess and conduct detailed monitoring of landslide-prone areas to support risk reduction and preparatory planning for disaster management.

In our analytical hierarchy process model, the Normalized Difference Vegetation Index (NDVI) component is represented as a block. Using the vegetation index of the normalized difference, we conducted a ten-year study of the study region - Tsageri municipality.

Based on the research, we obtained an empirical approach to the dynamics of the vegetation index of the normalized difference, which allows us to use the predictive change of the vegetation index of the normalized difference in connection with atmospheric precipitation, which is very important in the context of the current global warming.

The analytical hierarchy process of the new landslide focus research, that we have adopted, allows to obtain more accurate data on the origin of the landslide occurring points, which allows us to preselect appropriate engineering measures to combat landslides and ensure the safety of populated areas and infrastructure located in risk zones.

Keywords: Landslide, erosion, Analytical Hierarchy Process (AHP), Geographic Information Systems (GIS), Digital Elevation Models (DEM), Normalized Difference Vegetation Index (NDVI).

INTRODUCTION

A landslide is a geological phenomenon characterized by the collapse of rock, soil and debris down a sloped section of land. Landslides can be triggered by several factors, including heavy rains, earthquakes, volcanic activity, human activity, and changes in slope stability (erosion). Landslides can have serious consequences, causing damage to infrastructure, loss of life and environmental destruction.

Analytical Hierarchy Process (AHP) using Geographic Information Systems (GIS) and remote sensing technologies is often used to assess and monitor landslide-prone areas, helping to reduce risk and plan for disaster preparedness.

The Analytic Hierarchy Process (AHP) is a structured decision-making methodology developed by Thomas L. Saaty. It is a mathematical and analytical approach used in decision making to solve complex problems. AHP facilitates decision-making that involves multiple criteria and alternatives. It is used to divide the problem into a hierarchical structure and to determine the relative importance of small criteria and alternatives.

AHP can be implemented using software such as Thomas L. Saaty's Analytic Hierarchy Process - (AHP); GIS tools such as ArcGIS, QGIS or other specialized landslide vulnerability assessment mapping software.

Using AHP for landslide hazard mapping in GIS provides a robust and systematic approach that integrates spatial data and expert judgment to develop valuable insights and insights for landslide risk analysis, land use planning and management.

MAIN PART - STUDYING THE PILOT AREA

Study area - Tsageri municipality is located in the southeastern part of Racha-Lechkhumi and Kvemo Svaneti. It is bordered by Lentekhi municipality from the north, Martvili municipality from the west, Tskaltubo and Khoni municipalities from the south, Ambrolauri municipality from the east. The area of the municipality is 755.4 km². The average height of the municipality is 540 m above sea level.

Photo 1. Satellite view of Tsageri municipality

Climate

The municipality belongs to the maritime subtropical humid air region, where the air temperature and atmospheric precipitations change dramatically depending on the altitude.

The climate of Tsageri municipality is humid, the average annual air temperature is 15^0C, the maximum possible is 40^0C, and the minimum - 12^0C. The average annual rainfall is 1,020 mm.

The maximum amount of precipitation occurs in autumn, the minimum in summer. In the mountainous part, the air temperature drops, and the amount of precipitation increases and reaches 2000 mm in the highest places.

Topography and soils

It should be noted that the entire territory of the municipality belongs to the mountainous zone and is characterized by difficult landscape-climatic conditions, due to which it is unevenly utilized and settlements are mainly located in river valleys. The relief is strongly divided by the tributaries of rivers Lajanur, Rioni, Tskhenistskali, Jonouli and Rachkhi, which creates conditions for the creation and formation of floods and landslides.

As is known, the municipality is one of the most vulnerable areas in terms of geological hazards and climate changes and is characterized by debris flows, landslides and erosive processes, floods and groundwater inundation.

Hydrology

Surface and underground water resources in Tsageri municipality are moderate. There are no wetlands in the municipality. The main rivers are Rion and Tshnistskali. The largest tributary of Rion is Janoula, and the largest tributary of Tshnisskali is Lajanura.

Table 1

Characteristics of the main rivers passing through the territory of Tsageri municipality

Name of river	Length of the river, km	Water catchment area, km^2	Belonging
Rioni	333	13400	Black Sea Basin
Tskhenistkhali	176	2120	Black Sea Basin

Rivers are fed by rain, snow and groundwater. The rivers Tskhenistkali and Rioni in the upper reaches are also fed by the melt water of the glaciers. Some of the small rivers have a karst regime, some have a torrential nature. Rivers flood in spring, water falls in summer-autumn.

The city of Lentekhi is distinguished by the special activity of the waterfalls of Tshnisskali itself and its tributaries Khledula-Laskadura basins.

Flora

The main part of the territory of Tsageri municipality is occupied by forests (47,000 ha). There are industrial, subalpine and floodplain forests in the administrative unit.

Vegetation is mainly distributed in the form of altitudinal zones. In the lower part, there is a Kolkhi forest, in the undergrowth of which we find both deciduous and evergreen bushes. In the southern part there are remnants of a chestnut tree.

The foothills are dominated by beech and hornbeam forests, which have been greatly reduced due to frequent settlement and land use. There are mixed and coniferous forests on the mountain slopes. Among deciduous forest the oak-shrub, beech, brushwood predominates; Among coniferous forest - spruce, fir, pine.

RESEARCH METHODOLOGY - ANALYTIC HIERARCHY PROCESS (AHP)

Analytic Hierarchy Process (AHP) is a decision-making methodology based on pairwise comparisons of fundamental components. The process involves the systematic comparison of elements of a decision hierarchy to determine their relative importance, and it is often used to identify landslide-prone regions. The AHP method includes the following steps:

- **Determination of criteria and sub-criteria:** identification of landslide factors.
- **Determination of weight:** each criterion and sub-criterion is assigned a weight according to the importance of their influence; A comparison is used to determine the value of the criteria.
- **Data collection and preparation:** Collection of spatial data related to each criterion. It includes the collection of geological maps, satellite imagery (DEM), climate data and land use information; Data standardization and preprocessing to ensure interoperability and consistency.
- **Compile a matrix for each pair of criteria and sub-criteria** that determines their importance to calculate the weight of each criterion and sub-criteria.
- **Spatial Data Integration:** Combining weighted criteria to create a composite landslide hazard map, using GIS (Geographic Information System) tools to overlay and integrate spatial data layers.
- **Validation:** validation of the sensitivity map using historical landslide data (if possible); Statistics such as the area under the ROC curve (AUC) to evaluate the accuracy of the model.

For our study, we use a value scale to express preference or strength of value (Table 2). The block diagram of the study is given in Fig. 1. Drawing up a descriptive map of landslide vulnerability (using the AHP method).

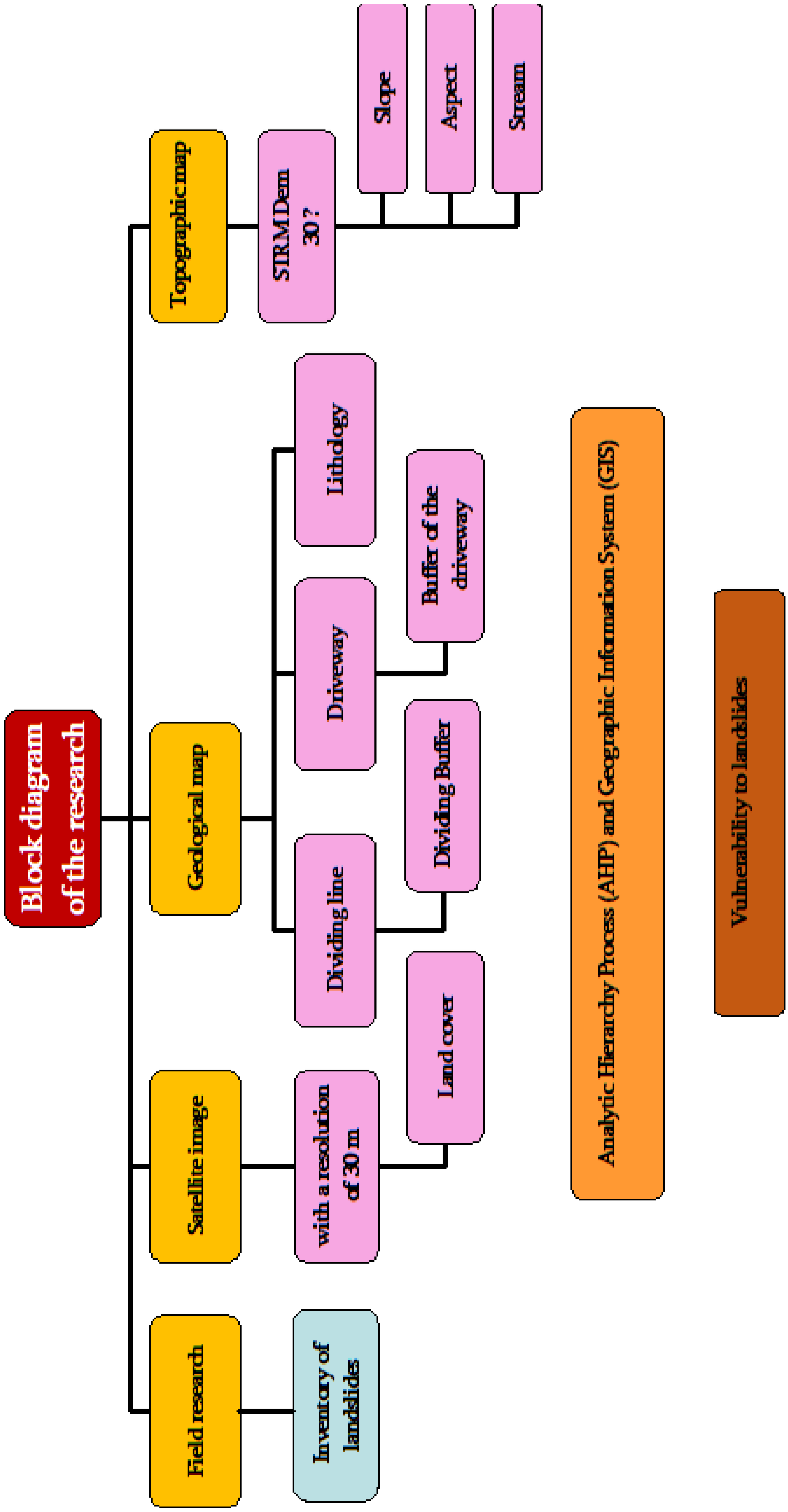

Fig. 1. Descriptive map of landslide vulnerability (diagram)

Table 2

Description of the pairwise comparison scale within the Analytic Hierarchy Process (AHP)

Values	Description	Definition
1	Equal importance	Two factors are involved equally
3	Moderate preference of one over another	Experience and judgment favor one factor slightly or moderately over another
5	A strong or significant advantage	Experience and judgment strongly favor one factor over another
7	A very strong or marked advantage	The activity has a clear advantage over the other and its dominance is manifested in practice
9	Extremely high advantage	Evidence in favor of one activity over another has the highest possible degree of support
2, 4, 6, 8	Intermediate values	Used when accessibility is required

n	1	2	3	4	5	6	7	8	9	10
RI	0.0	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

RESULTS AND DISCUSSIONS

According to our proposed research methodology, first of all, we find the slope (slope) of the study area (area) using STRM DEM (30 m resolution), which corresponds to the digital model of (terrain) heights generated by the data collected by the Shuttle Radar Topographic Mission, where each pixel of the grid represents a 30m/30 m area on the Earth's surface. This type of DEM model is useful for a wide range of applications, including topographic mapping, hydrologic modelling, and environmental studies.

Based on the goals of our research and to obtain accurate data of the terrain of the research object (Slope), Digital Elevation Models (DEM) were processed using ArcGIS (see Fig. 2).

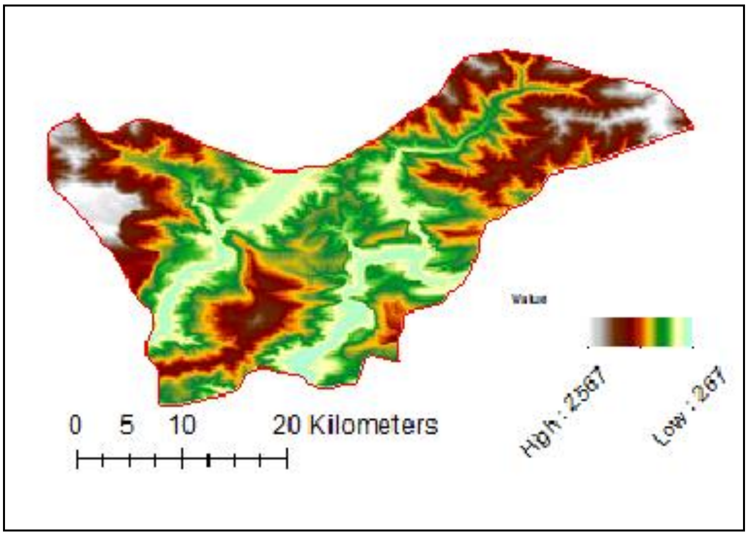

Fig. 2. Digital Elevation Model (DEM)

In order to determine an accurate picture of the distribution of landslide events and to identify landslide foci, we studied and classified the topography of the study region through ArcGIS software (see Fig. 3).

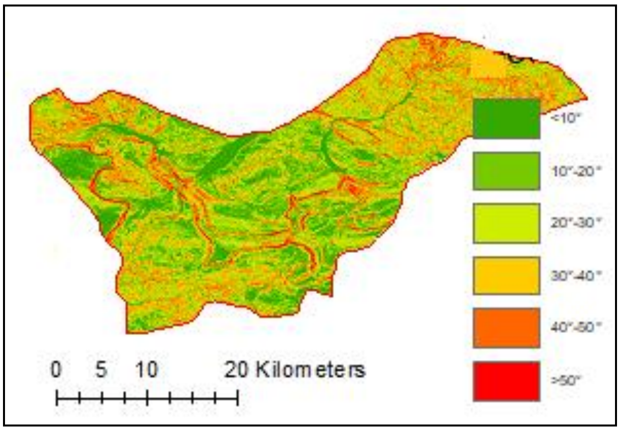

Fig. 3. Topography of the study region

As a result of the study, it has been revealed that a large part of the research area is represented by Jurassic-type plants (water catchment of the river Rioni), and the river Lajanura flows mainly in Proterozoic sediments. Consequently, studying the resistance to erosion of these two sub-basins requires different approaches. Fig. 4 shows the lithological map of the study region.

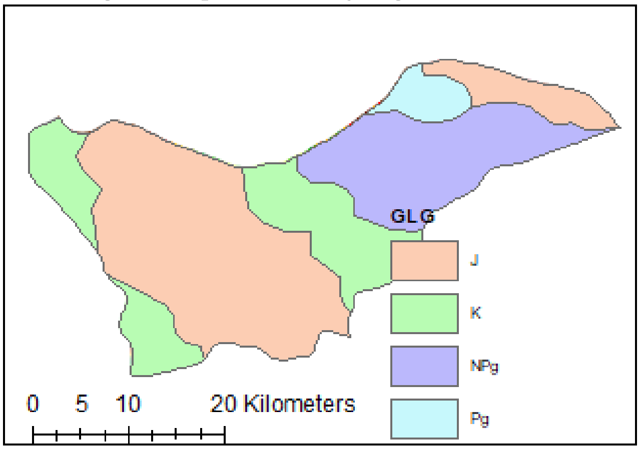

Fig. 4. Lithological map of Tsageri municipality

As for the soils of the study area, there are alluvial soils at the bottom of the Tsageri basin. On the slopes of the mountain, the forest cover and sod-carbonate soils prevail. In the high mountains, the open and decomposing forests of the upper belt of the mountain forest, as well as sod and sod-peat mountain meadow soils prevail. Steep, rocky areas are completely devoid of soil cover. For our studies, we used the soil classification proposed by FAO (see Fig. 5).

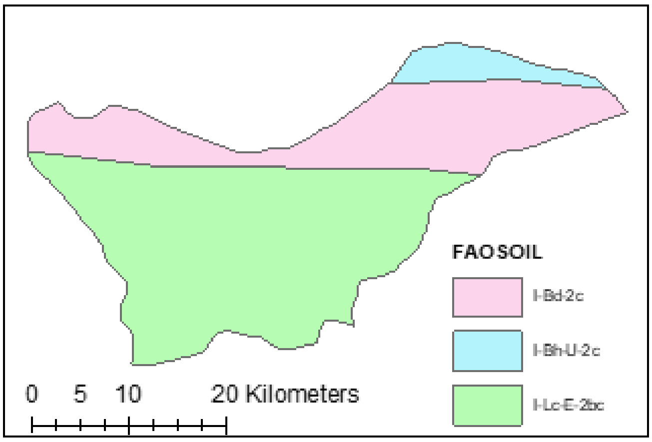

Fig. 5. Soil map of Tsageri municipality (according to FAO classification)

For our study, annual mean atmospheric precipitation data were processed based on official NASA data. The average annual atmospheric precipitation in Tsageri municipality in 2011-2020 was studied. The obtained data are given on the Fig. 6.

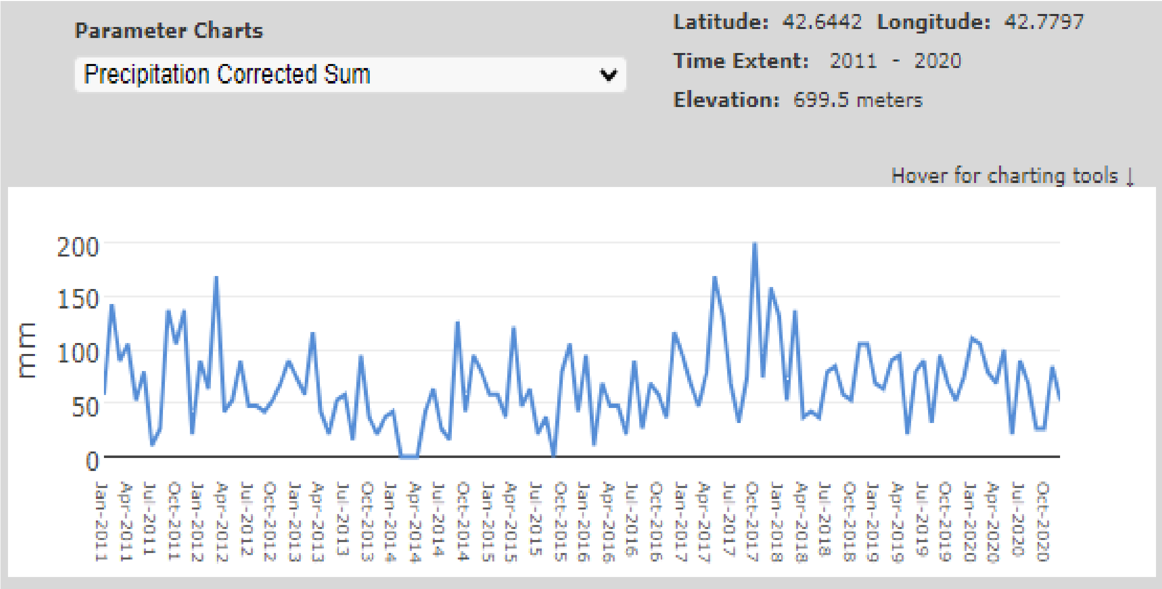

Fig. 6. Average monthly atmospheric precipitation (2011-2020)

As a result of data processing, it was found that atmospheric precipitations in the study area are unevenly distributed throughout the year and the maximum occurs in autumn-spring periods. Therefore, in the same period, the formation of abundant surface runoff and the activation of erosion-flood and landslide events are likely.

In order to study the mechanical impact of surface runoff on solid particles in the region, we have studied the hydrological network of Tsageri municipality in detail using GIS technologies.

A 30 m resolution DEM - digital terrain model (coordinate system D_WGS_1984) obtained from the SRTM of the region (Shuttle radar topographic mission - Shuttle radar topographic mission) was used for modelling, based on which the characteristics of the hydrological network located in the research area were determined.

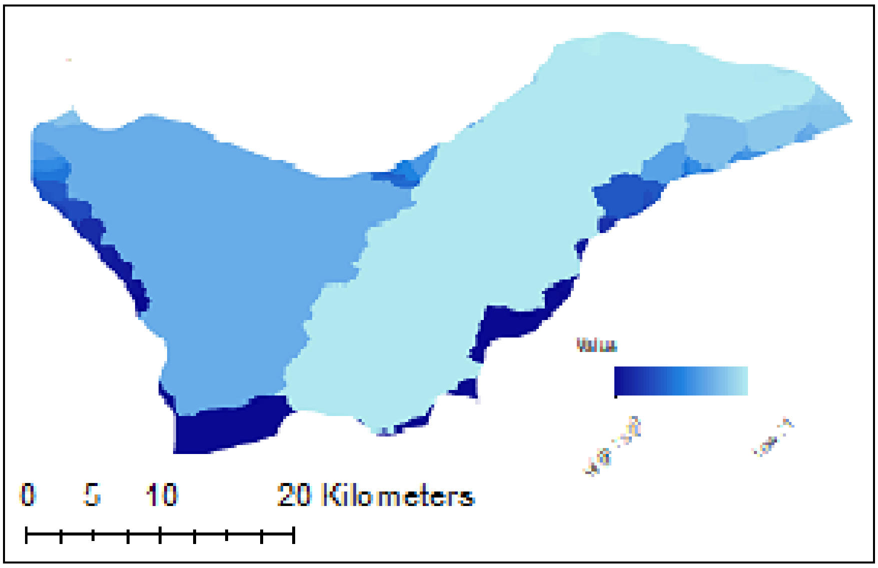

Fig. 7. Water catchment basins of Tsageri municipality

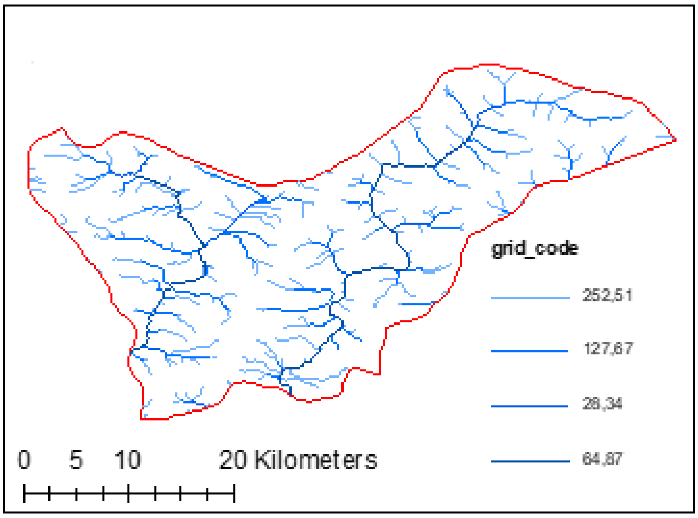

Fig. 8. Hydrographic network of Tsageri municipality

Figure 8 shows the hydrographic network of Tsageri municipality, and Figure 9 represents the classification of streams according to water abundance.

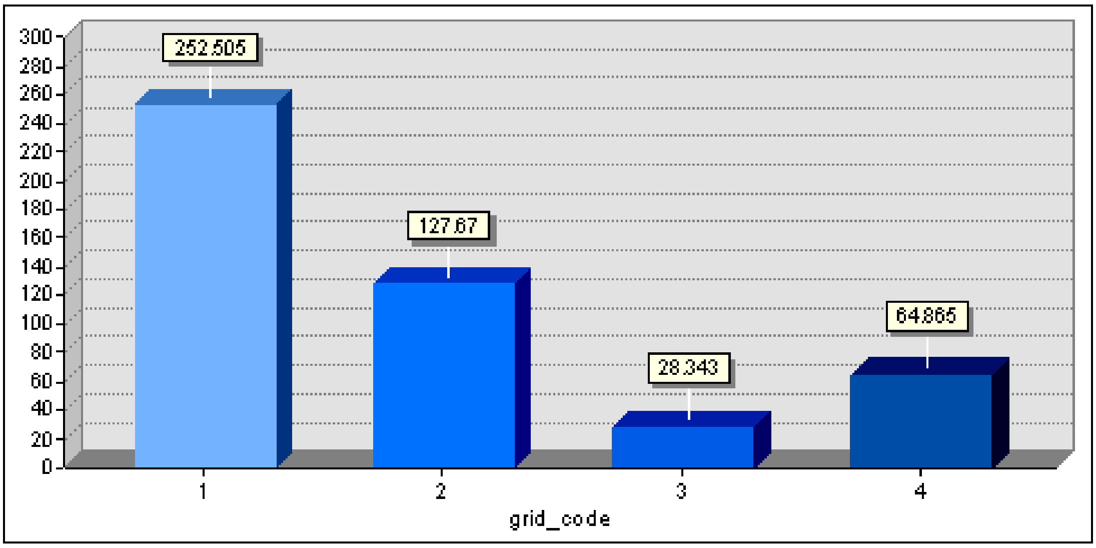

Fig. 9. Classification of streams according to water abundance

Based on the conducted studies, we can conclude that the most erosive in Tsageri municipality are the valleys of Rion and Tskhenistskali rivers. In addition, after using the DEM - terrain digital model and classifying the surface runoff by the Strahler method, the hydrographic network is divided into 4 rows according to water abundance: the total length of the first row (the smallest tributaries) is 252.54 km; second row - 121.67 km; third row - 28.34 km, and the wateriest section is forth row - 64.87 km. The length of the entire river system with its tributaries is 473.39 km.

Based on the goals of the research, we studied the Normalized Difference Vegetation Index (NDVI) of the research area.

For NDVI analysis, we used only 2 layers - Red & Near Infrared (Red & NIR) USGS, Landsat8:

- Band 4 – Red - wavelength 0.64-0.67. Used to outline vegetation slopes on the map;
- **Band 5** - Near Infrared (NIR). - Wavelength 0.85-0.88. Used to determine biomass volume and boundaries.

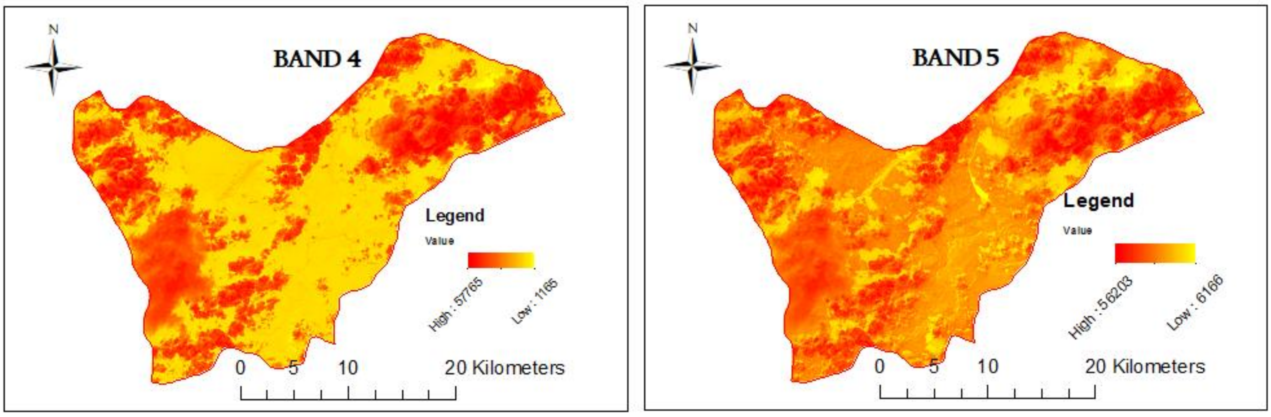

Fig. 10. Band 4 - Red and Band 5 - Near Infrared (NIR)

The Normalized Difference Vegetation Index (NDVI) is calculated with the following equation:

$$NDVI = (NIR - \mathrm{Re}\,d)/(NIR + \mathrm{Re}\,d). \qquad (1)$$

For Landsat 8 data:

$$NDVI = (Band\ 5 - Band\ 4)/(Band\ 5 + Band\ 4) \qquad (2)$$

The GIS equation for determining NDVI looks like this:

$$Float("dem\_b5\_2013" - "dem\_b4\_2013")/Float("dem\_b5\_2013" + "dem\_b4\_2013") \qquad (3)$$

and

$$Float("dem\_b5\_2020" - "dem\_b4\_2020")/Float("dem\_b5\_2020" + "dem\_b4\_2020") \qquad (4)$$

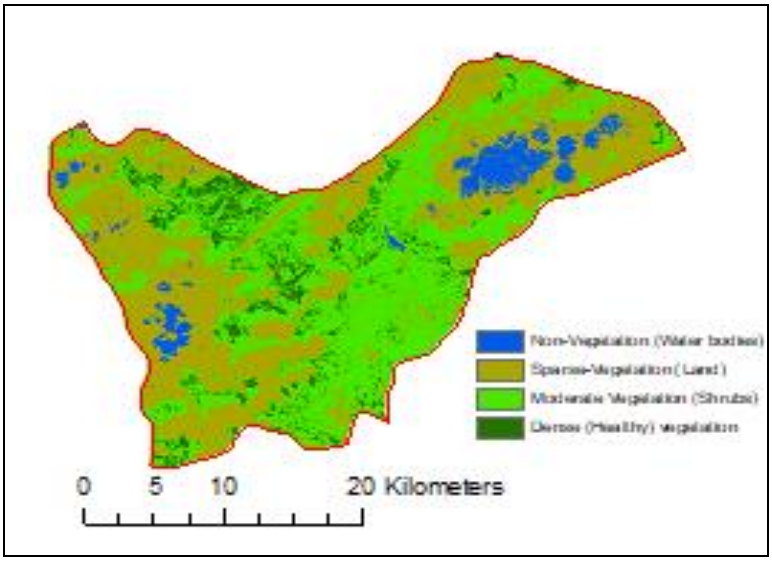

Fig. 11. Values of NDVI

NDVI values were calculated with the help of "raster calculator" (Fig. 11). The value of NDVI varies from -1 to 1. A high NDVI value reflects the NIR and indicates dense vegetation. The classification of the obtained results has the following form:

NDVI = from -1 to 0 – Water - Non-Vegetation;
NDVI = from -0.1 to 0.1 - rocks, earth, sand or snow (Sparse-Vegetation);
NDVI = from 0.2 to 0.5 - Shrubs and herbaceous vegetation or moist vegetation (Moderate Vegetation);
NDVI = from 0.6 to 1.0 - Dense (healthy) vegetation cover (Dense-Vegetation).

At the 2nd stage of solving the problem, we find the "Aspect" of the research area. It indicates the direction of the slope of the rock. "Aspect" is measured in degrees clockwise from true north, and typically ranges from 0 to 360 degrees, where 0 degrees is north, 90 degrees is east, 180 degrees is south, and 270 degrees is west (see Figure 12).

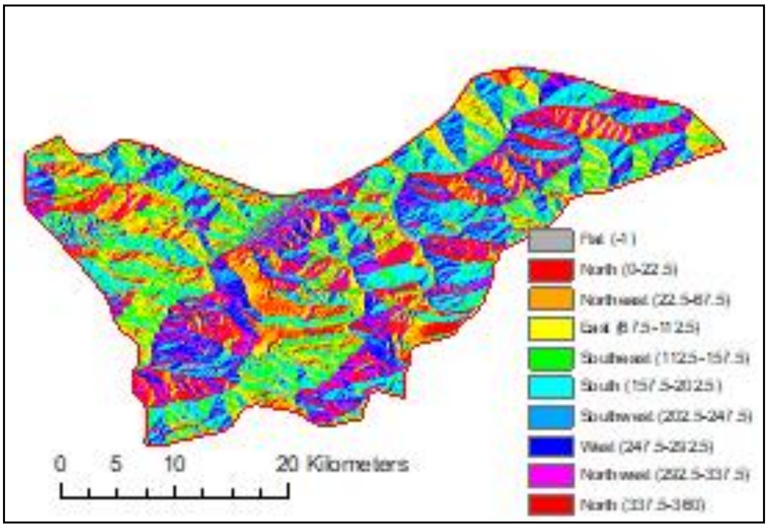

Fig. 12. "Aspect" of the study region

The 3rd stage of our research is the search (fixation) of streams and stream buffer zones in the study area. For this reason, we also use DEM (30 m resolution) and ArcGIS (the so-called "Hydrological Toolbox"). Buffering in GIS classifies a space into two zones, one within a specified distance from the selected feature and the other outside it. The zone within the limits of the specified distance is called the buffer zone.

In GIS and spatial analysis, we use Euclidean distance to calculate the straight-line distance between points. It is particularly useful in situations where the terrain is relatively flat and an approximation of straight-line distance is acceptable.

We determined the buffer zones of the surface flows of the study region in the radius of 200, 400, 600, 800, 1000 and 1100 m (Fig. 13). The purpose of this is to determine the areas vulnerable to water erosion, transit, and accumulation areas of solid sediment. Based on this, it is possible to fix the potential occurring point of landslides and mudslides and to predict the future.

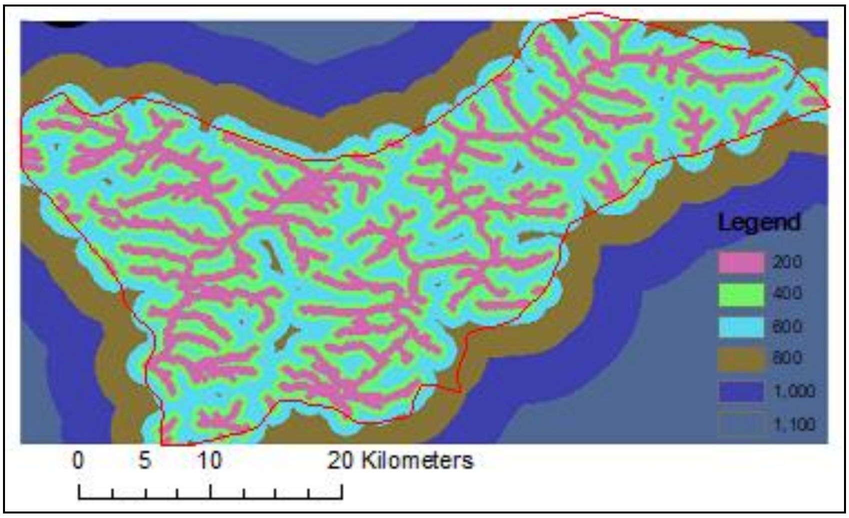

Fig. 13. Stream Buffer

CONCLUSIONS

In Analytic Hierarchy Process (AHP), land cover research, the given diagram did not provide accurate information regarding future prediction.

In the analytic hierarchy process model developed by us, we include the Normalized Difference Vegetation Index (NDVI) component as a “Block”. We conducted a 10-year study of the study region by means of the normalized difference vegetation index.

Based on the research, we obtained an empirical approach to the dynamics of the NDVI, which allows us to use the predictive change of the NDVI in connection with atmospheric precipitation, which is very important in the context of the current global warming. The AHP for new landslide focus research, that we have adopted, allows to obtain more accurate data on the origin of landslide occurring points. This allows us to pre-select the appropriate engineering measures to combat landslides and ensure the safety of populated areas and infrastructure located in risk zones.

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Hydrology and meteorology

MATHEMATICAL MODELING OF TORRENT INFLOW INTO A RESERVOIR USING THE NUMERICAL SOLUTION OF THE TWO-DIMENSIONAL (2D) EQUATION OF SMALL-AMPLITUDE WAVE THEORY

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Annotation. The article refers to the two-dimensional (2D) ultimate problem of the torrent inflow potential movement and non-dimensional feature on rectangle and trapezoidal area.

Keywords: pond; dam; torrent; flood; wave; riverbed; flow; Bottom.

INTRODUCTION

In a narrow and deep reservoir of uniform width, as a result of torrent inflow on the bottom, it is possible to generate a long wave of the type of extreme alluvial tsunami. Since in this case the transverse component of the velocity is practically zero in relation to the vertical and longitudinal (along the riverbed) velocity, Therefore, for the calculation of such extreme wave characteristics, it is better to consider the two-dimensional (2D) problem of small-amplitude wave theory only in the vertical XoZ plane.

MAIN PART

With such an assumption, the following equations:
The continuity equation

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right)\varphi(x,y,z,t)=0$$

Free surface condition

$$-\frac{\partial}{\partial z}\varphi(x,y,z,t)\bigg|_{z=0}=\frac{1}{g}\frac{\partial^2}{\partial t^2}\varphi(x,y,z,t)\bigg|_{z=0}$$

It will be simplified and will take the following form:
The continuity equation

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial z^2}\right)\varphi(x,z,t)=0 \quad (1)$$

Kinematic boundary conditions

$$\frac{\partial}{\partial n}\varphi(x,z,t)\bigg|_{z=-h}=v_n(x,z,t) \quad (2)$$

Free surface condition

$$-\frac{\partial}{\partial z}\varphi(x,z,t)\bigg|_{z=0}=\frac{1}{g}\frac{\partial^2}{\partial t^2}\varphi(x,z,t)\bigg|_{z=0} \quad (3)$$

The obtained system of equations can be used for numerical modeling of torrent inflow in mining reservoirs of sufficiently deep, narrow and uniform width. Reviewing the bounded area Ω on the vertical plane oXZ (Fig. 1) with boundary $\partial\Omega = \partial\Omega_1 + \partial\Omega_h + \partial\Omega_2 + \partial\Omega_\eta$, corresponding to the inflow (wet), bottom (solid), outflow (wet) and free surface contours, the boundary condition $\partial\Omega_h$ boundary can be represented by the angle α of the intersection of its boundary sides with the oX axis.

$$\mp\frac{\partial\varphi}{\partial x}\sin\alpha + \frac{\partial\varphi}{\partial z}\cos\alpha = v_n \tag{4}$$

Where:

α	Is the angle of intersection of the tangent of the boundary with the oX axis;
$\alpha = 0, \pi$	Tangent is parallel to oX and $\frac{\partial\varphi}{\partial z} = v_n$ and horizontal velocity is not defined;
$\alpha = \frac{\pi}{2}, \frac{3\pi}{2}$	Tangent is parallel to oZ and $\pm\frac{\partial\varphi}{\partial x} = v_n$ vertical velocity is not defined;
$\pm$	Taken according to the direction of the projection of the normal along the oX axis;
$v_n = 0$	There is a wave reflection at the boundary.

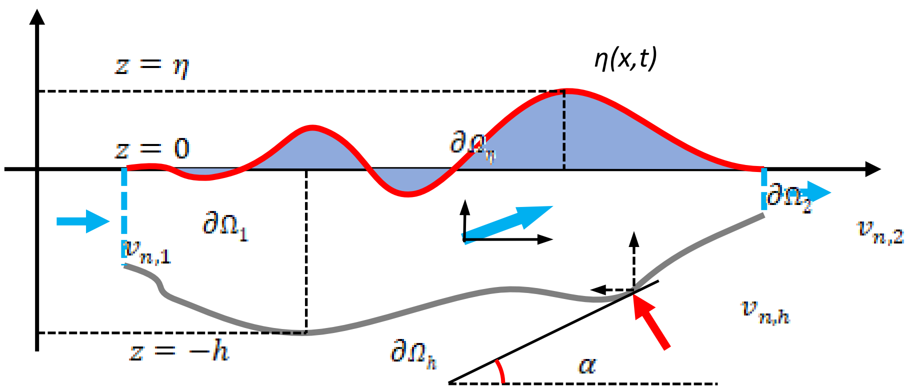

Fig. 1. Calculation scheme for the study of the two-dimensional (2D) wave potential problem on a bounded area

As can be seen from the diagram, the wet boundaries of $\partial\Omega_1, \partial\Omega_2$ are taken parallel to the oZ axis, therefore there are simplified boundary conditions. In particular, the velocity at the boundary $\partial\Omega_1$ has the direction of the normal and the normal has the direction of the oX axis, therefore

$$\frac{\partial}{\partial x}\varphi(x,z,t)\Big|_{\partial\Omega_1} = v_{n,1}(z,t); \;\; v_{n,1} \geq 0$$

Since the direction of the velocity at the boundary $\partial\Omega_2$ is opposite to the direction of the normal and the normal is directed against the oX axis, the flow condition will be

$$-\frac{\partial}{\partial x}\varphi(x,z,t)\Big|_{\partial\Omega_2} = v_{n,2}(z,t); \;\; v_{n,2} \leq 0$$

For transitionto non-dimensional form, assume that $h_0 = h_{max}$ and using non-dimensional parameters:

$$
\begin{aligned}
&x^* = x\frac{1}{M}, \quad z^* = z\frac{1}{M}, \quad t^* = t\frac{1}{S} \\
&\varphi^* = \varphi\frac{S}{M^2}, \quad u^* = u\frac{S}{M}, \quad w^* = w\frac{S}{M} \\
&M = h_0, \quad S = \sqrt{\frac{M}{g}}, \quad \frac{M}{S} = \sqrt{Mg}
\end{aligned}
\tag{5}
$$

Accordingly, equations (1)-(3) including initial conditions and formulas for calculating output parameters will take the following form:

The continuity equation

$$\left(\frac{\partial^2}{\partial x^{*2}} + \frac{\partial^2}{\partial z^{*2}}\right)\varphi^* = 0, \qquad (x^*, z^*) \in \Omega^* \tag{6}$$

Boundary conditions on a free surface

$$\left(\frac{\partial^2}{\partial t^{*2}} + \frac{\partial}{\partial z^*}\right)\varphi^* = 0, \qquad (x^*, z^*) \in \partial\Omega^*, z^* = 0 \tag{7}$$

Boundary condition on solid (wet) boundary

$$\mp \sin\alpha \frac{\partial \varphi^*}{\partial x^*} + \cos\alpha \frac{\partial \varphi^*}{\partial z^*} = v_n^*, \qquad (x^*, z^*) \in \partial\Omega^*, z^* < 0 \tag{8}$$

Initial condition

$$\varphi^*|_{t^*=0, \Omega^* + \partial\Omega^*} = \varphi_0{}^*, \qquad (x^*, z^*) \in \Omega^* + \partial\Omega^* \tag{9}$$

Output parameters

$$\eta^* = -\frac{\partial}{\partial t^*}\varphi^*, \qquad z^* = 0 \tag{10}$$

$$u^* = \frac{\partial}{\partial x^*}\varphi^*, \quad w^* = \frac{\partial}{\partial z^*}\varphi^* \tag{11}$$

$$\left(\frac{1}{\rho}p\right)^* = -z^* - \frac{\partial}{\partial t^*}\varphi^* \tag{12}$$

Similarly to (5), the following formulas are obtained to transfer the results from non-dimensional parameters to dimensional ones:

$$
\begin{aligned}
&x = x^* M \qquad z = z^* M \qquad t = t^* S \\
&u = u^* \frac{M}{S} \qquad w = w^* \frac{M}{S} \qquad \varphi = \varphi^* \frac{M^2}{S} \\
&\eta = \eta^* M \quad \left(\frac{1}{\rho}p\right) = \left(\frac{1}{\rho}p\right)^* \frac{M^2}{S^2}
\end{aligned}
\tag{13}
$$

One of the most important factors when considering the boundary value problem is the approximation of the riverbed shape. The two most common shapes in numerical modeling are the rectangle and the trapezoid (triangle), for which analytical problem statements are available in a number of cases and can be compared with the numerical solution.

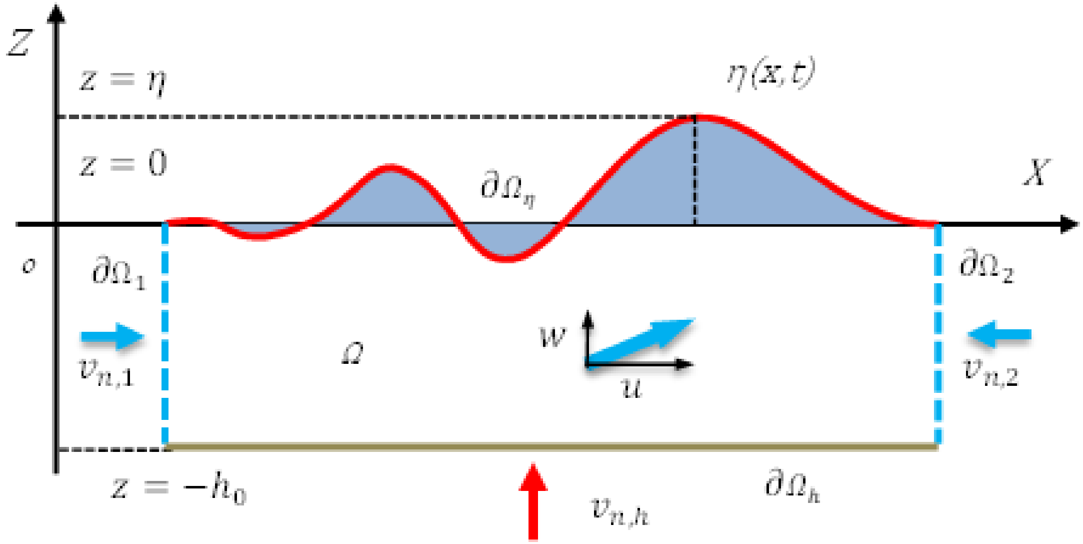

Fig. 2. Calculation scheme for the study of the two-dimensional (2D) wavelet potential problem on a rectangular bounded area

Suppose $\Omega + \partial\Omega$ represents a rectangular area with a corresponding boundary (Fig. 2). This means that $h = h_0 = const$. In the system of equations (6)-(9), only the boundary condition on the solid boundary (8) changes and will have the following form:

Boundary conditions on a rectangular solid boundary

$$\begin{aligned} &+\frac{\partial}{\partial x}\varphi^*\Big|_{\partial\Omega_1^*} = v_{n,1}{}^* \\ &-\frac{\partial}{\partial x}\varphi^*\Big|_{\partial\Omega_2^*} = v_{n,2}{}^* \\ &\frac{\partial}{\partial z}\varphi^*\Big|_{\partial\Omega_h^*} = v_{n,h}{}^* \end{aligned} \tag{14}$$

Where v_n are the normal velocities from the boundary to the inside of the sphere.

The task is approximated to a rectangular area during the study of longitudinal wave fluctuations, when the angle of inclination of the bottom does not exceed $\pi/6$ or the angle of inclination of the bottom exceeds $\pi/3$.

Suppose $\Omega + \partial\Omega$ represents a trapezoidal area with a corresponding boundary (Fig. 3). This means that in the system of equations (6)-(9) only the boundary condition on the solid boundary (8) changes again and will have the following form:

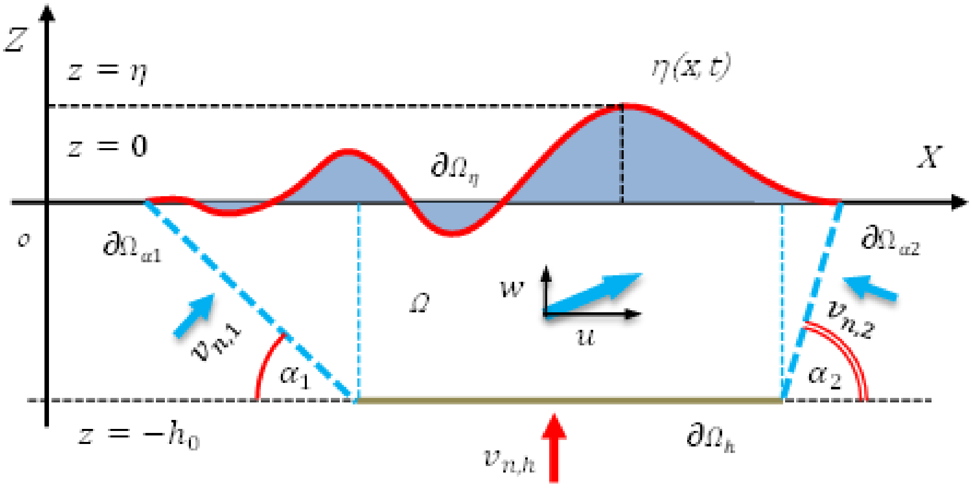

Fig. 3. Calculation scheme for the study of the two-dimensional (2D) wavelet potential problem on a trapezoidal bounded area

Boundary conditions on a trapezoidal solid boundary

$$\begin{gathered}\left(+\sin\alpha_1\cdot\frac{\partial}{\partial x}+\cos\alpha_1\cdot\frac{\partial}{\partial z}\right)\varphi^*\Big|_{\partial\Omega_1{}^*}=v_{n,1}{}^*\\ \left(-\sin\alpha_2\cdot\frac{\partial}{\partial x}+\cos\alpha_2\cdot\frac{\partial}{\partial z}\right)\varphi^*\Big|_{\partial\Omega_2{}^*}=v_{n,2}{}^*\\ +\frac{\partial}{\partial z}\varphi^*\Big|_{\partial\Omega_h{}^*}=v_{n,h}{}^*\\ 0<\alpha_1,\alpha_2\le\frac{\pi}{2}\end{gathered}\tag{15}$$

or

$$\begin{gathered}\left(+\frac{\partial}{\partial x}+\mathrm{ctg}\,\alpha_1\cdot\frac{\partial}{\partial z}\right)\varphi^*\Big|_{\partial\Omega_1{}^*}=\frac{1}{\sin\alpha_1}v_{n,1}{}^*\\ \left(-\frac{\partial}{\partial x}+\mathrm{ctg}\,\alpha_2\cdot\frac{\partial}{\partial z}\right)\varphi^*\Big|_{\partial\Omega_2{}^*}=\frac{1}{\sin\alpha_2}v_{n,2}{}^*\\ +\frac{\partial}{\partial z}\varphi^*\Big|_{\partial\Omega_h{}^*}=v_{n,h}{}^*\\ 0<\alpha_1,\alpha_2\le\frac{\pi}{2}\end{gathered}\tag{16}$$

The trapezoidal area of the task is approximated during the study of transverse wave fluctuations, when the angle of inclination of the bottom is less than ${}^{\pi}/_{6}$, or the angle of inclination of the bottom does not exceed ${}^{\pi}/_{3}$.

CONCLUSION

Various carried-out calculators show the advantage of numerical solutions, which can approximate the riverbed as accurately as possible, which allows to divide the computational area into several simple rectangle, triangle and/or trapezoidal subareas. A numerical grid and area bond ultimate conditions are defined as an arbitrary shape. Accordingly, their joint numerical solution is obtained, which significantly will simplify the calculation process.

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Water management

IMPACT OF DAMS AND BARRAGES ON AQUATIC ECOSYSTEMS AND FISHERIES: A CASE STUDY ON GANGA RIVER

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Annotation. Dams and barrages play a crucial role in water management, flood control, and hydroelectric power generation. However, they significantly impact aquatic ecosystems and fisheries by altering natural flow regimes, disrupting habitats, and affecting water quality. This paper examines the effects of dams and barrages on aquatic ecosystems and fisheries, focusing on the Ganga River in India. The Ganga River is heavily regulated by numerous hydraulic structures, resulting in profound ecological and socio-economic consequences. Common carp (*Cyprinus carpio*), a species widely distributed and cultivated globally, is particularly susceptible to disease outbreaks exacerbated by the environmental changes caused by these hydraulic structures. This paper explores how dams and barrages contribute to the spread of diseases in common carp, focusing on alterations in water quality, changes in fish behavior and migration, and the creation of conducive environments for pathogens. Specific case studies from the Ganga River basin are used to illustrate these impacts.

Keywords: dams, barrages, aquatic ecosystems, common carp, fisheries, Ganga River, sustainable management.

INTRODUCTION

Dams and barrages are integral components of modern water management systems, providing benefits such as irrigation, flood control, and hydroelectric power. However, these structures also pose significant ecological challenges, particularly to aquatic ecosystems and fisheries. The construction and operation of dams and barrages disrupt natural river flows, alter habitats, and degrade water quality, which can profoundly impact aquatic life. One notable species affected by these changes is the common carp (*Cyprinus carpio*), a fish of great ecological and economic importance.

The Ganga River, one of the most vital and revered rivers globally, is home to diverse aquatic species, including the common carp. This river basin has been extensively modified by numerous dams and barrages, such as the Tehri Dam and the Farakka Barrage, which have significantly altered its hydrology and ecology. These alterations have led to various adverse effects on the river's aquatic ecosystems and fisheries *(Sinha et al., 2004; Mitra, 2000).*

Common carp is particularly susceptible to environmental changes induced by hydraulic structures. These fish thrive in well-oxygenated, flowing waters and are vulnerable to diseases that proliferate in altered conditions. Dams and barrages create stagnant or slow-moving water bodies, which can increase pathogen loads and stress fish populations *(Baldock et al., 2006; Ward & Stanford, 1982).* Additionally, these structures can fragment habitats, isolating populations and reducing genetic diversity, which further compromises the health of fish populations *(Vrijenhoek, 1998).*

The impact of hydraulic structures on fish health and populations is a critical area of research, especially in the context of the Ganga River. The Tehri Dam, for instance, has created large reservoirs that alter water temperature and quality, promoting conditions favorable to pathogens such as *Aeromonas hydrophila*, which causes ulcers and hemorrhagic septicemia in common carp *(Sharma & Dubey, 2017).*

Similarly, the Farakka Barrage has disrupted the migration patterns of fish, including common carp, leading to increased stress and disease susceptibility *(Mitra, 2000).* The line diagram of dams and barrages on ganga (Fig.1.) shows the ganga river network with dams and barrages.

Impacts of Dams and Barrages on Aquatic Ecosystems

Habitat Fragmentation

Dams create physical barriers that impede the migration of fish and other aquatic organisms, leading to population fragmentation and reduced genetic diversity *(Lucas & Baras, 2001).* The fragmentation of aquatic habitats can isolate common carp populations, impacting their health.

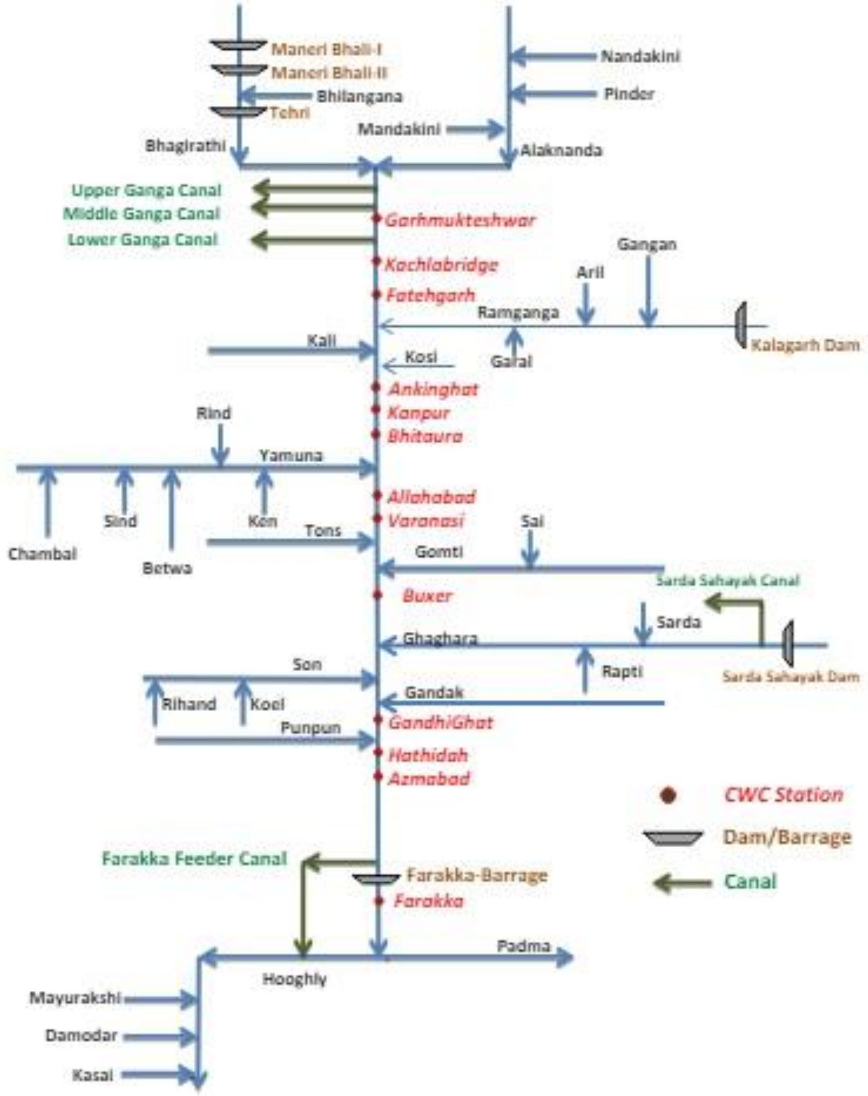

Figure : Line Diagram of Ganga River Network (with major dams/ barrages, canals, and flow and water quality measuring stations).

Source: *Ganga River Basin Management Plan 2015*

Isolated populations have reduced genetic diversity and resilience to diseases, leading to higher mortality rates during outbreaks of viral diseases such as koi herpesvirus (KHV) *(Vrijenhoek, 1998).* Ecological function is highly dependent on physical connectivity *(Fuller et al., 2016; Grant et al., 2007).* The needs of fish for diverse habitats are strongly dependent on river connectivity and natural mobility *(Arthington et al., 2016).*

Hydrological Changes, Ecological Disruptions and Disease Spread

Dams and barrages regulate river flow, often resulting in stagnant or slow-moving water bodies. Stagnant water behind dams creates conditions favorable for pathogen proliferation. Slow-moving or stagnant water can increase the residence time of water, allowing pathogens like bacteria and parasites to thrive and spread more easily *(Baldock et al., 2006).* Barrages obstruct natural water flow, altering sediment transport and disrupting the continuity of river ecosystems (Bunn & Arthington, 2002). Fish passages, such as ladders and bypasses, are often inadequate for all species and life stages, leading to incomplete connectivity restoration (Bunt et al., 2012).

Sediment is an essential component in rivers, and plays a pivotal role in maintaining the ecological status of global river systems *(Chapman & Wang, 2001)* Under natural conditions, adult fish usually initiate spawnng activity when the water level continues to rise for 0.5–2 days, and reduce or even cease spawning when water levels begin to recede *(B. Yi et al., 1988).*

Altered Fish Behavior and Migration

Dams and barrages disrupt the natural behavior and migration patterns of common carp, leading to increased disease transmission.Common carp often congregate at barriers such as dams and barrages, increasing the likelihood of disease transmission due to higher densities and prolonged contact. This can facilitate the spread of parasitic infections like *Ichthyophthirius multifiliis* (white spot disease) *(Williams et al., 1996).*The stress associated with blocked migration and altered habitats can weaken the immune systems of common carp, making them more susceptible to infections like bacterial gill disease and saprolegniasis (*Barton & Iwama, 1991).*

Altered Flow Regimes

Dams and barrages often reduce flow variability, which is essential for maintaining diverse habitats and ecological processes *(Poff et al., 1997).* Reduced flow variability can diminish floodplain connectivity, affecting nutrient cycling and habitat availability for fish (Junk et al., 1989). The timing and magnitude of flow releases from dams can affect downstream ecosystems, altering temperature and oxygen levels critical for aquatic life *(Olden & Naiman, 2010).*

Seasonal flow alterations due to water extraction and regulation can impact the timing and extent of flooding, which is crucial for fish spawning and recruitment.

Water Quality

Changes in water quality due to dams and barrages can exacerbate disease spread among common carp populations. Reservoirs behind dams can develop thermal stratification, creating temperature gradients that impact the distribution and health of aquatic organisms *(Ward & Stanford, 1982).* Accumulation of pollutants in reservoirs and reduced flow can lead to water quality degradation, impacting sensitive species and overall ecosystem health *(Malmqvist & Rundle, 2002).* Water temperature regime can affect the whole life cycle of fish *(Servili et al., 2020),* including migration timing, reproductive performance, embryo health, and growth rate.

Eutrophication

Nutrient retention in reservoirs can lead to eutrophication, causing algal blooms and oxygen depletion, which adversely affect fish populations. Thermal stratification in reservoirs can create temperature gradients that favor different pathogens. Warmer surface waters can promote the growth of disease-causing organisms, including those affecting common carp (Ward & Stanford, 1982). Reduced flow can lead to higher concentrations of pollutants, including organic matter and nutrients, which can foster the growth of pathogens such as *Aeromonas* and *Pseudomonas*, known to cause diseases in common carp *(Malmqvist & Rundle, 2002).*Stagnant water and increased organic load can lead to hypoxic conditions, stressing common carp and making them more susceptible to diseases like hypoxia-induced fin rot *(Friedl & Wüest, 2002).*

Habitat and Food Availability

Changes in sediment transport and deposition alter the physical structure of habitats, affecting spawning grounds and nursery areas critical for fish populations *(Kondolf, 1997).* Reduced flow and habitat fragmentation lead to the loss of critical refugia, affecting fish survival during adverse conditions *(Lake, 2003).* Flow regulation impacts the availability and distribution of food resources, affecting the growth and survival of fish *(Arthington et al., 2006).*

Case Study from the Ganga River

Tehri Dam

The Tehri Dam, one of the largest dams in India, significantly impacts the Ganga River's flow regime and aquatic ecosystems. The Tehri Dam on the Bhagirathi River, a major tributary of the Ganga, has led to significant ecological changes affecting common carp.

Ecological Impacts

The dam has created a large reservoir, inundating upstream habitats and affecting the natural migration patterns of fish species *(Sharma & Dubey, 2017).* Downstream flow regulation has altered sediment transport, leading to habitat degradation and changes in river morphology *(Gupta et al., 2013).* Dams block the passage of migration of fish, which disrupts the life cycle of many fishes. Life cycle of many fishes requires both fresh and sea water.

Impact on Fisheries

The blockage of migratory routes by the Tehri Dam has particularly impacted species such as the Mahseer (Tor putitora), leading to population declines *(Bhatt et al., 2000)*. Efforts to mitigate impacts include regulated flow releases to mimic natural flow patterns and fish passage facilities, though effectiveness remains limited.

The creation of the Tehri Reservoir has led to changes in water quality, including increased temperatures and nutrient levels, which have promoted the growth of pathogens such as *Aeromonas hydrophila*, causing ulcers and hemorrhagic septicemia in common carp The dam has caused common carp to congregate in certain areas, increasing the risk of disease transmission among individuals and populations *(Sharma & Dubey, 2017*). Water temperature regime can affect the whole life cycle of fish *(Servili et al., 2020),* including migration timing, reproductive performance, embryo health, and growth rate

Farakka Barrage

The Farakka Barrage, constructed to divert water for the Kolkata port, has caused significant ecological disruption in the Ganga River. The Farakka Barrage, constructed to divert water from the Ganga to the Hooghly River, has also had significant impacts on common carp health.

Ecological Impacts

The barrage has obstructed sediment transport, leading to sedimentation problems downstream and affecting riverine habitats *(Sinha et al., 2004).*Elevated levels of sediment and turbidity (a measure of the lack of clarity of water) can reduce the biological productivity of aquatic systems.

Although elevated levels of suspended sediment elicit adverse responses in individual aquatic organisms, it is difficult to extrapolate effects to the population or ecosystem levels. However, the biological productivity of turbid systems has been shown to be less than that of non-turbid systems. Anthropogenic activities, such as some placer mining operations, have resulted in lowered densities of aquatic organisms in watersheds through the elevation of suspended and deposited sediments *(Anonymous, 2000).*

Impact on Fisheries

The blockage of migratory routes by the Farakka Barrage has led to drastic declines in the population of Hilsa fish, an important commercial species (Payne et al., 2004).The barrage has disrupted the natural migration and spawning patterns of common carp, leading to overcrowding and increased stress, which in turn has heightened the incidence of diseases such as fungal infections *(Mitra, 2000).* The altered flow regime downstream of the barrage has led to decreased water quality, with increased sedimentation and pollution contributing to the spread of diseases among common carp populations *(Sinha et al., 2004).*

Mitigation Strategies

Designing effective fish ladders and bypass channels that accommodate various species and life stages is critical for restoring connectivity *(Bunt et al., 2012).* Regular monitoring and adaptive management are necessary to ensure the effectiveness of these structures *(Noonan et al., 2012*).

It can help to maintain natural migration patterns and reduce congregation at barriers, thus lowering disease transmission risks *(Bunt et al., 2012)*. Regular monitoring of common carp health and pathogen levels, combined with adaptive management practices, can help mitigate disease outbreaks *(Noonan et al., 2012).* Removing obsolete dams and restoring river continuity can significantly benefit fish populations and overall ecosystem health *(Bednarek, 2001).* Restoration projects should consider historical flow regimes and habitat requirements of target species to maximize ecological benefits *(Palmer et al., 2005).*

Water Quality Management

Implementing environmental flow regimes to maintain more natural flow patterns can help reduce stagnant water conditions and improve water quality, thereby mitigating disease spread *(Arthington et al., 2006)*. Reducing nutrient and pollutant inputs into the river system through improved wastewater treatment and agricultural practices can help mitigate disease spread among common carp *(Malmqvist & Rundle, 2002*). Table 1 shows the lethal range of water quality for fish.

Habitat Restoration

Restoring riparian vegetation can improve water quality and provide refuges for common carp, reducing stress and susceptibility to diseases *(Gregory et al., 1991).*Managing sediment transport and deposition can help maintain habitat quality and reduce the proliferation of disease-causing microorganisms *(Gupta et al., 2013).*

Table 1

Tolerant, desirable and lethal ranges of some water quality parameters

Water quality Parameter	Tolerant Range	Desirable Range	Lethal Range
Temperature ^{0}C	15 - 32	22 - 28	7 - 35
Dissolved Oxygen mgl $^{-1}$	1 - 5	5 - 7	0 - 1
Carbon diaoxide mgl $^{-1}$	10 - 60	0.5	>60
Nitrites mgl $^{-1}$	0.1 -0.4	00	>0.5
Ammonia mgl $^{-1}$	0.002 -0.05	0.002	0.6 – 3.4
Hydrogen Sulfide mgl $^{-1}$	00	00	>0.1
pH	6.5 – 8.5	4.6 – 6.5	1 – 4 acid dead point 9.5 -11 alkaline dead point
Alkalinity mgl $^{-1}$	20 - 150	20 - 100	>300
Hardness mgl $^{-1}$	10 - 100	10 - 20	>100
Turbidity mgl $^{-1}$	1000 – 40,000	1000 – 20,000	>20,000

Source: Boyd, 1984; Edgar, 1974; Ikeogu et al, 2010)

Ecological Flow Management

Implementing adaptive management strategies that adjust flow regimes based on ecological monitoring can help maintain habitat suitability and support fish populations *(Richter et al., 2003).* Seasonal flow variations that mimic natural patterns can enhance spawning success and habitat diversity. Integrating fisheries management with water resource planning ensures that the needs of aquatic ecosystems are considered in water allocation decisions *(Pahl-Wostl et al., 2007).* Collaboration among stakeholders, including water managers, ecologists, and local communities, is essential for successful implementation (Ostrom, 2009).

CONCLUSION

Dams and barrages have significant and complex impacts on the aquatic ecosystems and fisheries of the Ganga River. Health of common carp, contributs to the spread of diseases through changes in water quality, habitat fragmentation, and altered migration patterns. Understanding these effects and implementing integrated management strategies are crucial for mitigating negative impacts and promoting the sustainability of fish populations and aquatic ecosystems. Mitigation strategies, including improved water quality management, fish passage solutions, and habitat restoration, are essential for reducing these impacts and promoting the health of common carp populations in the Ganga River. Implementing these strategies requires a holistic approach that integrates ecological, hydrological, and socio-economic considerations.

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Water management

EXPLORING IRRIGATION WATER LIFE CYCLE FOR IRRIGATION PROJECT MANAGEMENT AND TO IMPROVE WATER PRODUCTIVITY

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Annotation. The world distribution of water use shows the highest consumption of water in agriculture sector. Various techniques and methods adopted to reduce the consumption of water in agriculture are only partially successful due to restriction of crop, soil type and climatic conditions. Canal irrigation has been the most widely used method of irrigation water supply throughout the world. Grain crops have been the most important source of food and covers a substantial area under cultivation throughout the world. Various approaches have been adopted in farm decision making for better crop management, improving crop yield and reducing water losses. Irrigation water life cycle has been adopted as the most advance concept for reducing water losses throughout the crop period and improving water productivity. A conceptual framework has been developed to reduce the water losses in irrigation life cycle by considering the optimization of various sub-systems of Irrigation water life cycle, and its components. The concept analyses that the water productivity can be successfully improved with the Irrigation life cycle management approach.

Keywords: irrigation Life Cycle, canal supply, optimization, water productivity

INTRODUCTION

The scarcity of water is a major issue throughout the world, whether it is for drinking, industrial or agriculture and it needs attention for its conservation and management for sustainability. The rainfall and snow are the ultimate source of surface and ground water replenishment which are now highly prone to temporal and spatial variability throughout the globe due to accelerated climate change impacts.

Table 1

Global water use in different sectors

Sector	Water Use (%)		Description
	Europe	South Asia	
Agriculture	30%	91%	Agriculture is the largest consumer of freshwater, primarily for irrigation and livestock.
Industry	26%	7%	Industry uses water for processes such as manufacturing, cooling, and cleaning.
Domestic	44%	2%	Domestic use includes water for drinking, cooking, cleaning, and sanitation.
Total	100%	100%	Represents the total global freshwater withdrawals across all sectors.

Source: UNESCO World Water Development Report 2023

The world distribution of water use shows the highest consumption of water in agriculture sector. According to the United Nations, in south Asia agriculture accounts for approximately 91% of global freshwater withdrawals, highlighting the necessity for effective water management strategies in this sector. Various techniques and methods adopted to reduce the consumption of water in agriculture are partially successful due to restriction of crop, soil type and climatic conditions. While irrigated areas account for 24% of croplands, roughly 40% of global food production is from irrigated croplands (Portman et al 2000, World Bank, 2020)

Canal irrigation has been the most widely used method of irrigation water supply throughout the world. Cereals were the leading group of crops produced in 2021 (Figure 2), representing 32 percent of the total, **(FAOSTAT, 2000–2021)**, covers a substantial cultivation area throughout the world. Worldwide, over 307 million hectares are currently equipped for irrigation, of which 304 million hectares are equipped for full control irrigation and 261 million hectares are equipped for full control and actually irrigated (Aqustat)

Farm crop production is highly dependent on crop water use at its various environmentally sensitive critical growth stages. Molden et al. (2010) defined water productivity as net return per unit of water used and improvement in water productivity could be made possible by producing more food, better income livelihoods and ecosystem services with less water. Adequate supply of food and fibers for the populace at affordable prices is only possible if we maximize the farm production but the water becomes the major constraint in most of areas and hinders farm decisions.

Irrigation water life cycle management is a critical component of sustainable agricultural practices, aiming to optimize the use and management of water resources throughout the various stages of its lifecycle. This approach encompasses the collection, distribution, application, and recycling of irrigation water, ensuring efficiency and sustainability in agricultural production systems. The concept of water life cycle management in irrigation integrates several key principles: resource efficiency, environmental protection, and economic viability. It involves the assessment and optimization of water usage from its source—whether it be surface water, groundwater, or alternative sources like treated wastewater—through its application in agricultural fields, and finally its potential reuse or discharge back into the environment. Innovations in irrigation technologies, such as drip irrigation, sprinkler systems, and advanced monitoring tools, play a significant role in enhancing water use efficiency. These technologies allow for precise water application, reducing wastage and improving crop yields. For instance, drip irrigation systems can reduce water use by 30-70% compared to traditional flood irrigation methods, while also minimizing runoff and evaporation losses (Food and Agriculture Organization, 2020).

Moreover, the integration of data analytics and remote sensing technologies has revolutionized irrigation management. These tools provide real-time data on soil moisture, weather conditions, and crop water needs, enabling farmers to make informed decisions and optimize water use. A study by the International Water Management Institute (IWMI) demonstrated that the use of remote sensing and geographic information systems (GIS) in irrigation management can lead to significant water savings and enhanced agricultural productivity (IWMI, 2019).

Sustainable irrigation water life cycle management also addresses the environmental impacts of agricultural water use. It promotes practices that reduce water pollution from agricultural runoff, enhance groundwater recharge, and maintain ecological balance in surrounding ecosystems. For example, adopting controlled irrigation methods can mitigate the leaching of fertilizers and pesticides into water bodies, thus protecting water quality and aquatic life (Environmental Protection Agency, 2022).

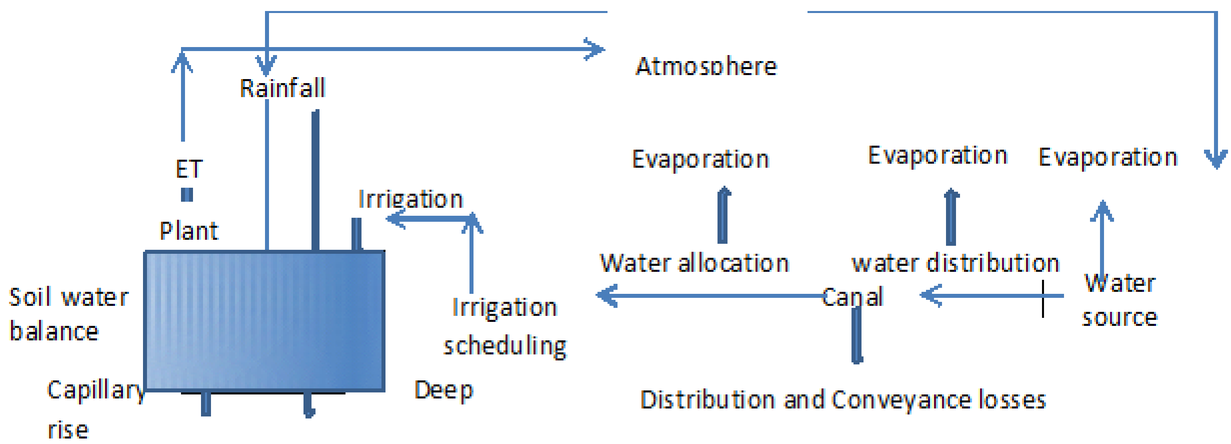

Fig. 1. Irrigation water Life cycle Management framework

Irrigation Water Life Cycle

Irrigation Water Life Cycle Management (IWLCM) is an integrative approach aimed at optimizing water use throughout its entire cycle—from source extraction to distribution, application, drainage, and eventual return to the environment. This approach ensures not only the efficient use of water but also the maintenance of water quality and the protection of ecosystems.

Effective IWLCM is vital for several reasons. Firstly, it addresses water scarcity by maximizing the productivity of available water resources. Agriculture is the largest consumer of fresh water, accounting for approximately 70% of global withdrawals (FAO, 2017). With the advent of IWLCM, farmers can reduce wastage and enhance water use efficiency, thus ensuring the sustainability of water supplies for future generations. Secondly, it helps in adapting to climate change. Climate variability affects water availability and demand, making it imperative for agricultural practices to adapt through resilient water management strategies (IPCC, 2014).

Components of IWLCM

The life cycle of irrigation water involves several stages, each presenting unique challenges and opportunities for optimization:

1. **Water Source Management**: This includes the identification and sustainable extraction of water from sources such as rivers, lakes, aquifers, and reservoirs. Proper management at this stage can prevent over-extraction and depletion of water resources (Gleeson et al., 2012).
2. **Water Distribution Systems**: Efficient conveyance systems are crucial to minimize losses through evaporation, seepage, and leaks. Modern techniques such as drip and sprinkler irrigation systems significantly reduce water loss compared to traditional flood irrigation methods (Postel et al., 2001). Optimization of water supply at this stage can effectively reduce the water losses.
3. **Field Application**: The application phase focuses on delivering the right amount of water at the right time to crops, based on their specific needs. Advanced technologies, including soil moisture sensors and automated irrigation systems, have proven effective in optimizing water use at this stage (Jones, 2004). Choosing right method and right hydrologic design can reduce evaporation and deep percolation losses.
4. **Drainage and Reuse**: Proper drainage systems ensure excess water is removed efficiently, preventing waterlogging and salinization. Additionally, treated drainage water can be reused for irrigation, further enhancing water use efficiency (Khan et al., 2006).
5. **Soil water storage** Irrigation water storage in soil is a critical component of agricultural water management that directly impacts crop yield, soil health, and overall farm productivity. Soil serves as a natural reservoir that can store significant quantities of water, which plants can access during periods of

drought or when rainfall is insufficient. Understanding and optimizing the capacity of soil to retain and supply water is thus essential for sustainable agriculture.

6. **Crop water use and water productivity** the amount of crop yield or economic return per unit of water used, is a critical metric in agricultural water management. As global water resources become increasingly stressed due to population growth, climate change, and competing demands, improving WP is essential for sustainable food production.
7. **Environmental Impact Management**: The final stage involves assessing and mitigating the environmental impacts of irrigation practices. This includes managing the return flows to ensure they do not pollute water bodies and maintaining ecological balance in the surrounding environments (Gleick, 2003).

Techniques for Irrigation water life cycle Management

Optimization Techniques in Crop Decision Making

Various optimization techniques have been widely used to optimize crop planning by maximizing or minimizing an objective function (Isaac et al. 2011), such as profit or cost, subject to various constraints. Linear Programming models can help determine the best combination of crops to plant on a given area to achieve the highest profit margins (Isaac and S.H. Abbas,1998). Multi-Objective Optimization approach considers multiple goals, such as profit maximization, risk minimization, and environmental sustainability (Isaac et al 1995). Stochastic Programming deals with uncertainty in agricultural planning, such as weather variability and market prices. By incorporating probability distributions into the models, farmers can develop strategies that are robust against uncertainties. (Dwivedi and Isaac, 2012). Dynamic Programming is useful for making a series of interdependent decisions over time. In crop planning, it can optimize planting schedules and crop rotations to enhance long-term soil health and productivity. Genetic Algorithms (GA) are heuristic optimization techniques inspired by natural selection. They are effective in solving complex agricultural problems, such as optimizing crop mix and resource allocation, by iteratively improving solutions based on fitness criteria.

Optimization techniques offer powerful tools for improving crop decision-making and planning. farmers can enhance productivity, profitability, and sustainability. The integration of these methods into agricultural practices not only aids in better resource management but also contributes to the overall resilience of farming systems against environmental and economic challenges by optimum use of water and reducing the system losses.

Optimization technique is successfully used by various researchers in Canal water distribution and allocation, Crop Selection, Planting Schedules, Resource Allocation, Irrigation Planning.

Irrigation Scheduling Using Various Models

Efficient water management is critical for sustainable agriculture, especially in the face of increasing water scarcity and climate variability. Irrigation scheduling is a key component of this management, aiming to apply water at the right time and in the right amount to meet crop needs while minimizing waste and environmental impact. Various models have been developed to aid in irrigation scheduling, leveraging advances in technology and data analysis to optimize water use. Soil Moisture-Based Models rely on real-time soil moisture data to determine irrigation needs. By using sensors placed in the field, soil moisture-based models can provide precise information on when and how much water to apply, enhancing water use efficiency and crop yield .Weather-Based Models also known as evapotranspiration (ET) models, these use weather data to estimate the rate at which water is lost from the soil and plants. The FAO Penman-Monteith equation is a widely used CropWAT ET model that helps in scheduling irrigation by predicting the crop water requirement based on climatic conditions .Crop growth models integrate physiological processes of crops with environmental conditions to predict water needs. They can simulate various stages of crop development and their corresponding water requirements, allowing for more tailored irrigation scheduling, include the CropSyst and AquaCrop models, which have been extensively used in research and practice Decision Support Systems (DSS) combine various models, historical data, and real-time information to provide comprehensive irrigation scheduling recommendations. They often include user-friendly interfaces and can be tailored to specific crops and local conditions. Examples include the Irrigation Management Online (IMO) and the Decision Support System for Agro technology Transfer (DSSAT). Remote Sensing and GIS-Based models qdvances in satellite technology and Geographic Information Systems (GIS) have enabled the development of models that use remote sensing data to monitor crop conditions and soil moisture over large areas. These models can provide spatially distributed information, making them particularly useful for large-scale irrigation management.

The integration of these various models into irrigation scheduling practices can lead to more sustainable water use in agriculture. By using a combination of soil moisture sensors, weather forecasts, crop growth simulations, decision support systems, and remote sensing data, farmers can optimize irrigation, improving both water use efficiency and crop productivity.

Soil Water Storage

Knowing the soil water storage capacity allows the irrigator to determine how much water to apply at one time and how long to wait between each irrigation. Only a portion of the total soil water is readily available for plant use. Plants can only extract a portion of the stored water without being stressed. Soil moisture storage has a physically important role in the hydrological cycle, and it has a vital influence on the amount of rainfall which becomes runoff and groundwater recharge.

Water Productivity

Enhancing water productivity is essential for ensuring food security, especially in water-scarce regions, and for promoting sustainable agricultural practices globally. The focus on water productivity arises from the need to balance the growing demand for food with the limited availability of freshwater resources. (Isaac R.K., 2015)

In agricultural systems, water productivity can be measured in terms of crop yield per unit of water consumed (crop per drop). This metric is vital for evaluating the efficiency of water use in crop production and for identifying opportunities to improve irrigation practices. Improved water productivity can be achieved through various means, including the adoption of modern irrigation techniques, the development of drought-resistant crop varieties, and the implementation of best management practices that reduce water wastage and enhance soil moisture retention (Isaac R.K. 2014).

Several studies have highlighted the importance of water productivity in addressing the challenges posed by climate change and population growth. For instance, (Rockström et al.,2010) emphasize the need for a paradigm shift towards sustainable intensification, which involves increasing food production without proportionally increasing water use . Similarly, Molden et al. (2010) discuss strategies for improving water productivity through integrated water resource management and the adoption of innovative agricultural practices.

Technological advancements play a crucial role in enhancing water productivity. Precision agriculture, which uses data-driven techniques to optimize water use, and advanced irrigation systems like drip and sprinkler irrigation, have shown significant potential in improving water use efficiency. Studies by Fereres and Soriano (2007) and Howell (2001) demonstrate that these technologies can significantly reduce water consumption while maintaining or even increasing crop yields.

Policy interventions and institutional frameworks are also crucial for promoting water productivity. Governments and international organizations are increasingly recognizing the need to support farmers through subsidies, training programs, and infrastructure development to facilitate the adoption of water-efficient practices. The Food and Agriculture Organization (FAO) and the International Water Management Institute (IWMI) have been at the forefront of promoting policies that enhance water productivity globally.

CHALLENGES AND OPPORTUNITIES

While IWLCM offers a comprehensive framework for sustainable water management, its implementation faces several challenges. These include the high initial costs of modern irrigation technologies, lack of technical expertise among farmers, and inadequate policy support. However, these challenges also present opportunities for innovation and collaboration among governments, private sector, and international organizations. Investments in research and development, capacity building, and supportive policies can significantly enhance the adoption of IWLCM practices (World Bank, 2006).

CONCLUSION

IWLCM represents a holistic and sustainable approach to managing irrigation water in agriculture. By addressing the entire water cycle, it ensures efficient use, conservation of water resources, and protection of the environment. As global challenges related to water scarcity and climate change intensify, IWLCM will play a crucial role in securing a sustainable and resilient agricultural future. In summary, improving water productivity is fundamental to achieving sustainable agriculture and ensuring food security in the face of growing water scarcity. By adopting efficient water management practices, leveraging technological advancements, and supporting policy frameworks, significant strides can be made towards more sustainable and productive agricultural systems to meet the challenges of the 21st century.

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Water management

WATER SECURİTY UNDER CLİMATE CHANGE İN AZERBAİJAN

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Annotation. The article is devoted to the assessment of the priority directions of ensuring water security under climate change in Azerbaijan.The paper discusses how effective are existing water conservation and resource management policies in Azerbaijan, and what effective solutions can be proposed to enhance water resilience in the face of scarcity under climate change. In terms of ensuring water security in Azerbaijan during the analysis of changes in the volume of water taken from natural water sources was observed stable in the volume of water taken from surface water sources, an increase in the volume of water taken from groundwater sources.

Keywords: climate change, water security, water management, water shortage.

INTRODUCTION

One of the current global challenges of our century is the water supply for the population and various sectors of the economy. In line with the population growth and economic development, the use of water resources is growing rapidly all over the world, while water supply is sharply deteriorating in most regions and countries. As a result of the global warming, there is an observed trend of decline in existing water resources. The aggravation of the water problem has a direct impact on the food supply and regional ecological security of the population. Currently, water has become one of the decisive factors for the sustainable development of a country. In future researches and practical actions should be accelerated towards reduction of water use and implementation of technologies enabling efficient water use.

Under the conditions of population growth and development of the economy all over the world, the usage of water resources has increased rapidly and water provision has worsened sharply in most regions and countries. As a result of climate change and global warming, a tendency of decrease of available water resources is observed. Aggravation of water problems directly affects food supply and ecological security in certain regions.

MAIN PART

Water scarcity and inadequate water supply and sanitation services adversely affect food security and human well-being in many countries around the world. Drought leads to hunger and poor living conditions in many poor countries. It is no coincidence that 6 of the 17 goals of sustainable development are dedicated to clean water and sanitation. It is noted that by 2050, one in four people living in the countries of the world will be exposed to chronic or recurring shortage of fresh water. Taking into account all these risks, one of the important factors is the assessment of the priority directions of ensuring water security in Azerbaijan.

Population growth and economic development in Azerbaijan increase the demand for water use in the area. The lack of water resources, global climate change and the decrease of water resources coming from neighboring countries, on the other hand, the rapid growth of the population, the development of agriculture, the increase in the demand for water as a result of the expansion of agricultural areas, irrigation and drinking water supply networks, require the implementation of measures to ensure the water security of the republic (Imanov & Alakbarov, 2017; İsmayılov, 2017). Water resources of Azerbaijan's, their use and protection are characterized by the following numbers (table 1).

Table 1

Water resources of the Republic of Azerbaijan and consumption

Water resources		**Water resources, km^3**	**Water withdrawals from sources, km^3**
Surface water	Local water resources	10,6	10,2
	Transboundary	20,3	
Groundwater		4,38	1,40
Total		35,3	11,6

While the local river water resources are on average 10.6 km^3, in recent years 11.6 km^3 of water is used annually. Unfortunately, approximately 70% (20.3 km^3) of our river water resources are formed in the territory of neighboring countries and enter the territory of Azerbaijan through transboundary rivers (Rustamov & Gashgay, 1989). As a whole, the Republic of Azerbaijan is considered a country with limited water resources. The amount of water per person is 3253 m^3/year. If we consider only local water resources, then this figure will be equal to 1051 m^3/year (İsmayilov, 2021).

In Azerbaijan, climate change can impact water resources through altered precipitation patterns, changing temperatures, and shifting hydrological cycles. Changes in precipitation may affect the availability of water, impacting agriculture and ecosystems. Rising temperatures can lead to increased evaporation, potentially reducing water availability. Sustainable water management strategies and adaptation measures are crucial to address these challenges in the context of climate change. Azerbaijan experiences hot summers (especially in lowland areas) and moderate winters. Average temperatures for the latest climatology, 1991–2020, ranged between approximately 24°C in the summer months of July and August, and −1°C to 1°C during the winter (December to February). The average monthly temperatures vary significantly between different regions and altitudes across Azerbaijan. Average temperatures in Baku and other parts of the east and southeast reach approximately 27°C during the hottest months of July and August, while temperatures during these months remain between 15°C and 20°C in parts the mountainous north and west. Similarly, during the winter (December to February) temperatures in Baku average between 3°C and 4°C, whereas in western and northern areas average monthly temperatures fall to between −5°C and −10°C. Average rainfall in Azerbaijan follows a bimodal distribution throughout the months of the year, with average levels above 40 millimeters (mm) per month from April to June, and again in October (Figure 1).

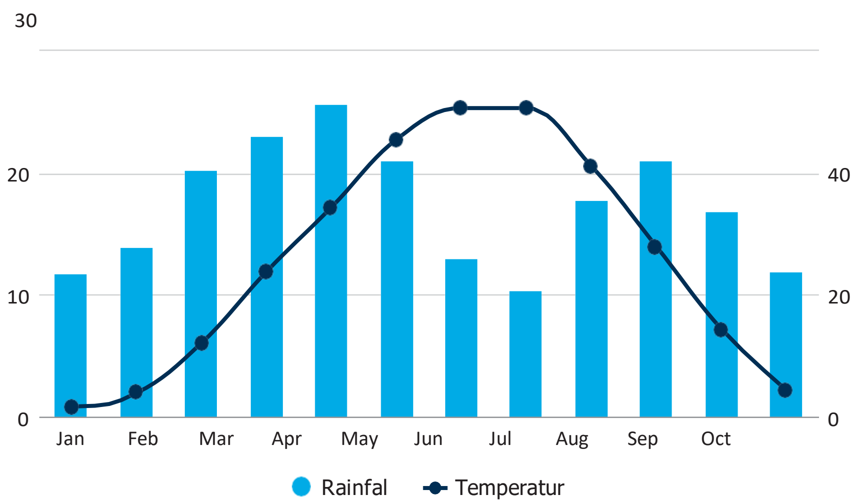

Fig. 1. Average monthly temperature and rainfall in Azerbaijan (1991–2020)

Precipitation is highest in May and June in the northern and western areas of Azerbaijan, where it can exceed 100 mm per month in places. On the other hand, precipitation in Baku remains below 25 mm per month on average for much of the year (from January to September) and averages only 33 mm in the wettest months of October and November (Safarov et al., 2020; Huseynov & Huseynov, 2022).

During a detailed study of climate changes, if we look at the trend of multi-year average temperature and precipitation for every 10 years, it can be seen that the amount of precipitation across the country has a decreasing trend, and the temperature has an increasing trend. During the years 1961-2020, the average annual temperature of the Republic of Azerbaijan has increased. Also, during this period, more precipitation fell on the territory of the country in 1961-1970 (Safarov et al., 2020). During this period, as less precipitation fell in 1991-2020, the dry areas in the area expanded. Over the past 30 years, precipitation has been steadily decreasing. If we look at the pictures, it is possible to see that the amount of precipitation decreases with the temperature (Figure 2).

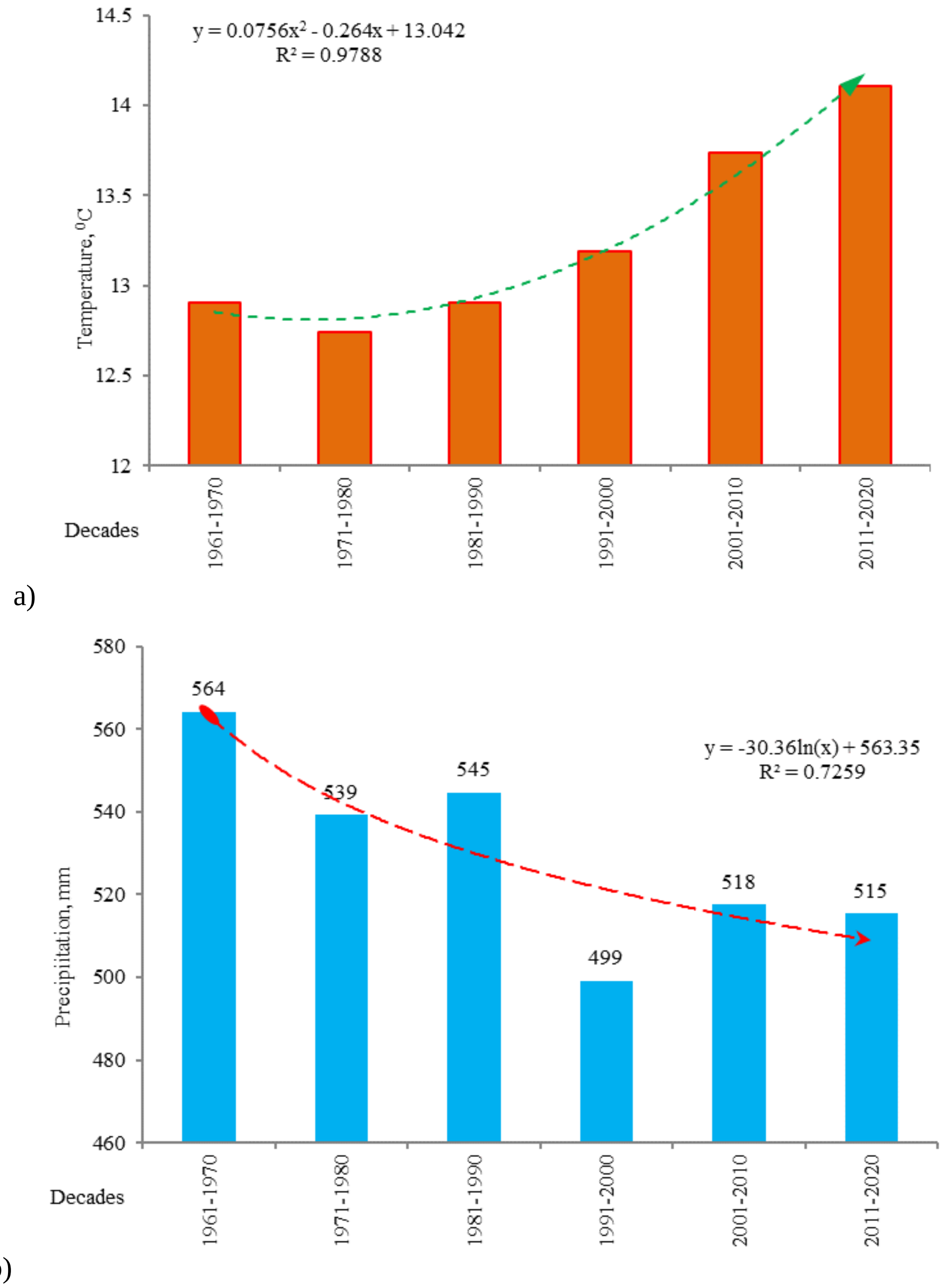

Fig.2. Average annual variation of temperature (a) and precipitation (b) in the Republic of Azerbaijan

Climate change can significantly impact water resources in the Republic of Azerbaijan. At present, the average annual water deficit in the republic is 3.7 km^3, and in low-water years it is 4.75 km^3. If we take into account the forced release of water from rivers for environmental, energy and other purposes, the quantitative indicators of water shortage will have an unimaginable value.

Increasing water withdrawal from sources in Azerbaijan should be approached with caution to avoid negative environmental impacts. It's important to consider sustainable water management practices, including efficient irrigation methods, water conservation, and monitoring of water quality. Balancing increased demand with responsible usage is key to ensuring long-term water availability. Several factors can influence changes in water withdrawal from sources in the Republic of Azerbaijan. These may include population growth, agricultural demands, industrial activities, climate variations, and water management policies. Understanding and managing these factors are crucial for sustainable water resource usage and ensuring adequate water availability for various sectors in the country. Using the state water use accounting information (2000-2022), the amount of water withdrawal from water sources was analyzed by sector. Thus, during this period, the amount of water withdrawal from water sources sources varied from 9.91 to 13.03 km^3. The highest amount of water withdrawn from water sources was in 2022, and the lowest amount was in 2002 (Figure 3). In general, an average of 11.6 km^3 of water was withdrawal from natural water sources in the last 22 years. During this period, an increase of 2.20 km^3 (11.4%) was observed in the volume of water withdrawal from water sources.

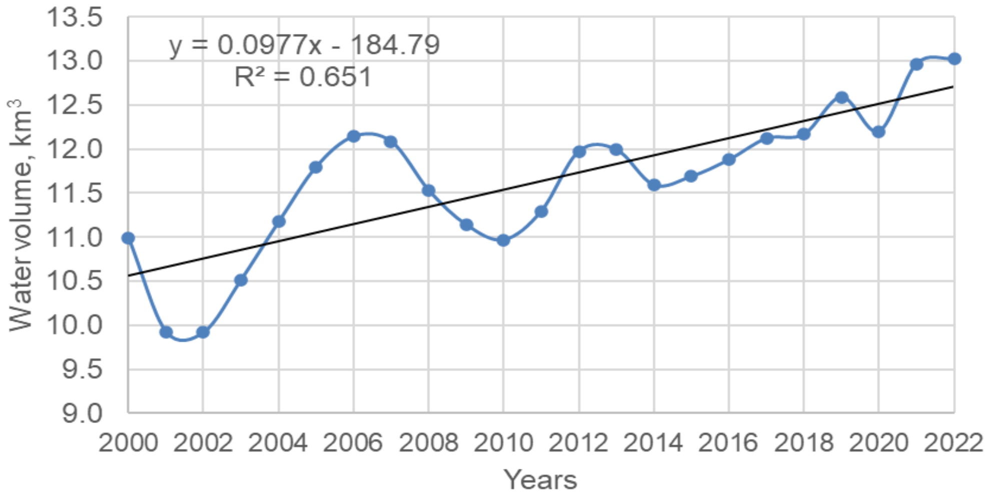

Fig. 3. Changes in the volume of water withdrawal from sources

If the volume of withdrawal from water sources continues at this rate, it is predicted to be 13.8 km^3 in 2030, 14.8 km^3 in 2040, and 15.8 km^3 in 2050. Predicting changes in water withdrawal volume in Azerbaijan requires considering various factors like population growth, industrial development, and climate patterns. Analyzing these can help anticipate potential impacts on water resources, allowing for informed resource management and conservation strategies.

The analysis was carried out separately for both the amount of water withdrawn from surface water sources and the amount of water withdrawn from groundwater sources. No major change was observed in the amount of water withdrawal from surface water sources during the multi-year period (Figure 3). During this period, an average of 0.28 km^3 of water was withdrawal from surface water sources.

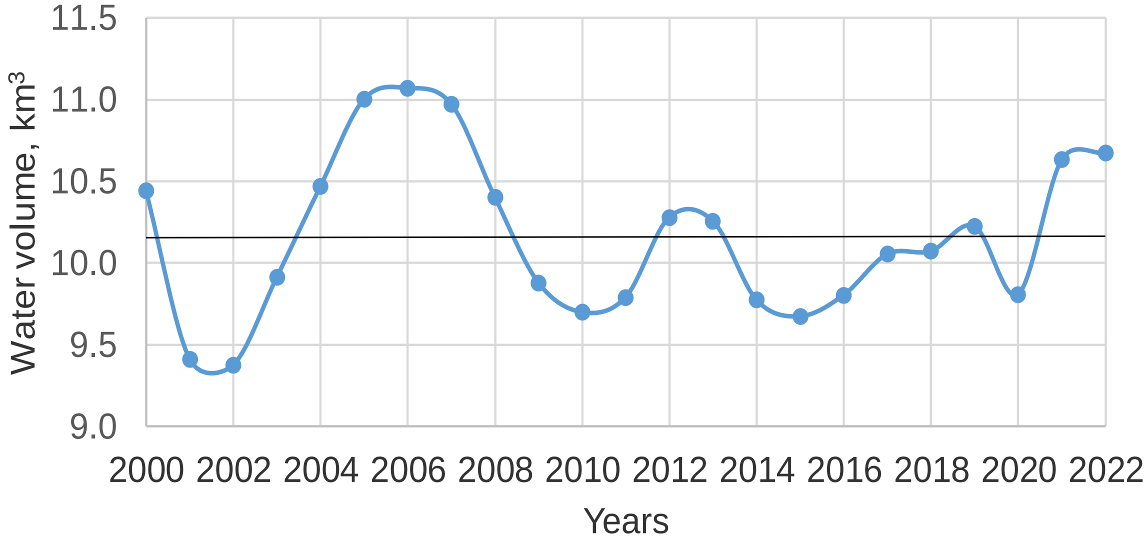

Fig. 3. Changes in the volume of water withdrawal from surface water source

The same analysis was performed for the volume of water withdrawn from groundwater sources. During the analysis, a significant increase in the amount of withdrawn from groundwater sources was observed during the multi-year period (Figure 4). During the average multi-year period, a decrease of 2.55 km^3 was observed in the volume of water withdrawal from groundwater sources.

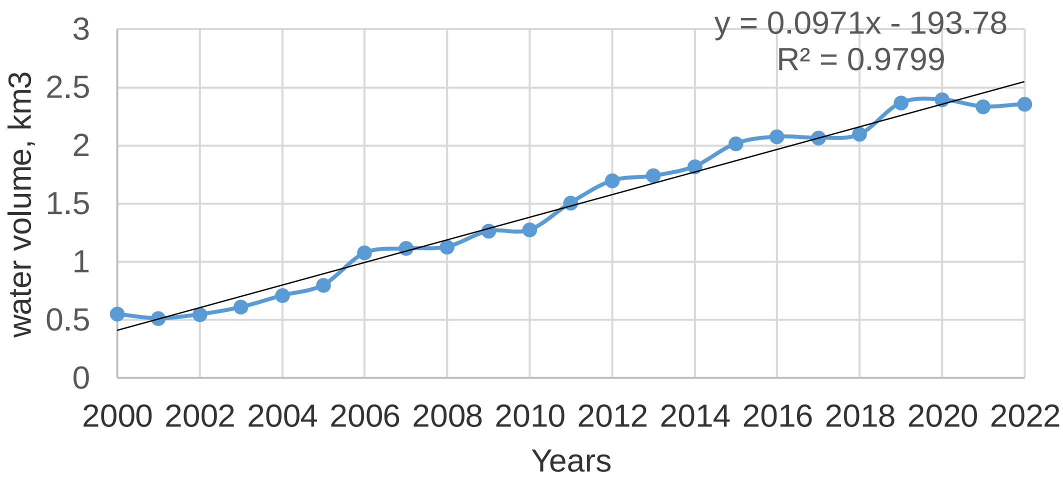

Fig. 4. Changes in the volume of water withdrawal from groundwater sources

Increasing water withdrawal from groundwater sources can have several impacts on water management. Firstly, it can lead to the depletion of aquifers, reducing the availability of groundwater for future use. This poses a significant challenge for sustainable water management, as groundwater often serves as a crucial resource for agriculture, industry, and domestic purposes. Excessive withdrawal may also lead to land subsidence, where the land surface sinks due to the emptying of underground water reservoirs. This can result in damage to infrastructure and ecosystems. Furthermore, over-extraction can cause saltwater intrusion in coastal areas, jeopardizing freshwater supplies. To manage water resources effectively, it's crucial to implement sustainable practices, monitor groundwater levels, and regulate extraction to avoid long-term environmental and socio-economic consequences.

CONCLUSION

This scientific investigation throws light on the severe difficulties that Azerbaijan faces in terms of water shortage such as a result of climate change. The complex combination of rising temperatures, fluctuating precipitation patterns, and developing hydrological cycles poses a significant danger to the country's water supplies. The intricate balance between supply and demand is exacerbated by outdated water management techniques that must be reconsidered immediately. In this light, the last call to action is consistent with the need to transcend traditional paradigms. The discovered weaknesses in conventional water supplies, together with increased demand from other sectors, highlight the importance of tackling water shortage concerns comprehensively.

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Earth Sciences

SOIL PLASTICITY AND ITS CRITICAL MOISTURE CONTENT

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Annotation. The article provides a critical analysis of existing methods for determining the lower limit of soil plasticity. It is shown that the applied methods are imperfect and the obtained results have no relevance to the critical moisture content. To determine the critical moisture content, the use of maximum molecular moisture capacity is proposed, which serves as an energetically equivalent parameter for all types of soils, regardless of their composition and origin.

Keywords: soils, moisture, plasticity, critical moisture content, maximum molecular moisture capacity.

INTRODUCTION

Engineering and construction practice is interested in obtaining a specific criterion of soil moisture, at which the intensity of deformation under load undergoes a sharp change, i.e., its plastic properties become evident.

The plastic state of soils manifests within the range of two moisture levels: a lower threshold, beyond which plastic properties begin to emerge, and an upper threshold, at which plastic properties vanish, giving way to fluid properties.

The methods commonly used to determine the lower limit of plasticity (such as the rolling method and the cone penetration method) yield similar results but bear no direct correlation with the actual lower limit of plasticity, as they tend to produce inflated values [1, 2].

The primary reason for this lies in the fact that despite their simplicity, existing methods vary in the clarity of individual technical operations, which allows for different interpretations.

Furthermore, the obtained results largely depend on factors such as the thickness of the sample, the force and method of finger pressure, the duration of rolling, and so forth. Naturally, this leads to varied outcomes, and even averaged values are far from being truly representative.

MAIN PART

It is known that the stickiness of soil directly correlates with the content of cohesive and binding substances. The lower their content, the more water is required for cohesion. Clearly, here we have a substitution of forces when low cohesion is compensated by water bonds. As a result, two different soils with varying contents of cohesive and binding substances (4% and 31%) have the same value for the lower limit of plasticity (Fig. 1) [3].

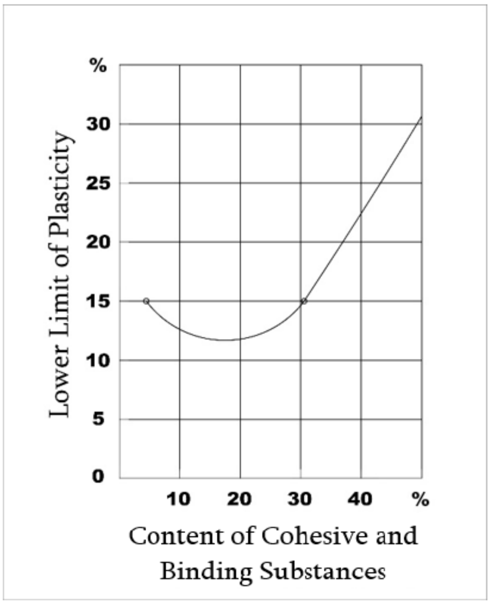

Fig. 1. Graph of Distortion of the Lower Limit of Plasticity

The curves depicted in Figure 2, illustrating the relationship between the liquid limit, plasticity index, and plasticity number for two different soils, clearly indicate the paradoxical convergence of curves at a single point, indicating that the soil simultaneously exhibits two opposing physical states - liquidity and plasticity [4]. Here, there is an apparent contradiction, as the concepts of liquid and plastic consistencies are fundamentally incompatible. The aforementioned graph serves, in our view, as an illustration of the assertion that during the rolling of clayey soils, the soil mass contains moisture significantly exceeding the established minimum. Consequently, the rolling method yields results that have nothing to do with the actual limit of plasticity.

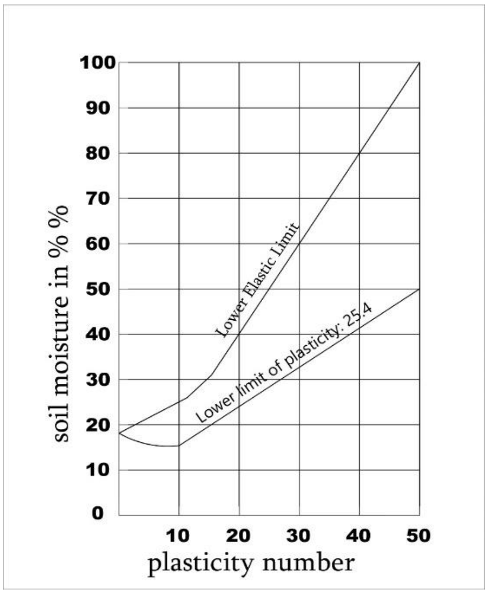

Fig. 2. Relationship between the liquid limit, plasticity index and plasticity number

During the rolling of soil, moisture evaporation occurs unevenly; the surface quickly dries out, while the inner core retains elevated moisture content and significant elasticity. Consequently, the surface develops cracks, and further uniform rolling becomes challenging, leading to the soil breaking into separate parts, and the results obtained are significantly inflated [4].

Once the moisture surpasses this critical value, soil deformation begins to increase at a much faster rate. Under a load of 0.4 kg/cm^2, the deformation increment equals 0.0065 mm per each percentage increase in moisture content, with this intensity of increment observed only up to 25.4% moisture content, which is critical for this soil. With further increases in moisture content, deformations escalate at a rate of 0.55 mm per each percentage increase in moisture content.

The lower the cohesion of the soil, the greater the difference between the actual physical characteristic - the critical moisture content, and the rolling limit, with the former always being lower than the latter [5].

Soil deformations under constant load increase at a certain, albeit small rate, as moisture content rises, until reaching a specific moisture level known as the critical moisture content [Fig. 3].

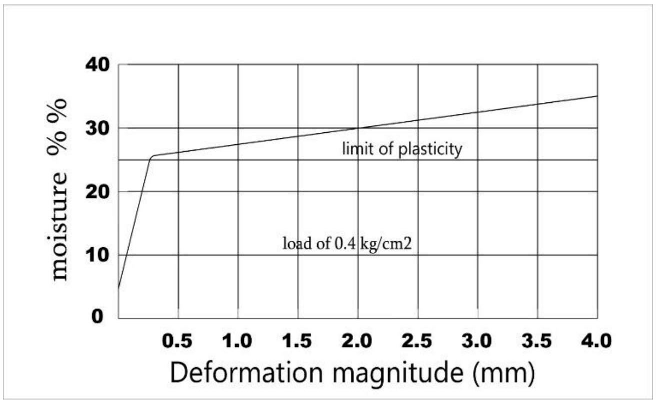

Fig. 3. Graph depicting the relationship between deformations and soil moisture content

Therefore, to determine the consistency boundaries, it is necessary to utilize fundamentally different methods devoid of the aforementioned shortcomings.

CONCLUSION

Our research conducted across a wide spectrum of different soils (from light clays to heavy clays) allows us to assert that moisture indicators such as maximum molecular moisture capacity (MMM) and critical moisture content are physically identical parameters.

As an example, we present a graph in Fig. 4, derived from experimental data [5, 6].

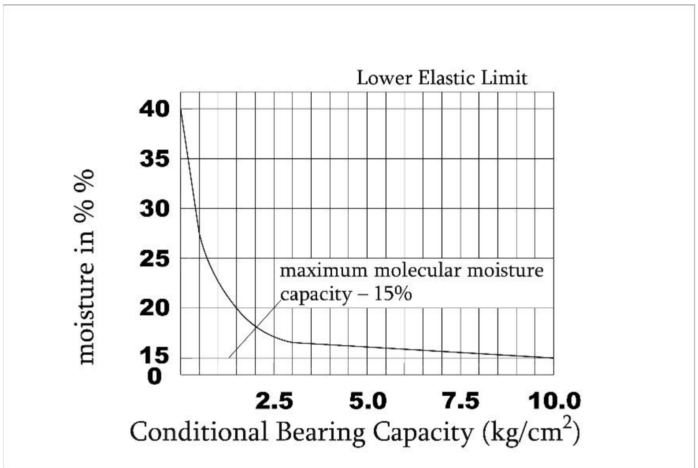

Fig. 4. Graph illustrating the maximum molecular moisture capacity as an indicator of the critical moisture content of the soil

The maximum molecular moisture capacity of the soil is a stable parameter of the surface of all soil particles, independent of their aggregation nature.

This parameter serves as a highly accurate passport for the soil, preserved regardless of external temporal factors affecting the soil.

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Earth Sciences

INFLUENCE OF SWELLING ON AIR-WATER REGIME CLAY SOILS

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Annotation. The article deals with the influence of swelling on the water-air regime of soils. The features of the change in water - physical indicators depending on the specific humidity. A method is proposed for calculating these indicators for different stages of swelling and humidity.

Keywords: soil, moisture, swelling, bulk density, water - air regime, calculation method.

INTRODUCTION

Swelling, or the ability to increase the volume when moistened, is a characteristic feature of clay soils and is one of the indicators of their hydrophilicity.

In the process of moistening (or drying), the swelling clay soil continuously changes its bulk density, total and differential porosity, cohesion, water permeability and other physical and technical indicators. Internal stresses of swelling pressure arise in the soil body.

To identify clay soils by the degree of their swelling, the following criteria [1] is used .

$$\frac{\varepsilon_0 - \varepsilon_T}{1+\varepsilon_0} < -0.3 \tag{1}$$

where ε_0 and ε_T are the coefficients of porosity at natural moisture and moisture at the fluidity boundary.

A negative value of this criteria characterizes the relative swelling with a change in moisture from natural to a state of fluidity and is a qualitative indicator that distinguishes this clay soil from others.

If the assessment of soil swelling by deformations as well as criteria (1) is sufficient for construction practice for reclamation problems, associated with clay drainage of soils (setting depending water-air condition, water permeability and water loss from humidity) is completely insufficient.

Therefore, the development of a methodology for a quantitative assessment of the swelling capacity of clay soils and the establishment of the effect of this process on the change in water-physical parameters as a function of moisture is relevant.

MAIN PART

The studies were carried out on samples of montmorillonite clays of the Colchis Lowland and heavy loams of the Alazani Valley of Georgia.

The research technique was reduced to the following [4; 5; 6].

The volumetric mass δ_W at natural humidity W and the corresponding volumetric mass of the skeleton

$$\delta = \frac{\delta_W}{1+W} \tag{2}$$

An elastic cover made of soft, thin rubber was stretched over the cylindrical sample compressed as a result of drying. As water saturation through the end surfaces and an increase in volume at a certain time interval, the test samples were weighed and the volume was determined (by the mercury method). At the same time, the rubber cover protected the sample from disintegration and simulated the lateral pressure of the soil in natural conditions.

Based on periodic weighing and volume measurements, a dependence diagram was built $\delta_w = f(w)$ и $\delta = f(w)$

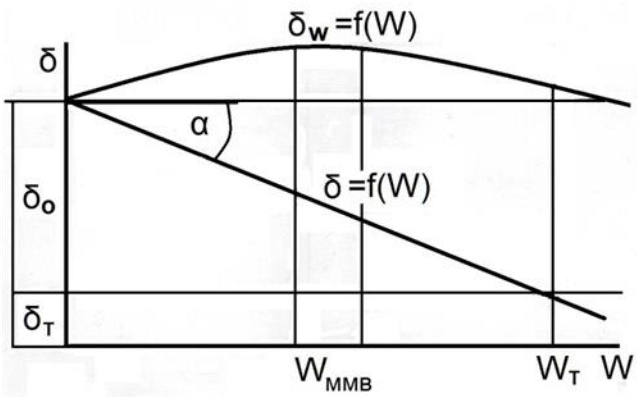

Fig. 1. Dependency diagrams $\delta_w = f(w)$ и $\delta = f(w)$

As shown in the diagram (Fig. 1), as the saturation proceeds, the bulk density of the wet soil increases monotonically to the maximum swelling (W_H), and then decreases. The change in the volumetric mass of the skeleton is expressed by a straight line, which forms a certain angle a α with the abscissa axis. the value of which is proportional to the volumetric deformation of the sample at water saturation, which can serve as a quantitative indicator of swelling. It should be noted. that the rectilinear dependence of the bulk mass of the swelling soil skeleton on moisture is well known in soil science [1, 2, 3].

Based on the foregoing, the expression can be taken as an indicator of swelling

$$N = tg\alpha = \frac{\delta_o - \delta}{W} \tag{3}$$

where δ_o and δ are the volumetric masses of the skeleton in an absolutely dry state and at any current moisture content W, respectively

$$\delta = \delta_o - Nw \tag{4}$$

According to (4) and (2), the bulk density of wet soil at any current moisture content

$$\delta_W = \delta(1+W) \tag{5}$$

By finding the maximum δ_W (Fig. 1), it is possible to determine the value of the swelling moisture W_H

$$W_H = \frac{\delta_o - N}{2N} \tag{6}$$

By the values δ and δ_0 by (3), the index N is calculated.

Let us compare the values of the proposed indicator N with criterion (1).

For this, according to (3) and (4), we get:

$$\varepsilon_0 = \frac{\gamma - \delta_0}{\delta_0} \qquad \varepsilon_\gamma = \frac{\gamma - \delta_T}{\delta_T}$$

and rewrite expression (1) in the notation we have adopted:

$$\frac{\varepsilon_0 - \varepsilon_T}{1+\varepsilon_0} = \frac{\delta_T - \delta_0}{\delta_T} < -0{,}3,$$

where γ is the specific gravity of soil particles;

δ_T is the volumetric weight of the soil skeleton at the moisture content of the yield point W_T

The results of calculating the N index and the corresponding values of the nomenclature criterion according to (1) and (7) for studied soils are shown in Table 1.

Table 1.

Indicator N and corresponding values of the nomenclature criterion

Name of soil	**Lot. weight, γ g/cm**	**Humidity fluid. W, %**	**About. weight skeleton, δ_o g / cm ^{3}**	**Volumetric mass of damp, δ_T g / cm ^{3}**	**Index swelling , N**	$\frac{\varepsilon_{\circ o} - \varepsilon_T}{1+\varepsilon_o}$
Khorga clay	2.74	61.0	1.57	1.13	0.72	0.39
Chaladidi clay	2.74	63.7	1.51	0.96	0.86	0.57
Kvalo clay	2.75	64.8	1.69	0.85	1.30	0.99
Alazani loam	1.79	45.0	1.72	1.32	0.88	0.30
Alazani loam	1.79	39.5	1.82	1.23	1.23	0.37

The data given in Table 1 make it possible to trace the dynamics of the water-air regime of soils, depending on the degree of swelling, using the following dependencies:

- swelling intensity $N = \frac{\delta_o - \delta_H}{W} \cdot 100$

- bulk density of the skeleton at any humidity $\delta_H = \delta_o - N\frac{W}{100}$

- porosity corresponding to δ_H $n = \frac{\gamma - \delta_H}{\gamma}$

- specific water saturation $G_{вод} = \frac{\delta_H \cdot W_{MMB}}{\gamma_{воды}}$

- specific content of bound water $G_M = \dfrac{\delta_H \cdot W_{MMB}}{\gamma_{воды}}$
- specific content of free water $B = G - G_M$
- specific air content (aeration) A = 1- G

The corresponding calculated values for the Chaladidi clays are given in Table 2.

Table 2

Indicator and	**Humidity, W, %**						
	10	**20**	**thirty W $_{m\,mv}$**	**40**	**50**	**60**	**64 W $_t$**
About. weight skeleton,	1.42	1.34	1.27	1.17	1.08	0.99	0.96
Water-saturated, G	0.30	0.52	0.66	0.82	0.90	0.94	0.95
Content bound water, G $_m$	0.30	0.52	0.66	0.57	0.50	0.44	0.40
Content free water, B	0 , 0	0 , 0	0 , 0	0.25	0.40	0.50	0.55
Aeration, A	0.70	0.40	0.34	0.18	0.10	0.06	0.05

CONCLUSION

Based on the above, the following conclusions can be drawn:
- swelling is the most important factor determining the ameliorative state (water - air regime) of clay soils;
- in heavy clay soils, as the moisture content decreases from W to $W_{ММВ}$, the indicators of the content of available moisture and air change significantly for the worse, as a result of which the efficiency of drainage reclamation spontaneously decreases;
- the proposed methodology and calculation methods may well be used in practice to assess the reclamation state of clay soils.

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STATISTICAL MODELS OF RESERVOIRS WATER QUALITY RELIABILITY

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Annotation. Application of the theory of reliability for solution of reservoirs' pollution problems allows us to establish the physical origin of each polluting element (component) failure, to more completely determine the effect of external and internal factors on water quality, to identify both quantitative and reliability characteristics for each element of water quality.

Using this method, the risk of Tbilisi, Sioni and Tsalka reservoirs pollution with some biogenic elements has been determined. Plugging these data, we obtain that Tbilisi reservoir pollution risk with nitrogen compounds brought by surface run-offs from agricultural land areas is 25%, while in case of phosphorus it equals to 18%.

The similar studies carried-out at Sioni and Tsalka reservoirs showed the following: Sioni reservoir pollution risk with nitrogen compounds is 27%, and that of Tsalka reservoir is 38%.

Reservoirs pollution with biogenic elements approaches to such a limit that is usually followed by activation of eutrophication processes.

Keywords: reservoirs' pollution, Pollution risk, Biogenic elements.

INTRODUCTION

Application of the theory of reliability for solution of reservoirs' pollution problems allows us to establish the physical origin of each polluting element (component) failure, to more completely determine the effect of external and internal factors on water quality, to identify both quantitative and reliability characteristics for each element of water quality.

GENERAL PART

Failure of each element of water quality may be characterized by generalized opposition – external action and internal stress. For instance, reservoirs of Georgia are mainly polluted by different biogenic elements and toxic chemicals brought from agricultural lands. Exactly the excessive transfer of these elements promotes excess of the same element concentrations in reservoirs over maximum permissible concentrations. In this case, polluting i-ingredient brought to the reservoir by the surface run-off may be considered as an inciting factor of i-ingredient failure or as a load, while concentration of the same ingredients available in the reservoir puts up an internal resistance.

Based on this, reservoir pollution probability, on the assumption of randomness of external stress (Q_d) and internal resistance (Q_w), may be expressed as follows [1, 2]:

$$P_i = P\left(Q_d > Q_w\right) = \left(Q_d - Q_w\right) > 0 \tag{1}$$

Proceeding from this dependence, a link between reliability and risk is determined according to following expression:

$$P_i + R = 1 \tag{2}$$

Intersection of stress and resistance curves points at the interaction of these two probabilistic processes. In this case, the reliability is the probability that resistance is higher than stress for its any possible values:

$$P_i = \int_0^{\infty} f\left(Q_w\right)\left[\int_0^{Q_w} f\left(Q_d\right) dQ_d\right] dQ_w \tag{3}$$

$$P_i = \int_0^{\infty} f\left(Q_d\right)\left[\int_0^{Q_d} f\left(Q_w\right) dQ_w\right] dQ_d \tag{4}$$

$$R = \int_0^{\infty} f\left(Q_w\right)\left[\int_0^{\infty} f\left(Q_d\right) dQ_d\right] dQ_w \tag{5}$$

where, $f\left(Q_d\right)$ and $f\left(Q_w\right)$ are the densities of stress and resistance distribution.

In general case, intersection of stress and resistance curves for their any and all values comprises the risk of reservoir pollution.

In the majority of cases, stress and resistance are determined by large accumulation of disturbances, that is why a Gaussian distribution law can be taken as the law of their distribution [1, 2, 4]. Based on this assumption and in the event of knowing the values of their mathematical expectation $\left(M_{Q_w}, M_{Q_d}\right)$ and mean square deviation $\left(\sigma_{Q_w}, \sigma_{Q_d}\right)$, the risk of reservoirs' water pollution with i - ingredient may be expressed by the following dependence:

$$P_i = \Phi\left[\frac{M_{Q_w} - M_{Q_d}}{\sqrt{\sigma_{Q_w}^2 + \sigma_{Q_d}^2}}\right] \tag{6}$$

where, Φ - Laplace function and its values are given in the books on the theory of probability and mathematical statistics [3].

If the stress Q_d and the resistance Q_w are described by log-normal distribution curve and their variation coefficients $\left(Cv_{Q_d}, Cv_{Q_w}\right)$ are known, then P_i is expressed by the following formula:

$$P_i = \Phi\left[\frac{\ln\left(\frac{M_{Q_w}}{M_{Q_d}}\sqrt{\frac{1+Cv_{Q_d}^2}{1+Cv_{Q_w}^2}}\right)}{\sqrt{\ln\left(1+Cv_{Q_d}^2\right)\left(1+Cv_{Q_w}^2\right)}}\right] \tag{7}$$

P_i calculating formulas for cases of other distribution of stress and resistance are given in detail in the works of A. Kapur and L. Lamberson [2].

Application of this curve for solution of practical problems is complicated due to absence of data on stress, in our case lack of observation data on polluting elements brought from agricultural land areas adjacent to reservoirs. That is why, in order to determine an approximate reliability of reservoir's water quality one may make use of known deterministic dependence, which functionally links the dependent variable values with independent variables. This dependence may be written as follows:

$$y = f\left(x_1, x_2, ..., x_n\right) \tag{8}$$

Independent variables $x_1, x_2, ..., x_n$ are random values, as a rule, so a consequence parameter has to be considered as a random value. If this dependence is a linear function, then determination of mathematical expectation and mean square deviation doesn't present severe difficulties. Mathematical expectation and dispersion of function (8) are determined by the formulas [5]:

$$m_y = \varphi(x_1, x_2, ..., x_n) + \Delta_1 + \Delta_2 \tag{9}$$

$$\sigma_y^2 = \sum_{i=1}^{n} \left(\frac{\partial \varphi}{\partial x_j} \right)_{x_j}^2 = \bar{x}\sigma_{x_j}^2 + \Delta_3 + \Delta_4 \tag{10}$$

where, Δ_1, Δ_2, Δ_3 and Δ_4 are nonlinearity coefficients [2].

Using linearization method it is possible to roughly assess mathematical expectation and dispersion of stress by the following formula:

$$q_c = \frac{4}{3} m' c_g \frac{\Omega}{Q_z} \sqrt{\frac{D}{\pi t}} \tag{11}$$

where, m' - soil porosity; Ω - water-catch basin area, m²; c_g - i-ingredient concentration in soil, mg/g; Q_z - surface run-off discharge m³/sec; D - i-ingredient diffusion coefficient.

Providing that c_g and Q_z factors variability is negligible, one can present (11) in the following form:

$$q_c = \varphi\left(m_{c_g}, m_{Q_z}\right) + \frac{\partial \varphi}{\partial c_g} \Delta c_g + \frac{\partial \varphi}{\partial Q_z} \Delta Q_z \tag{12}$$

If a sought-for value is an independent variable function, then its mean square deviation may be determined according to the following formula:

$$\sigma_{q_c} = \sqrt{\left(\frac{\partial \varphi}{\partial c_g} \right)^2 \sigma_{c_g}^2 + \left(\frac{\partial \varphi}{\partial Q_z} \right)^2 \sigma_{Q_z}^2} \tag{13}$$

CONCLUSION

Using this method, the risk of Tbilisi reservoir pollution with biogenic elements has been determined. The adjacent territory of Tbilisi reservoir with an area of 8,7 km^2 is occupied by orchards and arable lands, where soil concentration of nitrogen and phosphorus are (6.55 and 1.9) mg per 100 gr of soil. Surface run-off discharge is 2.5 m³/sec. Diffusion coefficient equals to ($10^{-6} \cdot 16.1$) cm²/sec for nitrogen, and ($10^{-6} \cdot 7.15$) cm²/sec for phosphorus. Consequently, an average concentrations of nitrogen compounds and phosphorus in surface run-offs, determined according to (11) formula, equal to: 8.81 mg/l and 0.469 mg/l, respectively.

Mean square deviation of biogenic element concentrations and surface run-off discharge is determined according to three sigma rule. For nitrogen, σ_{c_g} =0.56, for phosphorus σ_{c_g} =0.67, while for surface discharge it equals to σ_{Q_z} =0.84. Plugging these data in formula (6) we obtain that Tbilisi reservoir pollution risk with nitrogen compounds brought by surface run-offs from agricultural land areas is 25%, while in case of phosphorus it equals to 18%.

The similar studies carried-out at Sioni and Tsalka reservoirs showed the following: Sioni reservoir pollution risk with nitrogen compounds is 27%, and that of Tsalka reservoir is 38%.

As one can see, reservoirs pollution with biogenic elements approaches to such a limit that is usually followed by activation of eutrophication processes.

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Hydro technique and amelioration

DETERMINATION OF CRITICAL NON-FLUSHING BED VELOCITIES ON IRRIGATED AREAS

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Annotation. Protection of irrigated areas from erosion has become an urgent problem in many countries of the world.

The study of the regularities of the development of soil erosive processes, the implementation of measures in production, is of particular importance for Georgia, as a country with little land, where it is no longer possible to acquire new arable areas without significant capital expenditures and thereby increase the production of agricultural products. Therefore, along with other measures, great attention should be paid to the protection of existing beds from erosion and to the issue of rational land use.

In the article, it is substantiated that the calculation dependences of the allowable speed proposed by different authors are characterized by the same analog structure and if they are considered valid for solid sediment.

It is established that for the quantitative assessment of soil-soil irrigation erosion, the specific weight of a solid body is markedly different from the specific weight of a porous physical body, in particular, the specific weight of the soil-soil water-resistant aggregate; Soil-soil aggregates are prone to surface-molecular effects, and their formation in accordance with the degree of water filling radically changes the marginal equilibrium conditions of aggregates at different stages of erosion.

***Keywords**:* irrigation, washing speed, newtonian fluids, critical depth.

INTRODUCTION

The main function of irrigation is to create an optimal soil moisture regime for agricultural crops during the entire vegetation period. In addition, irrigation should not cause irrigation erosion, for which such irrigation rules, techniques and mode should be selected, during which the formation of surface runoff is excluded. Irrigation erosion takes place intensively during runoff irrigation.

The division of the water erosion processes into stages is mainly related to the indicator of the degree of water filling of the soil pores. It is the different interpretation of the influence of initial humidity and the mechanism of the process compared to the prevailing concept today.

MAIN PART

The interaction of the bed and surface flow is integrally reflected in the formation of the erosion processes and the regularity of the variability of its intensity. Due to this, it is necessary to study the hydraulic regime of the surface runoff under the influence of the atmospheric precipitation and especially its role in the formation of hydromechanical and morphological parameters of flat one-dimensional flow, which is one of the main tasks of the hydraulics of the open beds in general [1,2].

In general, in the case of flat flow, the cost balance equation will be written as follows:

$$\frac{dQ}{dx} = \left(\varepsilon - h_{inf} - h_a\right)y, \qquad (1)$$

Where: Q is Flow, from the source (watershed), in the intersection some x distance away;

$\varepsilon, h_{inf}, h_a$ - Accordingly, the calculated averaged values of the intensities of precipitation, infiltrative water absorption and evaporation in the time interval taken;

y - Width of the catchment area.

It is necessary to note that in all specific cases, the calculation model may not provide the perfect quantitative reflection of this or that factor, but in accordance with the pre-designated reliable level, it may be systematically perfected using any numerical method known in mathematics.

The specific cost of surface runoff for flat flows, in the intersection of the mileage path, is the continuous function of time together with the coordinates. This means that when we ignore the evaporation, then the cost is determined by:

$$q = \varphi(x, z, t; \;\; \varepsilon = \varepsilon(t); \;\; K = K(t) \;), \qquad (2)$$

Where: q is Cost per unit of the flow width;

x, z - Intersection coordinates taken;

t - Time setting;

ε and K - Accordingly, for the current moment of time.

From the point of view of the practical implementation, even trivial infiltration models are also associated with the insurmountable difficulties, although they often fail to provide the necessary results based on the physical essence of the non-established infiltration process. As for the complex multidimensional models, they are either not found at all or are rarely used in practical calculations. The main reason for this should be considered the difficulty of determining the coefficients included in the basic private derivative differential equations reflecting the process, since they are the functions of the independent parameter (in this case, the time). Because of this, it becomes necessary to determine these parameters only through the experiments, although in this case, it is rarely possible to maintain the parameter constancy even during the time period of conducting the experiments.

If we present in the calculation model only the characteristics of rain intensity and water absorption (water permeability) of the soils without any determination in determining the formation of the surface runoff, then obviously their ratio must uniquely determine the value of the main hydromechanical parameter of the surface runoff - the average speed value, and therefore the cost too. As we have mentioned many times, the variation of each of these components (water absorption-intensity) is the function of time and therefore is reflected by different analytical laws (curves), which excludes the use of the principle of superposition (dependency of the action of forces) to estimate the total effect of the process [3,4].

In the case of averaging, instead of the variable parameters, we will obviously get the constant coefficients, or even the indicator of the ratio of the averaged precipitation and water absorption. The acceptance of such assumptions and appropriate parameterization obviously automatically affects the nature (regime) of the motion of the surface runoff. However, from the formal point of view, this cannot have any effect on the variability of the real process regime and its quantitative assessment when $\varepsilon(t) = K(t)$ e.i., when the intensities of rain and water absorption coincide in the certain interval of time, or rather are equal, then obviously the surface runoff does not occur. It can also be assumed with high probability that the accumulation of the surface water, runoff will not occur when $\varepsilon(t) < K(t)$.

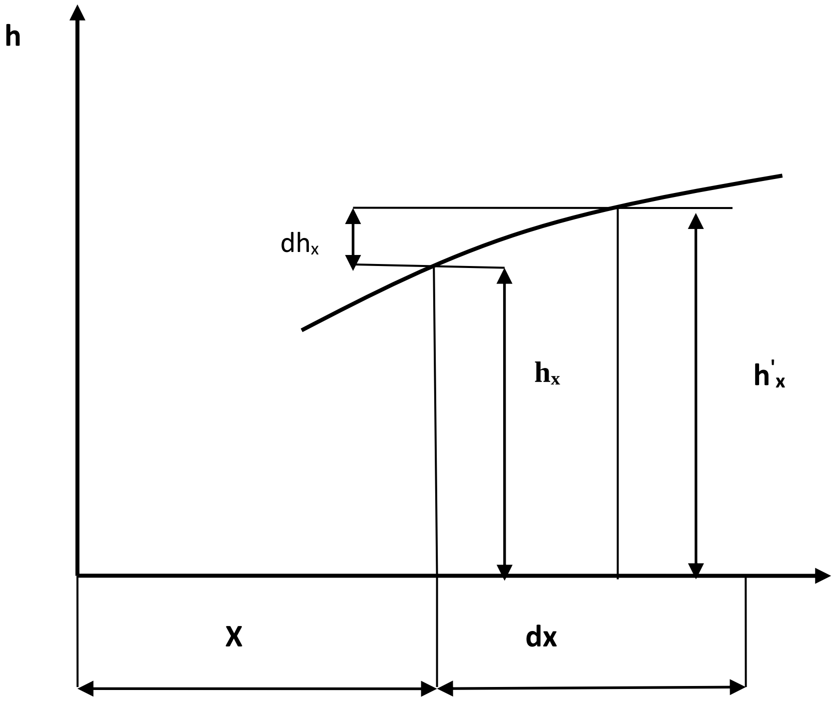

Fig. 1. Calculation scheme of the free surface of the flow for equal motion

Between two neighbouring intersections separated by the distance dx, in a certain period of time, the seepage (infiltration) of the part of the precipitation, and transit of the other part, which gives the increase in the specific cost. This change can be expressed as follows:

$$dq = h'_x V'_x - h_x V_x = \varepsilon dx - K dx. \quad (3)$$

The average speed in any intersection of the flow is determined according to Chezy:

$$V_x = \frac{87\sqrt{h_x}}{n_0}\sqrt{h_x i} = C h_x, \quad (4)$$

Where: $C = \frac{87\sqrt{h_x}}{n_0}$.

Considering (4), the equation (5) will take the form:

$$C(h_x^2 + 2h_x dh_x + (dh_x)^2) - ch_x^2 = (\varepsilon - K)dx. \quad (5)$$

Neglecting the infinitesimally small value of the high-order dh_x^2, we will have:

$$2ch_x dh_x = (\varepsilon - K)dx. \quad (6)$$

Integrating the latter, we will get:

$$h_x = \sqrt{\frac{x}{c}(\varepsilon - K)}. \quad (7)$$

The accepted dependence for describing the shape of the flow surface is based on the assumption, according to which the unequal motion is replaced by equal motion. Such an assumption in itself excludes the need to decipher the process using the differential equation, because the equation is quite easily obtained from the cost continuity condition. Suppose we have the right-angled area of unit width of length x, over which the volume of water flows per unit of time, equal to $x(\varepsilon - K)$, obviously this, according to the continuity condition, should equal the cost in the x intersection - $ch_x h_x$, that is, we will get the equation (7) determining h_x.

The mentioned method of determining the flow depth is based on a very rough linearization, and at the same time, the differentiated calculation for the description of the runoff formation process is devoid of the purposeful mathematization, which is expressed in the equation of the surface inclination of the irrigation area with the hydraulic inclination $i = I$.

According to the calculation scheme (Figure 1), we can write the following equation:

$$z = z_0 + h_x - ix, \tag{8}$$

From where,

$$\frac{dz}{dx} = \frac{dh_x}{dx} - i. \tag{9}$$

Since dz/dx is the derivative of the free surface in the point taken, i.e., in other words, the hydraulic inclination I, which will alternate with the bottom inclination and will give the following kind of dependence by the Chezy formula:

$$(\varepsilon - K)x = \frac{87}{n_0}\sqrt{h_x}\sqrt{h_x I}h_x. \tag{10}$$

In order to fully identify the latter equation, we present it as follows:

$$\frac{(\varepsilon - K)n_0}{87\sqrt{i}}\frac{x}{h_x^2} = \frac{1}{\sqrt{i}}\sqrt{\frac{dh_x}{dx} - i}. \tag{11}$$

The left side of this equation based on the assumption accepted can be considered equal to 1, and so the equation (11) will give:

$$\sqrt{i} = \sqrt{\frac{dh_x}{dx} - i}, \tag{12}$$

From where:

$$\frac{dh_x}{dx} = 2i. \tag{13}$$

Given the boundary condition, integration of $x = 0,\ h_x = 0$ (14) gives us:

$$h_x = 2ix. \tag{14}$$

Considering (14) and with appropriate transformations, we will get:

$$ax^2dx = h_x^4 dh_x - ih_x^4 dx. \tag{15}$$

The differential equation, obviously, cannot be solved using the usual tabular integrals, that's why if we get $b = ih_x^4$, then integration of (15) taking into account the boundary condition will give us:

$$h_x = \sqrt[5]{5/_3\, ax^3 + 5bx}. \qquad (16)$$

This equation is far from reflecting the real physical picture of runoff, but it expresses much better the nonstationarity of the flow motion. Therefore, with the first rough approximation we can determine the morphometric feature h_(x_1) in any x intersection of the flow. In accordance with h_x according to the method shown above, let's determine the permissible inclination, that is, the inclination that responds to the condition of the bed not being washed away.

CONCLUSION

The quantitative assessment of the erosion is possible only by engineering method or by direct calculation using this or that formula. As we have repeatedly noted, the calculation dependencies of the permissible speed proposed by different authors are characterized by the same analog structure, we also accepted that if they are considered sound for the solid debris, their use for the quantitative assessment of the irrigation erosion of the soils is completely unjustified, since the specific gravity of the solid body is is sharply different from the specific weight of the porous physical body, in particular, the specific weight of the waterproof aggregate of the soil. In addition, the tendency of the soil aggregates to the occurrence of the surface-molecular effects and their formation according to the degree of water filling radically changes the marginal equilibrium conditions of the aggregates at different stages of the erosion. We can always match the h_x flow depth determined by (Formula 16) with the diameter that will not be subject to the erosion and will ensure the stability of the self-washing bed, or otherwise we are given the opportunity to determine the critical non-washing speed.

Therefore, we can conclude that it is necessary to use the adjusted dependence of the permissible speeds for the quantitative prediction of the soil water erosion. This dependence takes into account some specifics that are caused by the wide range of physico-chemical processes taking place in the soil and ensures the relatively high reliability of the forecast of the irrigation erosion.

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Hydraulic engineering and irrigation

DESIGN AND SCIENTIFIC SUBSTANTIATION OF MEASURES TO REDUCE THE NEGATIVE IMPACT OF RIVER BED EVOLUTION ON THE EXAMPLE OF THE PRIPYAT RIVER

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Annotation. The results of the assessment of the hydrological regime and riverbed processes for problematic river sections are presented on the example of the Pripyat river section in Belarus. The quantitative characteristics of the transport and sedimentation of suspended loads as well as vertical riverbed deformations due to the movement of bottom ridges of entrained sediments, which can lead to sediment deposition, a decrease in the depth of the riverbed and deterioration of navigable conditions, as well as to the erosion of the channel, have been determined. Based on the theoretical and experimental studies carried out, a possible set of measures is presented to ensure the stability of the riverbed and reduce the intensity of the impact of riverbed processes, including strengthening the bank and periodic clearing of the riverbed with dredging and removal of bottom sediments.

Keywords: hydrological regime, probability of exceeding (availability of hydrological value), sediments, channel-forming water flow, permissible (non-washing) speed, river section.

INTRODUCTION

River bed evolution have a significant impact on navigation conditions on rivers, as well as re-formation river bed, which can endanger adjacent sites.

The river bed evolution include transport and the deposit of suspended load, as well as the formation and bed load ridges movement of sediments. The movement of the bed load ridges causes river bed deformations that can cause sediment deposition, reduction of river bed depth and deterioration of navigation, as well as the erosion of the river bed.

The development and implementation of appropriate measures is necessary to reduce the negative impact of river bed evolution on the hydrological regime of the river and adjacent territory, as well as water use, including shipping.

General Part (object of study and methods)

The object of the study is the section of the Pripyat River. Pinsk, Lubansky Bridge - 1.3 km below the bridge» (hereinafter - the design section), located in the Pinsky district of the Brest region in Belarus (Figure 1). Studies in this sector are due to deteriorating shipping conditions, the risk of shoreline re-formation and the threat to the safety of the left-bank road. An analysis of available cartographic material over 100 years showed a tendency of the bends river to move downstream and a shift of the left bank towards the road.

Scientific research was carried out in the research laboratory of landscape ecology of the Belarusian State University. As a result, measures to reduce the negative impact of riverbed processes have been developed and substantiated for the specified section.

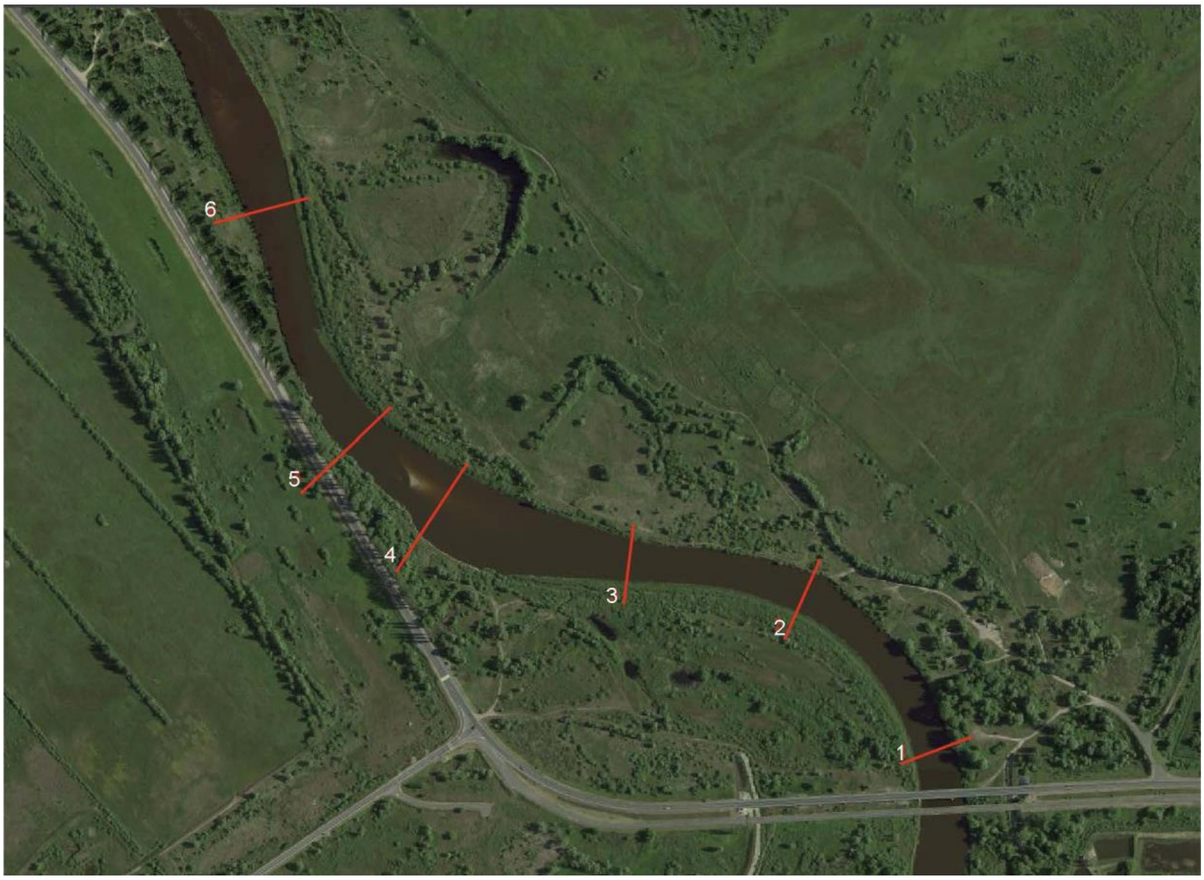

Fig. 1. The design section of the Pripyat River (Cross-sectional numbers in numerals)

The research included field experiments and theoretical calculations.

Field studies included the hydrometric measurements of stream cross-section of the design area (Figure 1), measurements of local longitudinal velocities and water consumption, sampling of bottom sediments and analysis of grain-size composition of.

Theoretical calculations are based on hydrological desing of water discharge for hydrological conditions under which the most intensive river processes take place, as well as hydraulic calculations of the corresponding water levels, average current speeds and characteristics of the river bed evolution. For hydraulic calculations of water levels and mean current velocities under given hydrological conditions, mathematical models of the design section Pripyat River are used. Model is based on the numerical solution of the equation of uneven movement of water with variable length flow rate [1]. At the same time, the morphometric and hydraulic parameters of ten characteristic levels, from the lowest to the highest, are calculated for the given cross-sections. Morphometrical characteristics include the area of the cross-section, maximum depth of water, bottom level and width. Hydraulic parameters include hydraulic radius, throughput capacity of waterway, reduced roughness coefficient.

For the assessment of possible river bed deformations and the stability of the course, the maximum water consumption of spring flooding was calculated at 50% of the probability of excess (availability) (hereinafter referred to as PE). For the evaluation of the transport of sediments, the low water period consumption of 50% of the PE was calculated. Verification of the mathematical model of the uneven movement of water at the design site was carried out on the basis of field hydrometric measurements materials (velocities of water and water consumption). The mean water flow rate on the design section was determined by measuring local longitudinal water velocities and with [5], and it equals 167.4 m^3/s.

The estimated water consumption corresponding to the maximum spring flood discharge of 50% of the PE (Figure 2) and the low water period discharge of 50% of the PE was determined on the published data on the hydrological regime Pripyat River hydrological post Pripyat River, t. Pinsk, Bridge Lubansky [3] (further - hydrological post), corresponding to the upper value due to of observation from 1979 to 2022. Expenses were calculated on [7]. An empirical and theoretical probability curve of water expenditure distribution with estimation of coefficients of variation C_V and asymmetry C_S (Figure 3) has been determined (using a three-parameter gamma-distribution). A summary of the results of the hydrological calculations is in table 1.

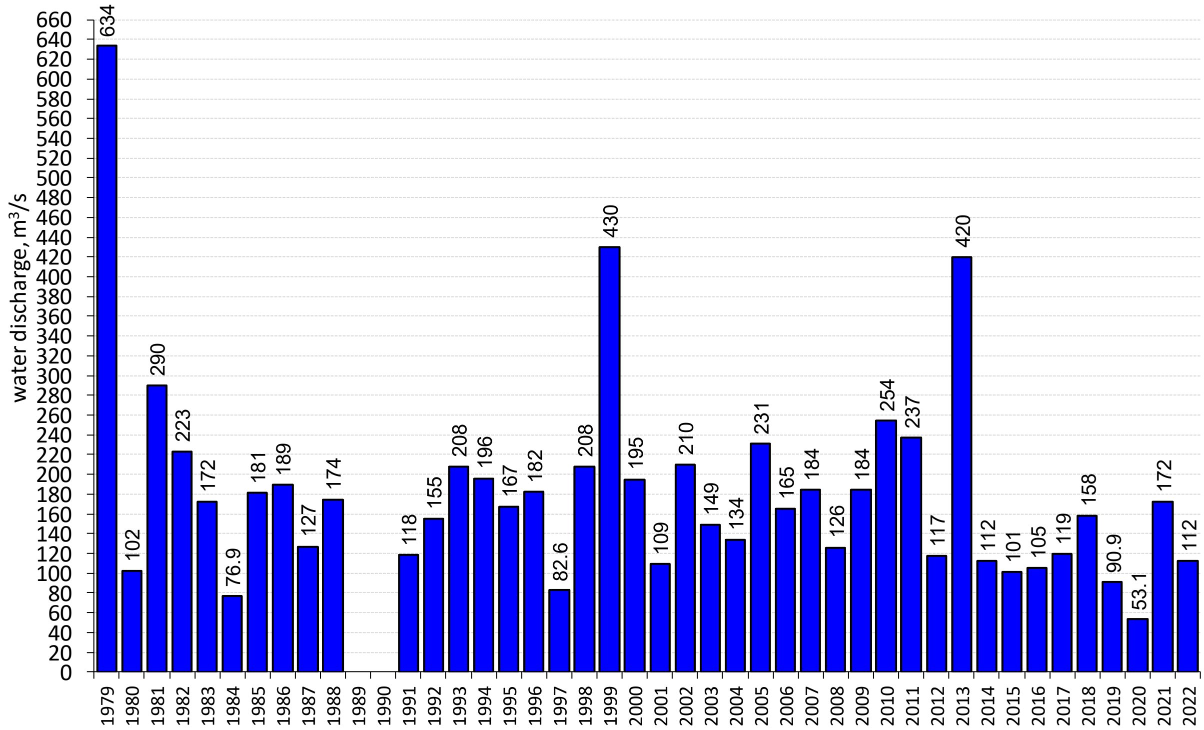

Fig. 2. Maximum spring flood (was no flood in 1989 and 1990)

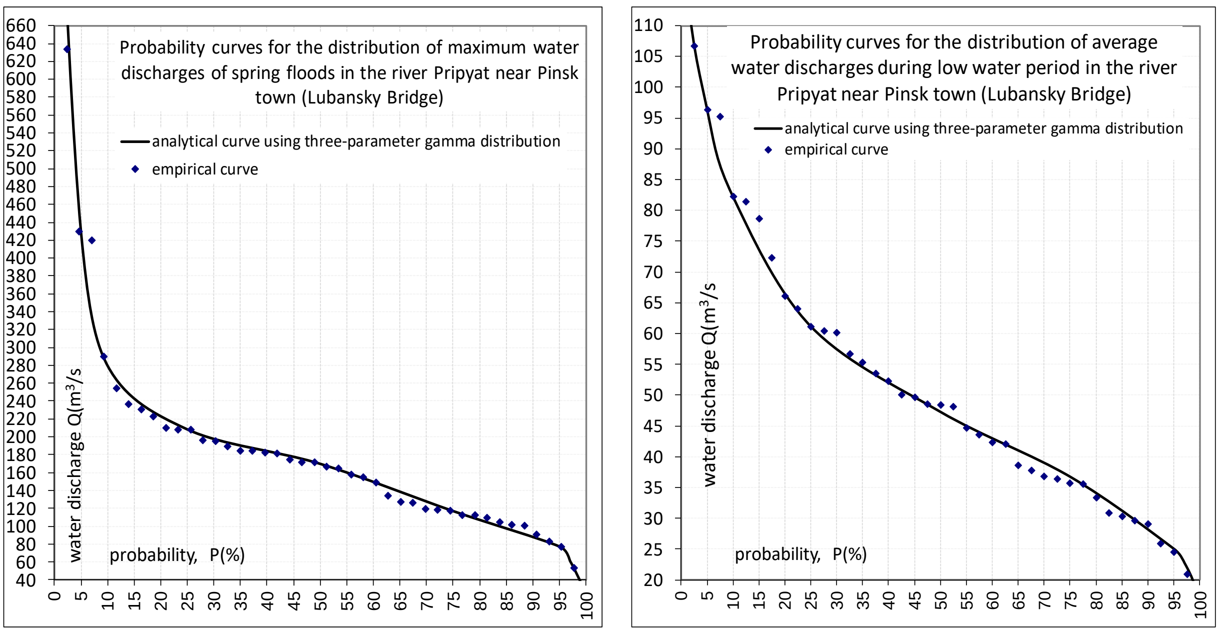

Fig. 3. Empirical and theoretical curves for the distribution of maximum spring flood water and average inter-annual water consumption

Table 1

Summary of hydrological calculations

Hydrologic conditions	
maximum spring flood of 50% PE (formative discharge), m^3/s	low water period 50%PE, m^3/s
169,5	47,3
coefficient of variation C_V	
0,61	0,42
coefficient of asymmetry C_S	
3,66	1,68

The results of calculations of water levels are on Figure 4.

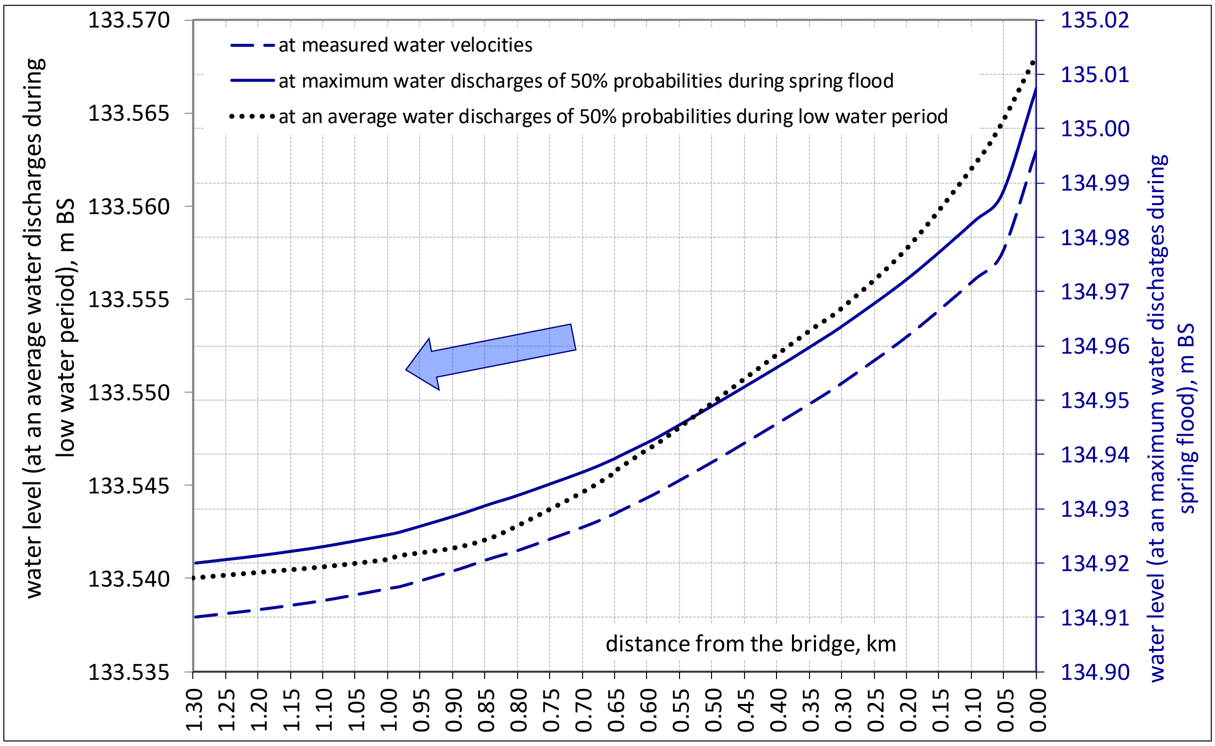

Fig.4. Results of calculations of the level regime in the settlement section of the Pripyat river

The stability of the riverbed was assessed by comparing the calculated averages on the verticals of the flow velocities with the calculated averages on the verticals of the permissible (non-erosion) flow velocities. The average vertical longitudinal water flow velocities were determined by numerically integrating the local vertical longitudinal flow velocities along the vertical flow depth, which were determined using a semi-empirical dependence [4].

The calculated permissible (non-erosion) average velocities on verticals are determined using the dependence of B.I.Studenichnikov [5], that allows to take into account the heterogeneity of the distribution of water flow velocities on the vertical by introducing the Coriolis correction (kinetic energy). The mean size of the bottom sediment bed loads was used, taking into account the percentage of the different fractions.

Calculations of the water flow in the river, close to the formative discharge, showed that the average water flow rate exceeds the permitted (non-erosion) water flow rate, which indicates that the Pripyat riverbed in the calculated area is not stable (Figure 5).

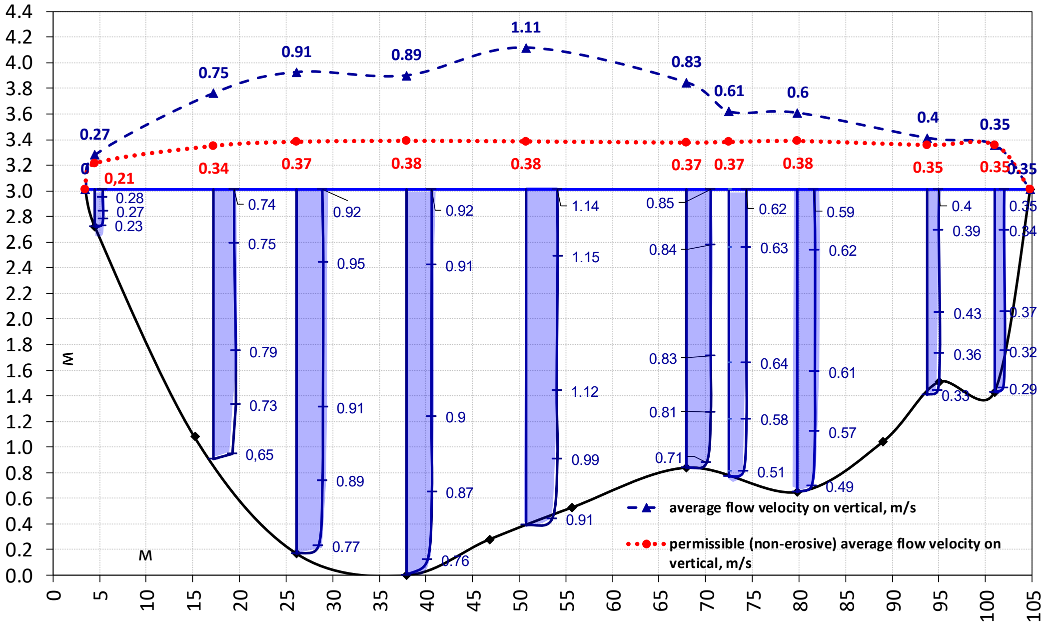

Fig. 5. Results of calculations of the distribution of flow velocities, average vertical velocities and permissible (non-eroding) average vertical velocities in the widest part (at the turn) of the problem area of the Pripyat river

The riverbed evolution in the case when the riverbed is not stable include the occurrence of vertical / deep riverbed deformations, the height of which ridges (deep deformations / washouts or the height of ridges of entrained sediments) as well as the length of the bottom ridges and the speed of their movement are determined by the dependencies of V.S.Knoroz [6]. A summary of the results of calculations of the characteristics of riverbed processes is presented in Figure 6. The maximum velocity of movement of bottom ridges on the cross-sectional 4 indicates the greatest intensity of riverbed processes in this section, which causes the shortest length of bottom ridges due to their faster re-form.

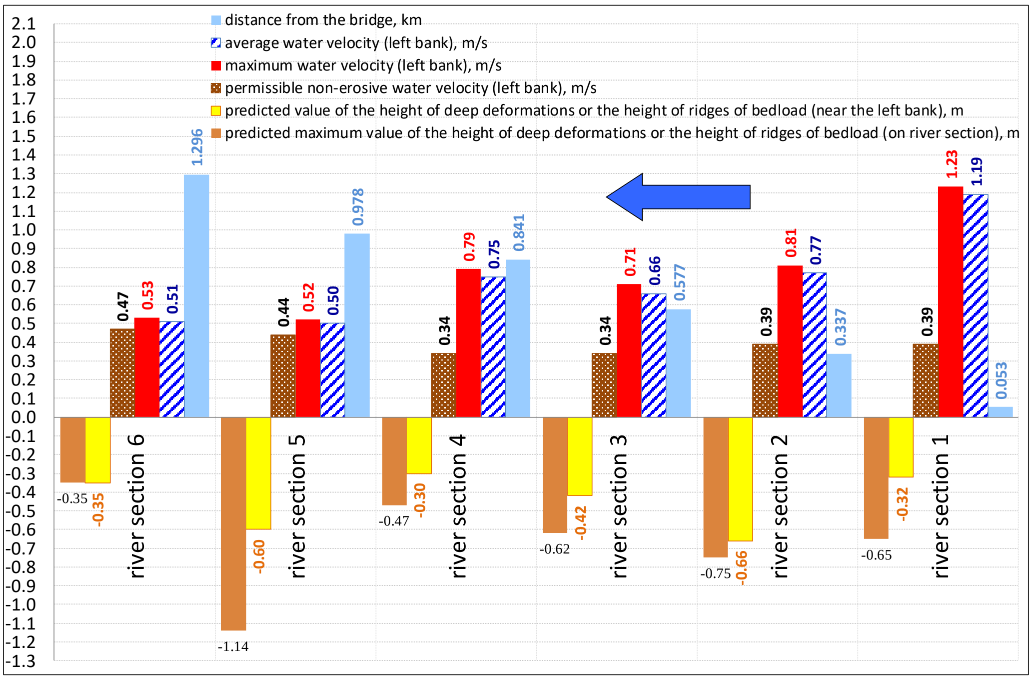

Fig. 6. Velocity regime, stability of the riverbed and characteristics of riverbed evolution of the Pripyat river

The dynamics of suspended sediment transport was considered for the summer-autumn period – when low flow conditions and "flushing" of the riverbed are observed. At the same time, the results of calculations of uneven water movement in the calculated section of the Pripyat river are used, corresponding to the hydrological conditions of average low water period 50% PE.

The range of movement and the deposition rate of suspended loads taking into account the longitudinal velocity of the water flow was calculated according to the dependence of G.I. Shamov [7]. The average diameter of suspended loads was 0.102 mm, taking into account experimental studies at the site and literature data [8]. The results of the assessment of the characteristics of sediment transport and deposition for the characteristic strata of the settlement section of the Pripyat river are shown in Table 2. The minimum length of the suspended sediment deposition path is typical for the section 4 at the site of the turn and expansion of the river bed due to significantly lower water flow rates.

Table 2

Characteristics of sediment transport for settlement section of the Pripyat river

Section	Distance from Lyuban bridge, km	Distance of the particle deposition path on the site, km	Speed of suspended sediment transport, cm/s	Deposition time, hours:min
1	0.053	1.599	5.29	8:24
2	0.337	2.310	3.01	18:39
3	0.577	2.121	2.65	17:08
4	0.841	1.171	0.42	9:27
5	0.978	1.921	0.15	15:31
6	1.296	1.923	0.86	15:32

CONCLUSIONS AND RECOMMENDATIONS

The results of the assessment of the stability of the riverbed of the Pripyat river in the calculated area show the need to strengthen the riverbed along the left bank in the area of the junction of the highway to prevent erosion of the riverbed and changes in the left bank. It is advisable to strengthen the left bank up to the calculated marks corresponding to the channel–forming water flow (if these marks are below the edge level - up to the edge level).

Geogrids (geomats, volumetric geogrids, flat and profiled geomembranes, etc.) can be used to strengthen the shore. Gabions, tongue-and-groove walls and composite concrete slabs, including those with flexible connections, can also be used.

Possible measures to narrow the channel from the right bank at its turn and increase the flow velocity may not significantly reduce sediment deposition in this area due to sediment deposition in its area from the upstream section due to an obstacle to rectilinear sediment transport caused by the turn of the river.

An important measure to reduce the negative impact of intensive riverbed processes in the area of turning and widening of the riverbed is periodic clearing of the riverbed with dredging and removal of bottom sediments. For to stability of the riverbed and prevent the crash of coastal slopes, dredging is recommended to be carried out at a distance of at least 10 m from the shore edge (left and right). The volume of material on the site at an average depth of 0.4 m and with an average width of 45 m will be around 13,000 m^3.

Possible the regulation of the riverbed by active fortifications, like semi-dams along the left concave bank of the Pripyat river. It should be made to prevent the erosion of the coastline outside the dams, taking into account the eroding flow rate for different water conditions and evaluating the optimal design of the straightening structures themselves. Dredging works are carried out together with the construction of straightening structures.

The choice of a specific type of work is solved not only by a complex of engineering and technical tasks, including the prevention of further erosion of the left bank in the area in close proximity to the highway, but at the same time must take into account the interests of navigation.

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Hydrology and Environmental Protection

PREDICTIVE ESTIMATION OF DEBRIS FLOW CONSUMPTION IN SOME RIVERS OF MOUNTAINOUS ADJARA

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Annotation. The article describes the specificity of the mountainous region of Adjara in relation to the hydrographic network of rivers. It discusses the factors facilitating the development of debris flow phenomena and all possible negative consequences stemming from this. It also examines the transportability of large amounts of debris by both debris flow and non-debris flow rivers and all possible negative consequences arising from this.

Keywords: debris flow, transit, channel, gravitational, erosion.

INTRODUCTION

The rivers in the mountainous region of Adjara, due to their physical-geographical properties, are characterized by a high capacity for sediment transportability. The headwaters of these rivers are rich in sand-clay slates, significantly contributing to the accumulation of debris in river valleys and the formation of flash floods during catastrophic rainfall events.

MAIN PART

The mountainous region of Adjara, due to its climatic and geographic factors, which means its climatic and topographic peculiarities, has a dense hydrographic network with unstable slopes, leading to ecologically unstable conditions that promote the development of debris flow phenomena with all the negative consequences.

To improve the current situation, it is deemed necessary to assess the existing conditions in the region, particularly by marking debris flow-prone areas, identifying the primary causes of debris flows, selecting calculating models for their flow and impact on structures, and developing flood protection constructions considering local conditions specifics.

The territory of Adjara is located in the southwestern part of Georgia, bordered by the Black Sea to the west. The western slopes of the Shavsheti, Arsiani, and Meskheti ranges, descend significantly towards the Black Sea coast. The location of these three ridges, which have an average height of 2000-2500m and the highest peak at 3007m, creates on the Arsiani ridge the steep terrain along the Adjaristskali River, which facilitates the formation of solid runoff from slopes into the riverbed.

The total area of Adjara is 2900 square kilometers, of which almost 80% is subject to intensive erosive-debris flow processes. Among the five administrative districts, Keda, Shuakhevi, and Khulo are at particularly high risk. The population in these districts is primarily located along the valleys, slopes, and deep gorges of the River Adjaristskali and its tributaries, predominantly on erodible and debris flow-prone soils.

Adjara is known for its high precipitation, with annual rainfall ranging from 2500 to 2800 mm, playing a significant role in the formation of erosive-debris flow phenomena and landslide processes.

The rivers in Adjara have a high transport capacity for solid runoff.

The specificity of Adjara Mountainous Region in relation of the hydrographic network lies in the fact that the main river, Adjaristskali, flows through a narrow valley and has both debris flow-prone and non-debris flow-prone tributaries, most of which have a high capacity for sediment transport. The debris flow floods often take place in these rivers during heavy rains.

The formation of solid runoff in the mountainous rivers of Adjara occurs both from the erosive-flood areas at the headwaters and from the products of mountain rock destruction that enter the riverbed directly from the slopes. The table below presents some hydrological characteristics of the Adjara rivers, including the expected maximum consumptions of water and predicted consumption of debris flow, determined according to the institute's thematic.

Table 1

Prognostic values of 1% provision of possible debris flow consumptions on the rivers of Adjara

#	Name of River, drain	Basin Area, F (km²)	Avg. Height of Basin, H (m)	Max. Water consumption with 1% Provision, $Q_{wat,\,max}$ (m³/s)	Basin Power, N (MW)	Max. consumption of 1% provision of Debris flow (Actual), $Q_{dmax.}$ (m³/s)	Max. consumption of 1% provision of Debris flow, calculated by the (2) and (3), Q_{dmax} (m³/s)	Difference Between Actual and Calculated Values (%)
1	Machakhela Tskali (State Border)	246	1620	399	6464,0	444	472	6,31
2	Machakhela Tskali, Sindieti	362	1390	494	6887,0	550	506	8,0
3	Machakhela Tskali, river mouth	369	1390	492	6922,0	554	509	8,12
4	Adjaristskali, Khulo	251	1590	219	3482,0	243	234	3,70
5	Skhalta (elevation 1200 m)	14.0	1990	59	1174,0	52,0	48,9	5,96
6	Skhalta (elevation 920m)	81,6	1880	116	2180,0	129	129	0,00
7	Skhalta, river mouth	223	1590	204	3244,0	227	214	5,73
8	Satsikhuri, Didachara	103	2010	133	2673,0	148	169	14,2
9	Chirukhistskali (elevation 1600m)	156	1890	166	3137,0	185	206	11,4
10	Chirukhistskali (elevation 1034.7m)	214	1870	200	3740,0	223	254	13,9
11	Chirukhistskali before confluence with Modula River	243	1820	214	3895,0	238	267	12,2

12	Chirukhistskali River after confluence with Modula River	326	1700	252	4287,0	280	298	6,43
13	Chirukhistskali River, Shuakhevi	328	1700	253	4301,0	282	299	6,03
14	Chirukhistskali, River mouth	329	1700	254	4318,0	283	300	6.01

The main river of Adjara is the right tributary of the River Chorokhi - Adjaristskali, which primarily drains the surface waters and rivers of the mountainous region of Adjara.

The main river in Adjara and its secondary, tertiary and higher order tributaries originate from mountain springs, with a total number of 988 and a combined length of 2165 km. The shape of the river basins is mostly asymmetric due to the different inclinations of their slopes.

Some headwater areas are composed of sand-clay slates, which significantly contribute to the formation of debris flow-prone areas. The river basin slopes are covered with deciduous forests up to the alpine and subalpine zones, where negative anthropogenic impacts are noticeable.

The river valleys predominantly have a V-shape with slopes ranging from 90 to 50 degrees, significantly facilitating the formation of gravitational processes. Terrace-like surfaces are rare and, if present, their widths range from 20-100 meters to 200-300 meters.

The longitudinal profiles of the rivers are characterized by clearly defined erosion, transit, and sedimentation areas, with defined sorting of riverbed formations. The first area is predominantly rocky, the second area has rocky-pebble formations, and the third area has pebble-gravel formations. This granulometric distribution of the solid component in mountain river channels indicates active processes of solid runoff formation and also erosive-flood phenomena in the headwater areas.

The formation of solid runoff in Adjara conditions occurs mainly through debris flow-prone mountain rivers. Although the debris flows often deposit a portion of the solid component on alluvial fans at the confluence with the main river, a significant part flows transitively and reaches the coastal zone of the sea. Therefore, the role of debris flows is significant both in terms of external environmental impact and solid runoff transport.

In recent years, landslide-flood events in mountainous Adjara have created problems for transportation, electricity, and water supply. Landslides have blocked roads, damaged infrastructure, and collapsed bridge near to the Tchvani Community, posing threats to many households and necessitating evacuations.

CONCLUSION

The shape of the river valleys significantly contributes to the formation of gravitational processes. Some headwater areas composed of sand-clay slates significantly contribute to the formation of debris flow-prone areas. Active processes of solid runoff formation, including erosive-flood phenomena, occur in the headwater areas. Solid discharge formation is carried out from both erosive-debris flow areas and directly from the destruction products of mountain rocks, which find themselves in the riverbed directly from the river slopes. The predicted values of water and debris flow consumptions and their 100-year recurrence intervals have been determined for the rivers in mountainous Adjara.

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Hydro technique and amelioration

APPROXIMATE ESTIMATE OF THE DECREASE IN SOIL WATER LEVEL AT A GIVEN TIME USING TUBE DRAINAGE

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Annotation. The creation of reliable systems, structures, devises is the subject of discussion of the theory of reliability. This theory is common to all technical construction devises. However, the methods of increasing the reliability of hydromelioration facilities have their own characteristics. Reliability means the ability of facilities, under normal operating conditions, in a specified time interval, to perform all given operations and not allow any unacceptable condition for the facility as a whole, or its individual elements.

Numerical value of reliability, it is the probability of performing a specified job under given conditions. In our case, the probability of lowering the water in the given amount from the drying area in the given time frame for the conditions of Kolkheti (Khobi region) is considered. Based on the design parameters of the tube drainage system, it is very effective and its reliability is 95%.

Finally, as we can see, in our case, the use of tube drainage is appropriate for the conditions of Kolkheti, including sandy to medium clay soils.

Keywords: tube drainage, soils, theory of probability.

INTRODUCTION

Closed tube drainage, which is widespread and practiced throughout Europe draining temperate wetlands, has been tested in the Kolkheti Lowland. But the operation of these systems has shown that due to the climatic, hydrogeological and topographical conditions of the saturated heavy soils of the Kolkheti Lowland, the field of application of tube drainage is limited to the delta areas of relatively large rivers and coastal arrays, which consist of sandy soils. Also, they consist of areas where medium and heave loams are common. Such soils are characterized by satisfactory waterphysical properties for plants.

Based on above, when designing drying systems, it is necessary to forecast and other methods that take into account not only the construction data, service, economy in time (system reliability), but also the probabilistic nature of the parameters. A creative systematic approach to design using sustainability theory and related scientific advances is necessary.

MAIN PART

One of the main tasks of systematic horizontal drainage is to lower the amount of water from the drying area in the given time. Due to the probabilistic nature of the variability of the factors that lead to these processes, the reported data are not so rarely different from the observed data.

For example, let's take the meadow of Saghvamichao village of Khobi district – alluvial loam, weakly marshy massif.

Granulometric composition of soils of Saghvamichao village

Point, notch, ground	Depth, sm	Size of fractions, mm						
		1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01
Meadow in the village Saghvamichao: alluvial loamy, slightly swampy	0-10	3.8	5.6	57.4	8.1	6.4	18.7	33.2
	22-32	0.8	3.0	59.9	11.1	9.0	16.2	36.3
	40-56	1,5	0.5	50.3	7.3	12.1	28.3	47.7
	70-80	3.5	2.4	52.8	9.2	9.1	23.0	41.3
	120-140	2.1	2.8	34.8	7.3	18.3	34.7	60.3
	150-190	4.0	9.3	22.9	10.5	16.8	36.5	63.8

The drying array is represented by a two-layer ground. The upper layer (where the drains are arranged) is with capacity 1.50 m, filtration coefficient K = 0.2 m/t-f. h, bottom layer: power - 1.0 m, K_3 = 0.05 m/t-f. h. 1.2 m at depth narrowly trenched with fissured perforation, with fiber glass and volumetric sand-gravel filter. The ground water level is standing h = 0.6 m. After the summer rain (80 mm) it is necessary to lower the ground water H_0 = 0.8 m within two days.

According to these data, the distance between the drains E = 4 m and the water supply δ = 0.42 were found using the well-known formulas [1].

Based on the above parameters, it is possible to estimate the reliability of lowering of groundwater from this drying area in a given time, with a given amount by the formula [2].

$$P = \Phi\left(\frac{t_{max}-t}{\sqrt{\sigma^2_{t_{max}}+\sigma^2_{t_{calc}}}}\right) \quad (1)$$

where σ^2 – total decomposition; t_{lim} – as we mentioned, 2 days are accepted for our conditions.
t – is estimated by the formula

$$t = \frac{\delta E}{\pi K}\ln\frac{2E}{\pi\sqrt{2d}\sqrt[4]{hH_0}}\ln\frac{H_0}{h} \quad (2)$$

To solve this problem, the function t in the range of nominal and average values of the parameters was decomposed into a Taylor series.

Due to the small amount of changes in the parameters, only members of the first ranks were considered sufficient:

$$\Delta t = \frac{\partial t}{\partial \delta}\Delta\delta + \frac{\partial t}{\partial E}\Delta E + \frac{\partial t}{\partial K}\Delta K + \frac{\partial t}{\partial d}\Delta d + \frac{\partial t}{\partial h}\Delta h + \frac{\partial t}{\partial H_0}\Delta H_0$$

From formula (2) we get the following images:

$$\frac{\partial t}{\partial \delta} = \frac{E}{\pi K}\ln\frac{2E}{\pi\sqrt{2d}\sqrt[4]{hH_0}}\ln\frac{H_0}{L}$$

$$\frac{\partial t}{\partial E} = \frac{\delta}{\pi K}\ln\frac{H_0}{L}\left(\ln\frac{2E}{\pi\sqrt{2d}\cdot\sqrt[4]{hH_0}} + 1\right)$$

$$\frac{\partial t}{\partial K} = -\frac{\partial}{\pi K^2}\cdot\ln\frac{2E}{\pi\sqrt{2d}\cdot\sqrt[4]{hH_0}}\cdot\ln\frac{H_0}{h}$$

$$\frac{\partial t}{\partial d} = -\frac{1}{2}\frac{\delta E}{\pi K}\cdot\frac{1}{d}\cdot\ln\frac{H_0}{h}$$

$$\frac{\partial t}{\partial h} = -\frac{\partial E}{\pi KH}\left(\frac{1}{4}\ln\frac{H_0}{h} + \ln\frac{2E}{\pi\sqrt{2d}\sqrt[4]{hH_0}}\right)$$

$$\frac{\partial t}{dH_0} = \frac{\partial E}{\pi K H_0}\left(\ln\frac{2E}{\pi\sqrt{2d}\sqrt[4]{hH_0}} - \frac{1}{4}\ln\frac{H_0}{h}\right)$$

By entering the numerical values in the given formulas, we get:

$$\frac{\partial t}{\partial \delta} = 4.16;\ \ \frac{\partial t}{\partial E} = 0.63;\ \frac{\partial t}{\partial K} = -8.74;\ \frac{\partial t}{\partial d} = -7.7;\ \frac{\partial t}{\partial h} = -10.84;\ \frac{\partial t}{dH_0} = 7.35;$$

For mean square deviation we have:

$$\sigma_{calc} = \sqrt{\left(\frac{\partial t}{\partial \delta}\right)^2 \sigma_\delta^2 + \left(\frac{\partial t}{\partial E}\right)^2 \sigma_E^2 + \left(\frac{\partial t}{\partial K}\right)^2 \sigma_K^2 + \left(\frac{\partial t}{\partial d}\right)^2 \sigma_d^2 + \left(\frac{\partial t}{\partial h}\right)^2 \sigma_h^2 + \left(\frac{\partial t}{\partial H_0}\right)^2 \sigma_{H_0}^2} \quad (3)$$

where σ_δ^2; σ_E^2; σ_K^2; σ_d^2; σ_h^2; $\sigma_{H_0}^2$ are the variances of the respective coefficients.

In the absence of statistical data, to determine the mean square deviation, we use the rule of three sigma, which is 1/6 of the acceptance field for the conditions of the given task.

As a first approximation, considering 10% of the average values of the parameters, there will be:

$\sigma_\delta = \frac{1}{6} \cdot 0.1 \cdot 0.42 = 0.007$

$\sigma_E = \frac{1}{6} \cdot 0.1 \cdot 4 = 0.066$

$\sigma_K = \frac{1}{6} \cdot 0.1 \cdot 0.2 = 0.0033$

$\sigma_d = \frac{1}{6} \cdot 0.1 \cdot 0.05 = 0.0003$

$\sigma_h = \frac{1}{6} \cdot 0.1 \cdot 0.6 = 0.01$

$\sigma_{H_0} = \frac{1}{6} \cdot 0.1 \cdot 0.8 = 0.013$

Inserting these values into formula (3), we get:

$$\sigma_{calc} = \sqrt{4.16^2 \cdot 0.007^2 + 0.63^2 \cdot 0.066^2 + (-8.74)^2 \cdot 0.0033^2 + (-7.7)^2 \cdot 0.00083^2 + (-10.44)^2 \cdot 0.01^2 + (7.35)^2 \cdot 0.013^2} = 0.1508$$

And the mean square deviation for the maximum time will be:

$$\sigma_{max} = \frac{1}{6} \cdot 0.1 \cdot 2 = 0.033$$

If we enter all values in formula (1), we get:

$$P = \Phi\left(\frac{2-1.75}{0.33^2+0.1508^2}\right) = \Phi\ (1.65) = 0.95$$

That is, the reliability of lowering the ground water in a given amount from the area to be dried in a given time is equal to 95%.

CONCLUSION

Agromelioration measures are many and very different. As we have seen in our case, the use of tube drainage is appropriate for the conditions of Colchis Lowland, including sandy to medium clay soils.

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Hydraulic engineering and irrigation

STUDY OF RADIATION BACKGROUND IN CITRUS FRUITS FOR THE GURIA REGION

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Annotation. The source of energy in our surrounding world is the sun. Only a small part of the energy emitted by the sun reaches the earth. Solar energy comes to earth in three forms: 1. Direct radiation, 2. Scattered radiation, 3. Radiation of the atmosphere. The amount of radiation that reaches us is determined both according to the season of the year and according to the geographical location of the research object. In addition, it is necessary to study the landscape and terrain, because the type of vegetation that has emerged and developed is significantly dependent on them.

The energy distributed in the solar spectrum that reaches the earth depends on the altitude of the sun. Its change takes place continuously according to the hours of the day. The amount of direct radiation entering the earth, along with the factors listed above, is determined by the humidity and transparency of the atmosphere. The intensity of direct radiation depends on the duration of sunlight. As is known, the average annual duration of sunlight in the Guria region changes to 1800-2000 hours. The maximum comes in the summer months.

Much of the direct radiation entering the atmosphere undergoes scattering, and as a result reaches the Earth as scattered radiation. Their intensity depends on cloudiness. It is known that the annual amount of solar radiation reaches 15-20% in Guria on clear skies, i.e. cloudless days, and 40-60% on cloudy days.

Radiation is emitting that comes from natural sources of cosmic and terrestrial origin, as well as artificial radionuclides. Radionuclides are nuclides whose nuclei are unstable and undergo radioactive decay. These nuclides are scattered in nature as a result of human activities.

Radiation background is created by: 1. Natural radiation background 2. Technogenically modified natural background 3. Artificial radiation background. Radiation damage is damage caused by ionizing radiation. In general, ionizing radiation is called high-energy electromagnetic waves, X-rays, (same as X-rays), rays, α and β particles and neutrons. They can "take away" electrons from atoms (ionization). Ionization changes the chemical properties of damaged atoms and molecules. As a result of changes in the molecules involved in the complex and orderly structure of the cell, ionizing radiation can cause damage to the cells, which increases the risk of disease development.

Keywords: Radon, radiation background, radionuclides, ground, solar radiation.

INTRODUCTION

A high dose of ionizing radiation affects the environment, which can cause inhibition of plant cell formation. This will definitely affect the fruit. In case of too high a dose of radiation, it can be manifested externally as well. For example, with various types of damage to the outer part of the stem or leaf (plant wilting and color change and etc). impact plants genetically damaging fruits and on plant development in the following year. The seeds of one-year crops affected by radiation give half the yield in the next year, and in perennial crops it has a certain dose on the yield quality of the next year [2,5]. Further research in this direction may give us more important results about plant diseases.

MAIN PART

The natural radiation background consists of external and internal radiation sources. Components of external radiation are: space, soil and atmosphere radiation. Components of internal radiation are: radionuclides of uranium and thorium, as well as radionuclides artificially created by nature. Technogenically modified natural radiation background: extracting minerals, burning various fuels, using fertilizer, flying at high altitude, household radiation (luminous clocks, televisions, computers, mobile phones, etc.) [2].

Most radionuclides decay very slowly. Therefore, they maintain the ability of radioactivity for a long time. The time during which half of the nuclei of radioactive elements decay is called the half-live period (T1/2). The radionuclides that are known today are characterized by half-lives period, and their lower and upper limits are in between (10-^{2} y-10^{10} years) [4].

Among the radionuclides common in nature, we studied cesium-137 (Cs-137), strontium-90 (Sr-90) and potassium-40 (K-40). Cesium-137 (half-decay period 30 years) emits β and radiation. Strontium-90 (half-life 29 years) emits β particles. 137 Cs and 90 Sr are concentrated in the upper layers of the soil at a depth of 5 cm. Their concentration in these layers is about 70-80%. The soil can be moved to the lower layers by deep plowing, to the point where the root system of the plants cannot reach. Potassium-40 (half-life period is 1.3 billion years). emits β and γ radiation. It is found naturally and replaces all plants and living organisms.

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We also studied the possibilities of spreading radon in the atmosphere, soil and ground water. Radon is a gas that has no smell, taste, or color. It accumulates in the cracks of the earth's rocks, from where it is gradually released into the atmosphere. Radon can remain in soil pores and cracks in rocks for long periods due to its chemical inertness. Its concentration in the atmosphere depends on the geographical location of the place, the season and the weather[3]. It can be measured with special tools. Common measurement units are: gray, sievert, rem and rad (1 rad=0.01 gray) [4].

RESULTS CAUSING RADIATION DOSES

• Up to 30 rads - light changes develop in living organisms, in particular in plants it causes slight wilting of leaves and loss of color.
• Up to 30-200 rads - various plant diseases are expected
• Up to 200-1000 rads - severe diseases that can cause plant wilting [4].

There are four naturally occurring isotopes of radon, all of which emit:
α-rays, characterized by low penetration, β-rays, high energy and -rays, characterized by heavy radiation.

The question is whether radon is dangerous or not? The danger from a radiation point of view does not come from radon, but from the ionizing radiation produced during its decay. Radiation occurs both from soil and water, because radon isotopes dissolve well in water and other liquids as well. As a result of radiation, living organisms are damaged. In plants, it can cause oxygen supply problems, which is reflected in the growth and development of the plant and the quality of the fruit.

In the territory of the region, it is necessary to study the duration of sunlight for optimal placement of citrus fruits, it contributes to obtaining a guaranteed and high-quality citrus harvest in the territory of the Guria region, along with other agroclimatic resources. Frequent non-sunny days create an unfavorable environment for them, especially during the flowering and ripening phase [1].

Consider the duration of sunlight in the Guria region with the data of meteorological stations.

Table 1

Duration of Sunlight

Weather Forecast Station	Month												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Anaseuli (Ozurgeti)	92	97	126	156	199	215	175	196	180	167	122	103	1828
Bakhmaro (Chokhatauri)	101	104	151	186	109	220	206	213	185	172	130	98	1975
Supsa (Lanchkhuti)	88	98	127	161	207	231	215	230	198	170	122	98	1945

As can be seen from the table, the duration of sunlight in the region increases from the winter months to July and amounts to 215-231 hours. In July, it decreases by 14-16 hours, which is explained by the increase in cloudiness. From August, the duration of sunlight continues to increase (196-230 hours), in the following months it decreases and reaches its minimum in December (98-103 hours). As for the duration of sunlight during the year, it is the highest in Bakhmaro (1975 hours), average in Supsa (1945) and the least in Anaseuli (1828) [1].

When we talk about the duration of sunlight, we must consider solar radiation, heat and radiation balance. We must pay attention to the movement of radon (atmosphere, soil, ground water). Our further studies will continue in this direction.

Our experiment was conducted from two farmers' farms in the Guria region, done with mandarin and orange samples. The experimental sample is whole fruit, fruit juice, fruit seed and fruit stalk. The collected samples were studied in the radiology laboratory of the Agricultural Scientific Research Center of the Ministry of Environment and Agriculture. Cesium (Cs137), strontium (Sr90) and potassium (K-40) were measured in the collected samples.

Table 2

Radionuclide content in mandarin samples by fractions

#	Mandarin	Content of Radionuclides Bq/kg					
		Cesium	**Total error, %**	**Strontium**	**Total error , %**	**Potassium**	**Total error, %**
1.	Sample1. Whole fruit	0,87	1,90	0,00	14,12	70,70	19,1
2.	Sample 2. Whole fruit	0,85	1,83	0,00	13,90	51,63	16,90
3.	Sample 1. Fruit juice	0,00	7,81	0,00	15,70	154,00	34,21

4.	Sample 2. Fruit juice	0,00	7,64	0,00	16,12	139,10	32,43
5.	Sample 1. Fruit seed	25,32	13,83	12,81	14,60	78,22	23,13
6.	Sample 2. Fruit seed	23,74	14,00	25,14	8,67	23,81	32,00
7.	Sample 1. Fruit stalk	26,50	14,82	20,67	13,54	21,82	15,01
8.	Sample 2. Fruit stalk	25,70	15,32	24,80	14,76	150,20	45,18

Radionuclide content in orange samples by fractions

	Orange	**Content of Radionuclides, Bq /kg**					
		Cesium	**Total error %**	**Cesium**	**Total error %**	**Cesium**	**Total error %**
1.	Sample1. Whole fruit	0,64	1,60	0,00	13,70	67,70	18,80
2.	Sample 2. Whole fruit	0,62	1,53	0,00	13,21	46,64	15,90
3.	Sample 1. Fruit juice	0,00	6,89	0,00	14,90	151,00	33,47
4.	Sample 2. Fruit juice	0,00	6,16	0,00	15,73	136,05	30,51
5.	Sample 1. Fruit seed	3,22	12,72	10,90	12,31	75,14	21,16
6.	Sample 2. Fruit seed	22,20	12,04	23,10	7,61	21,10	30,00
7.	Sample 1. Fruit stalk	24,20	13,10	18,60	12,60	149,00	13,30
8.	Sample 2. Fruit stalk	24,90	13,00	23,52	12,60	147,00	43,00

As can be seen from the table, 137 Cs is higher in the seed and stalk of the fruit than in the fruit and juice. 90 Sr is completely absent in the fruit and juice, and in the stem, it is relatively more than in seed. Moreover, it is more concentrated in mandarin than in orange. As for K-40, it is much more abundant in each fraction of both samples.

The obtained results are not sufficient for a final conclusion, but represent the first attempt in this direction in our research. It is necessary to continue research, which will give us more information for the final conclusion, and it will be possible to plan measures to eliminate the consequences caused by radiation. At this stage, we should turn to timely irrigation, when experiments will show the necessity of this. Irrigation will make it possible for the given radionuclides to move to the lower layers, thus reducing their impact on the quality of the crop. So, in order to increase the yield quality, it is necessary to continue the studies before fruiting, in all phases.

As for radon, it is constantly renewable and should be studied according to the seasons, specifically in terms of the effects of ionizing radiation resulting from the decay of radon.

CONCLUSION

- The article raises the issue of the influence of the radiation background on the development of citrus fruits (tangerines, oranges) in the Guria region.
- The content of 137 Cs, 90Cr, K-40 in the fruit, fruit juice, seed and stalk was studied.
- Based on the obtained results, it is clear that irrigation is necessary, depending on which stage of development it is needed depending on the radiation doses.

Also, the presence of radon isotopes has been studied. It is possible that they affect the quality of the fruit, because they are not constantly renewable and are present in the soil, ground water and atmosphere. It is planned to continue further research in this direction.

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Water management

EFFECTIVE USE OF WATER RESOURCES IN AZERBAIJAN AND CLOSE COOPERATION WITH GEORGIA IN THIS FIELD

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Annotation. The article provides an overview of the contemporary status of surface and underground water resources in Azerbaijan, offering an assessment of their current condition, as well as insights into the adoption of strategies aimed at their prudent and efficient utilization. Notably, it underscores Azerbaijan's concerted efforts to draw upon international experiences and deploy a plethora of measures in this domain.

Azerbaijan emerges as a nation demonstrating a steadfast commitment to the effective management and utilization of its water resources. Through a multifaceted approach, the country endeavors to implement diverse measures aimed at the judicious management of water resources, which play a pivotal role in fostering economic development, sustaining agriculture, facilitating energy production, and supporting various other sectors critical to national progress.

These measures encompass the formulation of comprehensive strategies and plans geared towards the protection and development of Azerbaijan's water resources. Moreover, they entail the ongoing modernization of infrastructure, adoption of technical innovations, implementation of robust monitoring and management protocols for natural resources, as well as the execution of educational and informational programs aimed at raising awareness and fostering responsible stewardship of water resources.

Water-related interactions between Azerbaijan and Georgia predominantly revolve around the Kura River and Aras River water basins.

Collaborative initiatives are underway between these two nations to address various facets of water management, including equitable allocation of water resources, enhancement of water supply infrastructure, and preservation of water reservoirs.

Efforts are being exerted across multiple domains to bolster water-related cooperation between Azerbaijan and Georgia:

Contracts, protocols, and agreements concerning water-related matters are regularly executed between the two nations.

Technical collaboration is orchestrated to facilitate the development of hydroelectricity and water supply infrastructure, with a focus on initiatives aimed at mitigating non-essential water consumption and augmenting water supply.

Engineering solutions are devised to safeguard water resources and regulate water navigation, complemented by safety measures to ensure the integrity of water-related infrastructure.

Surveillance programs are implemented to systematically monitor and manage water resources and their origins, ensuring the effective stewardship of these vital assets.

This collaborative effort represents a cornerstone in the proficient management of water resources by both Azerbaijan and Georgia, thereby contributing significantly to the stability and development of the region.

Keywords: water resources, water volume, agriculture, lakes, water supply, reservoirs.

INTRODUCTION

Water is the most precious mineral resource. It serves not only as a fundamental raw material and tool for agricultural advancement but also stands as the paramount catalyst for cultural progression, symbolizing the lifeblood that has rendered inhabitable places habitable [1].

One of the paramount challenges confronting humanity today is the scarcity of water. This issue is addressed through concerted efforts outlined within the United Nations Millennium Program. The Republic of Azerbaijan, having acceded to the UN Millennium Program in 2005, has assumed several commitments in this regard.

Preparations are underway to devise a comprehensive strategy for the sustainable utilization of global land and water resources. Notably, a significant proportion of the world's populace, amounting to one-third, inhabits regions characterized by aridity and semi-aridity, where water scarcity prevails. It is evident that agricultural cultivation heavily relies on freshwater reservoirs. Scientific consensus reveals that merely 3 percent of the planet's water reservoirs constitute freshwater, juxtaposed with the overwhelming majority of 97 percent comprising saline water. This conspicuous disparity in resource composition underscores a pressing concern. The prevailing issue of water scarcity, compounded by the limited availability of freshwater and its disparate distribution within Azerbaijan, adversely affects the agricultural ecosystem's development trajectory.

MAIN PART

Observations reveal a multifaceted challenge comprising the scarcity of freshwater resources within the country, compounded by the effects of global climate change and recent rises in average temperatures. This conundrum is further exacerbated by a significant decline in surface water resources, river water levels, and precipitation patterns, primarily stemming from neighboring jurisdictions.

Conversely, the nation grapples with the ramifications of rapid population growth, escalating living standards, and the burgeoning economy, notably spurred by agricultural advancement. The resultant surge in demand for water, driven by the expansion of farmland, irrigation initiatives, and the augmentation of drinking water distribution networks, necessitates the expeditious implementation of measures to safeguard the republic's water security [2].

The aforementioned issues have been addressed in the decree issued by the President of the Republic of Azerbaijan on April 15, 2020, titled "On measures to ensure the efficient utilization of water resources." Additionally, the presidential decision pertaining to "Measures for the implementation of a pilot project in the domain of seawater desalination for drinking water production" underscores the ongoing relevance of these challenges. The scholarly significance of research endeavors undertaken by scientists and specialists in assessing water resources and optimizing their utilization remains paramount. Furthermore, as underscored by the esteemed national leader H.A. Aliyev, the infrastructural investments in amelioration and water management represent invaluable assets, necessitating their effective and judicious utilization [3].

The Republic of Azerbaijan witnesses the formation of water resources totaling 32.3 billion cubic meters within its territory annually. However, Azerbaijan's ownership extends to only 14 percent of the water resources formed within the South Caucasus region. A significant proportion, approximately 67-70% (equivalent to 19.0-20.5 cubic kilometers), of these water resources originate from transboundary rivers, while the remaining portion (approximately 9.5-10 cubic kilometers) primarily derives from internal rivers. During periods of drought, the water reserves decrease to 27.0 - 22.6 cubic kilometers, of which 17.1 - 14.3 cubic kilometers pertain to transboundary rivers. An average of 1.5 thousand cubic meters of waterfall is available per person per year.

The annual water supply of rivers flowing directly into the Caspian Sea (excluding the Samur River) ranges between 2.2-2.5 cubic kilometers. Specifically, 1.0 - 1.1 cubic kilometers of this supply originate from rivers flowing from the northwestern slope of the Greater Caucasus Mountains, while 1.2 - 1.4 cubic kilometers are contributed by rivers in the Lankaran region. The water reserve of internal rivers within the Kura basin is estimated to be between 7.5-7.8 cubic kilometers. Moreover, the water supply of the Kura-Aras rivers experiences a reduction of 20% due to appropriation by irrigation facilities in neighboring countries. Consequently, this reduction exacerbates water scarcity within Azerbaijan, resulting in an approximate annual deficit of 4-6 cubic kilometers and impeding the nation's ability to meet its water demands [4].

According to statistical data, Azerbaijan is categorized among countries with low water resources. Concurrently, the rapid growth of the population exacerbates this situation. Within this program, the issue of the comprehensive utilization of land and water resources in Azerbaijan is highlighted as the most pressing matter on the agenda.

It is noteworthy that 85% of agricultural output in Azerbaijan is derived from irrigated lands. The aggregate area of irrigated land in Azerbaijan amounts to 1 million 420 thousand hectares. Surface irrigation constitutes 96% of this total, with water-saving irrigation techniques accounting for only 4%. Consequently, the occurrence of significant water losses emerges as one of the primary factors anticipated to contribute to the depletion of water resources in the future.

In light of these circumstances, the following recommendations are proposed to mitigate potential water shortages: Implementation of river and lake cleansing initiatives aimed at removing both organic and inorganic pollutants, to be conducted by municipalities and industrial enterprises.

Adoption of efficient irrigation methodologies and technologies in the following hierarchical sequence: Drip irrigation method, micro-sprinkler systems, aerosol irrigation method, injection irrigation method, raining method. Deployment of integrated management strategies, emphasizing both efficiency and sustainability, for natural water sources. This approach should encompass mitigation measures to address an anticipated 15% decline in the availability of both surface water and groundwater over the next five decades, factoring in projections indicating a potential increase in air temperatures by 3-4 degrees Celsius.

Optimal utilization of precipitation through the implementation of the following measures: establishment of artificial floodplains during the rainy season, regulation of mountainous rivers during periods of flooding. Adoption of practices to facilitate the re-circulation of collector-drainage waters by means of purification processes and supplementation with fresh water. Enhancement of irrigation infrastructure: widening the adoption of closed irrigation systems, implementation of reinforced concrete construction for water reservoirs. Subsequently, adherence to the basin principle should be prioritized, accounting for the potential of underground water basins. This entails the execution of forest management initiatives, refinement of wastewater and sewage systems, and augmentation of capital investments in these domains, all of which warrant meticulous oversight.

Furthermore, it is imperative to regulate ecological flows and foster the utilization of water reservoirs based on multipurpose principles, incorporating ecological considerations and addressing other exigencies during the construction of hydropower plants.

Additional measures encompass: Exploration of water desalination techniques for the Caspian Sea, compilation of Geographical Information System (GIS) data pertaining to river basin (catchment) areas and water infrastructure, educational campaigns targeting water users such as farmers, the general populace, and entrepreneurs. Advocacy for water conservation through substantial investments in education and the integration of novel technologies within the water sector.

In addition to the aforementioned principles, drawing upon extensive years of experience, it is pertinent to highlight that efficient utilization of water resources results in a notable conservation effect, yielding savings of water resources ranging from 2 to 2.5 times. Simultaneously, such efficiency drives a corresponding increase in agricultural productivity by 1 to 1.5 times.

Furthermore, in accordance with pertinent decrees issued by the President of the country, there exists a compelling mandate to deliberate upon conceptual propositions delineated under the theme of "Ways of efficient use of water resources." These propositions, formulated by us, are aligned with the directive outlined in Order No. 1986 of the President of the Republic of Azerbaijan, dated April 15, 2020, which underscores the imperative of ensuring the efficient utilization of water resources within the nation, enhancing water management practices, and coordinating endeavors in this domain. Given the gravity of these imperatives, it is imperative that they be deliberated upon within the dedicated Commission established for this purpose.

Azerbaijan has embarked on numerous initiatives encompassing water channels and projects geared towards optimizing water utilization within the region. These endeavors span a spectrum of infrastructure, including expansive water channels, water reservoirs, and drainage systems. The overarching objective of these projects is twofold: to augment water supply and to foster the judicious use of water resources. To this end, Azerbaijan has instituted a range of measures and programs aimed at enhancing water efficiency.

These measures encompass diverse strategies such as the collection of water from streams and rainfall, the adoption of drip irrigation systems, and the establishment of water channels, among others.

Furthermore, Azerbaijan leverages state-of-the-art technologies and projects within the realm of water management. This entails the deployment of modern sensors tailored for water management and monitoring, alongside the integration of cutting-edge technologies for water treatment and purification.

Moreover, Azerbaijan actively engages with international organizations and programs dedicated to promoting the efficient utilization and management of water resources. This collaborative endeavor extends to providing support for initiatives spearheaded by the United Nations and other international bodies, fostering knowledge exchange, and facilitating cooperation on joint projects aimed at enhancing water management practices.

Azerbaijan diligently endeavors to disseminate public awareness and facilitate educational initiatives concerning the judicious utilization and safeguarding of water resources. These efforts encompass a spectrum of topics including water management, conservation, and supply, and are manifested through a plethora of avenues such as conferences, seminars, webinars, and specialized events. The overarching objective of such endeavors is to impart comprehensive knowledge and insights pertaining to these critical themes. By adopting these measures and strategic directives, Azerbaijan advances its proficiency in the sphere of efficient water utilization and resource protection while adhering to internationally recognized standards and practices.

Drawing upon the wealth of international experience in the realm of efficient water resource management, Azerbaijan avails itself of the knowledge and expertise garnered from various countries. This exchange of insights encompasses facets such as water management strategies, supply mechanisms, and protection methodologies.

International experience serves as a pivotal resource in bolstering Azerbaijan's capacity for the effective utilization and safeguarding of its water resources. Numerous nations employ modern and efficacious methodologies for the management and planning of water resources. These methodologies are instrumental in ensuring the optimal operation of water channels, treatment systems, and drainage infrastructure, thereby enhancing overall water resource management practices.

Numerous countries worldwide have adopted drip irrigation technologies as a means to enhance water efficiency within the agricultural sector. This method facilitates the precise delivery of water to crops, thereby optimizing irrigation practices.

The utilization of international experience assumes a pivotal role in advancing the development of effective research and technologies aimed at the protection and treatment of water resources. Such initiatives are crucial steps towards safeguarding the health and quality of water reservoirs.

International organizations actively endorse projects and investments geared towards augmenting the efficiency of water resources, while also orchestrating observational initiatives to monitor and assess water-related developments.

Moreover, enhanced cooperation and knowledge-sharing in this domain are fostered through cross-country collaboration and exchange programs. These initiatives facilitate the transfer of expertise and best practices among nations.

International experience further underpins educational programs and information dissemination efforts focused on promoting the efficient utilization of water resources. These endeavors serve to disseminate guidelines and insights pertaining to water management and safety protocols.

Collectively, these instances underscore the invaluable role of international experience in fortifying Azerbaijan's capacity for the efficient utilization of water resources. They also underscore the nation's openness to fostering greater cooperation and knowledge exchange in this critical sphere.

CONCLUSIONS AND RECOMMENDATIONS

Additionally, it is imperative to highlight the significance of water cooperation between Azerbaijan and Georgia, given the mutual reliance of both nations on shared water sources and supply systems.

Engagement and collaboration on water-related matters between these two countries are deemed crucial steps towards fostering regional stability and promoting peaceful coexistence.

Of paramount importance within the context of Azerbaijani-Georgian water cooperation are the Kura River and the Aras River, representing two of the four common tributaries of the Kura River basin. The utilization of water resources from these rivers profoundly impacts various sectors of the economy, including agriculture, energy production, and other pivotal domains.

The imperative to address the needs and challenges pertaining to water resources assumes a central role in shaping the trajectory of relations between Azerbaijan and Georgia, underscoring the integral link between water management and the development of bilateral ties.

In order to enhance water cooperation between Azerbaijan and Georgia, concerted efforts are being undertaken across diverse spheres.

In the legal domain, bilateral agreements and protocols pertaining to the equitable distribution and effective management of water resources are regularly negotiated and formalized between the two nations.

Technical collaboration is fostered for the advancement of hydroelectric and water supply infrastructure, thereby bolstering the technical capacity and resilience of both countries.

Furthermore, cooperation extends to initiatives aimed at the protection, monitoring, and security of water resources. These endeavors encompass regulatory measures to govern water navigation, the implementation of engineering solutions, and other pertinent areas of engagement.

The collaborative framework on water between Azerbaijan and Georgia constitutes a pivotal focal point, enabling both nations to make informed decisions conducive to regional peace, security, and the safeguarding of entrepreneurial interests.

Such cooperation holds significant potential to engender holistic development and stability within both countries and the broader region.

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Water management

MOBILE WATER PURIFICATION STATIONS FOR PROMPT RESTORATION OF WATER SUPPLY IN UKRAINE

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Annotation. For the prompt restoration of water supply in Ukraine, an urgent task is to create a mobile water treatment system that should produce safe drinking water for consumers in the presence of all contaminants present in natural waters, including heavy metal ions, radionuclides, and pathogenic microorganisms that are widespread today. The research carried out at the Institute of Scientific Research of the National Academy of Sciences of the Russian Academy of Sciences established: 1) for the removal of heavy metal ions, radionuclides and organic pollutants from water, the most promising is the use of sorbents, namely: zeolite from the Sokirnyan deposit with a fraction size of 0.076-0.1 mm, bentonite clay powder with a fraction size of 0.072-0.1 mm and copper ferrocyanide ($Cu_2[Fe(CN)_6]$); 2) the effective operation of the filter with expanded polystyrene loading according to the color indicator is about 20 hours, and the zeolite filter about 30 hours; according to the turbidity indicator, the polystyrene foam filter works effectively for about 60 hours, the zeolite filter works effectively for about 40 hours. A combination of expanded polystyrene and zeolite loading is optimal. 3) oxidants produced as a result of the passage of electric current through the air-water environment effectively neutralize pathogenic microorganisms.

Keywords: mobile installation, water preparation, filter materials, reagents, oxidizers.

INTRODUCTION

The current state of the problem. As a result of the aggression of the Russian Federation on the territory of Ukraine, infrastructure facilities were destroyed, which provided centralized water supply in the South-Eastern region of Ukraine when water was taken from the Dnipro River and reservoirs located on it, mainly from the Kakhovsky, Kremenchutske and Dniprovske reservoirs, as well as from the Southern Bug rivers, Dniester and others. The cities Mykolaiv, Kryvyi Rih, Nikopol, Marganets, Berdyansk, Melitopol, etc. were left without drinking water with a population of more than 2.5 million people, and the termination of the operation of group agricultural water pipes led to the lack of access to high-quality drinking water for the rural population of about 900 settlements with a population of more than 120 thousand people. For the prompt restoration of water supply, it is necessary to create and widely use mobile installations capable of effectively purifying water with all modern contaminants, as well as being reliably protected from fire damage.

The peculiarity of the current situation is that to the traditional types of pollution of natural sources of water supply, pollution caused by climate change, anthropogenic load and the presence of combat poisons has been added. Among organic pollutants in surface drinking water sources, the emphasis is shifting from classic petrochemical products to products associated with agricultural and pharmaceutical production. As a result of the intensive influx of biogenic compounds into rivers and reservoirs, there is a massive development of phytoplankton in them, which complicates the processes of preparing high-quality drinking water at water purification stations. Screening monitoring of the Dnipro river basin [1] showed extremely high levels of predicted safe concentrations in water of herbicides, insecticides, fungicides, as well as pharmaceutical substances such as carbomazepine, lopinavir, diclofenac, efavirenz, etc. In general, studies of the quality of tap drinking water in Ukraine in recent years have revealed a tendency towards an increase in the frequency of deviations from hygienic requirements in terms of sanitary-chemical and bacteriological indicators. The increase in the number of samples that do not meet the regulatory sanitary and chemical parameters is due to organochlorine compounds. Priority among organochlorine compounds are trihalomethanes, the marker of which is chloroform (CF). The largest share of tap water samples (according to the data of the laboratory of natural and drinking water hygiene of the O.M. Marzeev Institute of Public Health of the National Academy of Sciences of Ukraine), the quality of which does not meet the hygienic requirements according to sanitary and toxicological indicators, falls on CF (36.6%). The current sanitary and epidemic situation is also due to the decrease in the effectiveness of classic chlorine-containing disinfectants due to the spread of chlorine-resistant microorganisms in treated water. Monitoring of the water demand of the population, especially in the regions that use imported water, has shown that in the conditions of military operations on the territory of Ukraine, the urgent task is to create a mobile water treatment system with a capacity of one module up to 1500 dm^3/day and the possibility of forming an integrated water treatment system from the modules in accordance with specific needs region. Such a system should:

- Produce drinking water that is safe for consumers in the presence of all impurities present in natural waters, including heavy metal ions, radionuclides, pathogenic microorganisms, demineralization of water and its purification from toxins, etc.

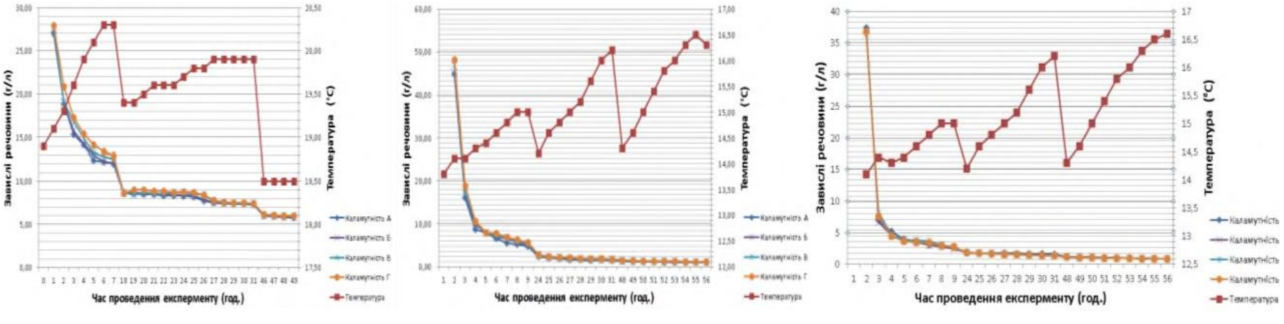
- In addition to ensuring the basic regulatory requirements for the quality of drinking water, mobile installations should be able to achieve a higher quality of treated water for use in hospitals, sanatoriums, kindergartens, maternity homes, and schools.

For this, technological processes in the installation should also saturate water with free hydrogen, which is a powerful detoxifier, as well as saturate water with electrons to form the appropriate electron-donating redox potential, which will allow obtaining healing antioxidant water.

MAIN PART

Statement of the research task: to carry out laboratory and experimental studies of the effectiveness of filter materials, sorbents and disinfectants to justify their optimal parameters when forming a water purification system in mobile water treatment stations.

The studies carried out at IWP&LR NAAS found [2, 3] that the most promising application of sorbents for the removal of heavy metal ions, radionuclides, and organic pollutants from water is: zeolite from the Sokirnyan deposit with a fraction size of 0.076-0.1 mm, clay powder bentonite with a fraction size of 0.072-0.1 mm and copper ferrocyanide ($Cu_2[Fe(CN)_6]$. Studying the hydrodynamic characteristics of the specified sorbents in laboratory conditions (Fig. 1.) made it possible to plot graphs of their sedimentation rate.



a) b) c)

Fig. 1. Graphs of the rate of deposition of sorbents: a) zeolite; b) bentonite; c) mixture of bentonite with ferrocyanide

The best result was shown by bentonite with ferrocyanide, which significantly accelerates the formation of flakes and their precipitation without reducing the effectiveness of the sorbent.

Study of the efficiency of radionuclide extraction using bentonite and zeolite clays and copper cyanoferanide. As a model mixture was an extract from the soil taken near the Fukushima nuclear power plant (Japan) after the accident was used. Leaching was carried out using concentrated nitric acid. The weight of the soil was 20 g. The obtained extract was diluted with distilled water to 5 dm^3. The activity of ^{137}Cs was measured by the ATOLL-3M gamma-ray spectrometer (hereinafter referred to as the spectrometer). The content of ^{137}Cs in the source water of the model solution was 1800 Bq/dm^3.

The dusty fraction of zeolite and a mixture of zeolite with bentonite clay powder was introduced into the model solution, actively mixed for 3 min. and stood for 0.5 and 20 hours. After settling, the solution was filtered and the activity of the filtrate was determined. Dusty fractions of zeolite were introduced in the form of dosages: - 1, 2, 4 g / dm^3. A mixture of dusty fraction of zeolite and powdered bentonite clay was introduced per 1 dm3 in the form of weights: 0.5+0.5; 1+1; 2+2 g.

Copper ferrocyanide ($Cu_2[Fe(CN)_6]$) is synthesized by mixing solutions of potassium ferrocyanide ($K_4[Fe(CN)_6]$) with copper sulfate ($CuSO_4$) in equimolar quantities. The obtained copper ferrocyanide with a model water solution (activity 1800 Bq/dm^3) after intensive mixing for 30 seconds. stood for 60 minutes, after which a polyacrylamide flocculant was added to accelerate the process of thickening of copper ferrocyanide colloid flakes and their precipitation. The research results showed the best indicators of 137Cs sorption from the model solution using copper ferrocyanide. All concentrations, including the minimum of 0.1 g/dm3, provided removal of 137Cs from the model solution beyond the lower sensitivity limit of the spectrometer by 100% in 1 hour.

The summarized results of research of effective sorbents on model solutions are shown in the Table.

Table

Results of studies on the effectiveness of using bentonite, zeolite clays, copper ferrocyanide and their mixtures to reduce the activity of ^{137}Cs

№	Name of sorbents	Concentration of sorbents, g/dm^3	Activity of ^{137}Cs, Bq/dm^3 after 1 hour contact	Activity of ^{137}Cs, Bq/dm^3 after 20 hours contact	Cleaning efficiency ^{137}Cs.%		Standing time until complete discoloration, t, hours	Hydraulic coarseness of the sorbent, U, mm	Concentrations of suspended particles, P,%
					In 1 hour	In 20 hours			
1	2	3	4	5	6	7	8	9	10
	Exit sample	0	1800	1800	0	0	24	0	26
1	Zeolite	1	441.5	203.7	75.47	88.68	47	0.28	25
2	Zeolite	2	441.5	237.7	75.47	86.79	49	0.27	22
3	Zeolite	4	373.6	0	79.25	100	51	0.25	18.8
4	Bentonite + zeolite	0.5+0.5	373.6	34	79.25	98.11	32	0.52	18.7
5	Bentonite + zeolite	1+1	305.7	0	83.02	100	35	0.48	11.1
6	Bentonite + zeolite	2+2	305.7	0	83.02	100	38	0.44	3.5
7	Copper ferrocyanide	0.1	0	0	100	100	6.2	1.39	10.4
8	Фероціанід міді	0.5	0	0	100	100	6	1.44	12.1
9	Copper ferrocyanide	1	0	0	100	100	6.5	1.23	10
10	Copper ferrocyanide	2	0	0	100	100	7	1.04	2

11	Copper ferrocyanide + bentonite	0.1+0.4	0	0	100	100	2.5	6.72	0.5
12	Copper ferrocyanide + bentonite	0.5+2	0	0	100	100	2.3	6.18	0.2
13	Copper ferrocyanide + bentonite	1+4	0	0	100	100	2.8	7.53	0.2
14	Copper ferrocyanide + bentonite	2+8	0	0	100	100	3	8.1	0.2

It was established that the highest efficiency of ^{137}Cs sorption is achieved when using a mixture of dusty bentonite and copper ferrocyanide in the proportion of 2 g/dm^3 and 0.5 g/dm^3. This concentration of sorbents ensured 100% removal of ^{137}Cs from the model solution beyond the lower sensitivity limit of the spectrometer and complete discoloration of the solution and precipitation of suspended particles.

For evaluate the effectiveness of domestic (Ukrainian) filter materials - zeolite and expanded polystyrene, we conducted studies of their effect on pollution using an experimental plant (Fig. 2) at the operating water treatment plant in the city of Nikopol at the intake of water from the Kakhovske water reservoir. The efficiency (E) of water treatment facilities was determined by the formula:

$$E = (C_{in} / C_{out}) \cdot 100\%, \quad (1)$$

where C_{in} and C_{out} are the concentration of pollutants, respectively at the entrance and exit of the water treatment plant, mg/dm^3. A set of factors affecting the efficiency of the water treatment facility is determined: E = f (A; B; T; C, t^o), (2) where A is the design and loading characteristics of the water treatment facility (diameters of granules, coefficients of their unevenness, thickness of the filter layer , download type, etc.); B – hydraulic operation mode of the structure (direction of water movement, filtration speed); T is the duration of operation of this facility, which leads to a change in parameter A due to the accumulation of impurities in the filter load, C is the totality of ingredients in the liquid; t^o - the temperature mode of operation of the building.

According to the results of the study of the effectiveness of polystyrene foam and zeolite filter loading in surface water purification, it was established:

1) During pre-treatment of water with the use of polystyrene loading for the studied conditions, the highest efficiency of water purification was E = 44% at the filtration speed V_f = 10 m/h, and the optimal parameters are: diameter of polystyrene granules d_p = 5–8 mm; thickness of filter load H_f = 1.5 m.

2) During water post-purification:

- the effective operation of the filter with expanded polystyrene loading according to the color indicator is about 20 hours, and the zeolite filter about 30 hours; according to the turbidity indicator, the polystyrene filter works effectively for about 60 hours and the efficiency is 60-80%, the zeolite filter works effectively for about 40 hours and the efficiency is 50-65%. The optimal parameters are: the diameter of polystyrene granules d_p = 2-5 mm, the thickness of the filter loading H_f = 0.8-1.0 m.

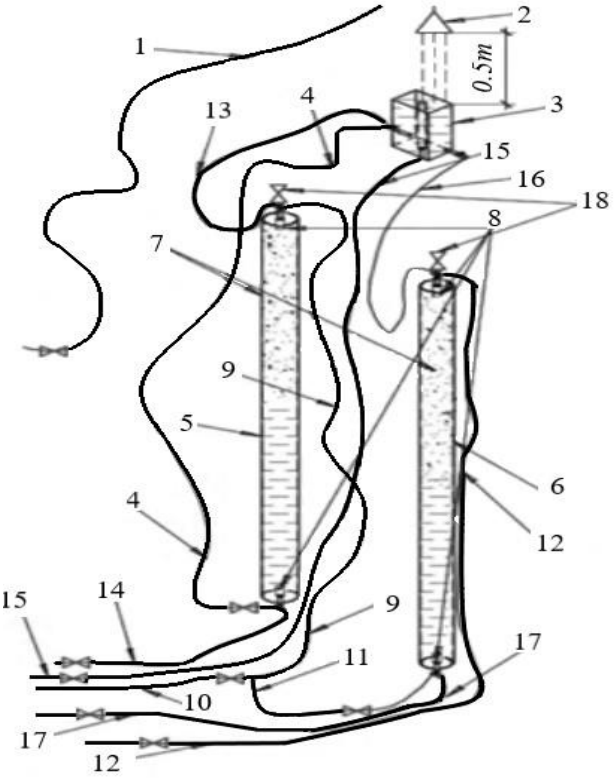


Fig. 2. Experimental installation at sewage treatment plants: 1 - line of incoming water for aeration; 2 - shower head; 3 - tank degasser with an overflow system; 4 - degassed water supply line for filtration; 5 - filter column F1 – prefilter model of a contact filter; 6 - filter column F2 - fast filter model; 7 - filter load from granules of expanded polystyrene and zeolite; 8 - slotted caps - return filters that hold polystyrene granules in the middle of the filter housing columns; 9 - the line of leachate from the F1 column to the F2 column; 10 - discharge of a fraction of the filtrate from the F1 column into the sewer to establish the velocity in the F2 column filtering less than the filtering speed in column F1; 11 - the line for receiving filtrate from the F1 column for further filtration to the F2 column; 12 - the leachate discharge line from the F2 column; 13 - the line of the washing water supply to the F1 column; 14 - the line for discharging the washing water from the F1 column into the sewer; 15 - overflow water discharge line from the degasser tank; 16 - the line of the washing water supply for washing the F2 column; 17 - the line for discharging the washing water from the column; 18 – faucets.

- the combination of filters for pre-cleaning and post-cleaning of water, loaded with expanded polystyrene, ensures a filter cycle time of up to 60 hours for turbidity at 70-80% cleaning efficiency and 24-25 hours for color indicator at 50% cleaning efficiency.

Research on the effectiveness of water disinfection was carried out at a laboratory facility (Fig. 3) at the Institute of Environmental Geochemistry of the National Academy of Sciences of the National Academy of Sciences of Ukraine together with the staff of IWP&LR NAAS. The installation ensures a cyclic flow of water into the reactor, where the decontamination process takes place. An ejector with electrodes inserted into it, to which electric current pulses are received, serves as a decontamination reactor and at the same time as a device for creating a heterogeneous water-air environment.

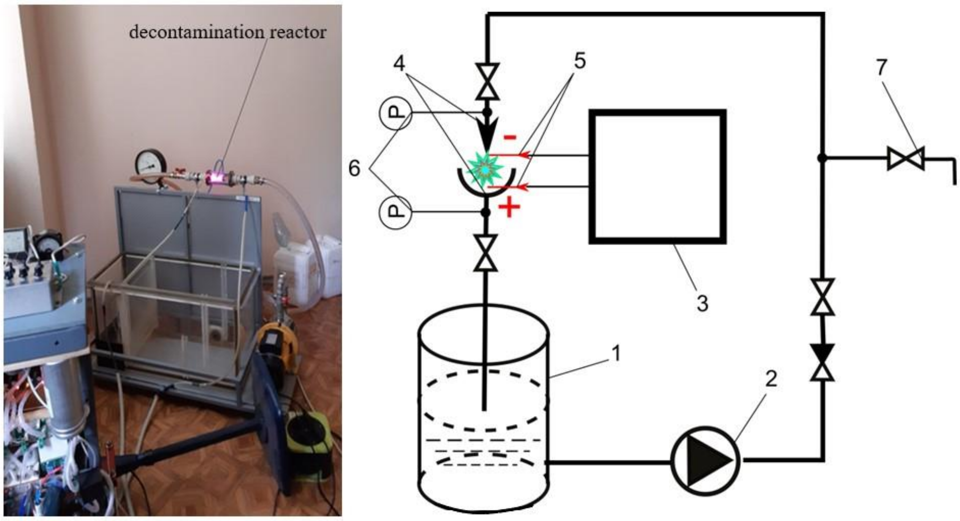


Fig. 3. Photo and Scheme of the installation for water treatment with pulsed spark discharge plasma: 1 - water tank; 2 - water pump; 3 - high-frequency pulse current generator; 4 - ejector (decontamination reactor); 5- electrodes; 6 - manometers; 7 - tap for sampling

Stainless steel electrodes are located in the vacuum zone of the ejector mixing chamber. Cavitations' "boiling" of the treated water flow occurs in the ejector, which ensures the formation of a water-air mixture in the vacuum zone of the ejector. The water-air mixture formed in this way makes it possible to significantly reduce the cost of electricity for the generation and maintenance of plasma in comparison with discharges in a purely aqueous environment [4].

Discharges initiate a whole spectrum of different physico-chemical phenomena, such as a strong electric field, intense ultraviolet radiation, shock waves of excess pressure and, especially, the formation of various highly active chemical compounds, such as radicals (OH•, H•, O•, HO_2•) and molecules (H_2O_2, H_2, O_2, O_3) [3,5]. These physicochemical processes, which occur during the discharge itself, determine the effect of disinfecting water from microorganisms. It is generally known that such molecular types of oxidants as ozone (O_3), hydrogen peroxide (H_2O_2) and OH• radical effectively restructured whole spectrums of organic compounds, such as: phenols, petroleum products, fats, lipids, synthetic dyes, etc. Accordingly, there is an assumption that the use of such processing will ensure high efficiency in disinfecting water from virtually all types and forms of microorganisms: viruses, bacteria, fungi, algae, cysts, protozoa, etc.

Productivity of the experimental installation Q = 0.45 m^3/h. at the working pressure at the ejector inlet of 0.3 MPA. The volume of water to be treated was 5 liters.

The total duration of the output pulses of the current generator was 5 ÷ 7 μs, the pulse frequency was 15 kHz, and the pulse amplitude was about 5 kV.

The test object was a culture of Escherichia coli, strain B-926, from the collection of the Institute of Microbiology and Virology named after D.K. Zabolotny National Academy of Sciences of Ukraine.

Experiments were conducted on model samples of tap water (hereafter referred to as technical water) with the inoculation of E. coli culture grown on meat-peptone agar (MPA).

The washed culture was transferred to a sterile vial and shaken thoroughly. After introducing the bacterial culture, the contents of the container were mixed well and a sample was taken aseptically to determine the initial concentration in the water of the test culture. The initial concentration of the microbial culture, as well as the content of microorganisms after exposure to plasma in the experiments, was determined by the method of water limit dilutions.

The effect of the concentration of microbial contamination was studied on technical water samples, where the washings from two test tubes of E. coli B-926 culture were added to MPA, as well as a double

amount of biomass. The total microbial count of the original water samples, as well as after exposure to plasma, was calculated by the method of limiting dilutions, that is, in all the conducted experiments, tenfold dilution were prepared from the selected samples. Next, 0.1 cm3 of water of each dilution was shown on the appropriate medium (Endo or MPA) with three repetitions. The crops were incubated for 24 hours at a temperature of 37°C. After incubation, the total number of colonies was counted and the total microbial number was calculated according to the formula: $X = \frac{A+B}{C}$,
where: X - total microbial number, CFU/cm^3; A - average number of colonies from repetitions, B - sample dilution, C - amount of inoculums, cm^3.

Results. At an initial E. coli concentration of $3.4 \cdot 10^6$ CFU/cm^3, water treatment for 30 seconds reduced the concentration of microorganisms by two orders of magnitude (to $5.4 \cdot 10^4$). After 1 minute of treatment, this indicator decreased to $1.7 \cdot 10^2$, and after 3 minutes, 5.2 CFU/cm^3 was recorded in the samples, that is, the treated water corresponded to the indicators of practically pure water.

The obtained research results were used in the creation of a mobile water purification plant for use in purifying water from local water supply sources (lakes, ponds, canals, etc.). The processes of saturating purified water with free hydrogen and electrons in order to achieve optimal oxidation-reduction potential, which provides the necessary therapeutic and preventive qualities of such water, are being studied at theScientific Research Center of Boris Vyhovanets LLC. Currently, the necessary procedures for the certification of the installation are being carried out, which will allow it to be used in hospitals, sanatoriums, kindergartens, etc.

CONCLUSIONS AND RECOMMENDATIONS

1. Data obtained as a result of research on filter and sorbent materials proved their high efficiency in the preliminary and deep purification of natural water. **2.** Strong oxidants formed as a result of passing an electric current through a water-air mixture effectively neutralize pathogenic microorganisms. **3.** The determined optimal parameters of filter and sorbent materials and pulse current generation parameters ensure reliable purification of natural waters by mobile water treatment plants.

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MONITORING OF THE MODERN ECOLOGICAL SITUATION OF LAKE ZIKH AND ASSESSMENT OF POLLUTION

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Annotation. Situated on Absheron land, Zikh lake boasts a vast surface area and a precarious ecological state. Zikh lake is 20 hectares in size and 1.5 meters deep. It receives its water from underground streams that come from the Zikh village as well as discharges from domestic industry. Each year, 73 thousand cubic meters of industrial waste and 1826 thousand cubic meters of home wastewater are dumped into the lake. The ecological situation in the village of Zikh is exacerbated by the discharge of domestic waste water into the lake and its environs due to the lack of sewage services.

In the research work, water, bottom sediments and soil samples from lakeside areas were taken and analyzed. Some anions, physicochemical parameters, heavy metals, organic pollutants, PAHs were determined in these water, bottom sediments and soil samples.

Keywords: lake Zikh, water samples, bottom sediments, soil samples from lake areas, anions, physico-chemical parameters, heavy metals, organic pollutants, PAHs

INTRODUCTION

The Absheron peninsula has seen an increase in landscaping and greening initiatives in recent years. Large-scale forest planting, the reconstruction of sewage networks, the cleaning of waste water, the reforestation of areas contaminated by oil and other substances, and other projects are all carried out within the framework of the comprehensive action plan. The Absheron peninsula has a larger need for the work being done in this direction. For almost 150 years, the Absheron peninsula's stutters and soils have been heavily impacted by human activity.

At this time, the peninsula's extensive oil field development—both on land and at sea—grew at a rapid pace while disregarding environmental safety regulations.

Because of the oil and utility industries, building debris, sewage, and other factors, Zikh lake and its environs are among the most polluted places on the Absheron peninsula. In this case, better environmental conditions will make it possible to lower the dangers to the inhabitants of the nearby settlements and, following restoration, reintegrate the lake region and its surrounding territories into the national economy.

Stricter adherence to environmental laws is currently necessary for the Absheron peninsula's oil production and other sectors to grow. Because of waste from oil, oil refining, petrochemicals, transportation, buildings, and other businesses, the more than 30,000 hectares of arable land on the peninsula, the coasts of the Caspian Sea, water basins, natural lakes, the atmosphere, and other spheres remain contaminated. People then start to experience issues as a result of the changing environment. These days, the economy is growing so quickly that it is causing increasingly complicated environmental issues. Thus, one of the most important problems of the day is identifying and removing the causes of environmental imbalance.

MATERIAL AND METHODS

Findings of an analysis of samples collected near Zikh lake

Samples from Zikh lake's water, sewage water dumped into the lake, bottom sediments, and soil surrounding the lake were collected and subjected to a variety of analytical procedures between June and August of 2022. Water samples were collected around the lake at various depths. The salinity of the water rises from east to west. The soil areas that were sampled have no natural soil cover. Drilling was used to get soil samples at various depths. One cannot identify the layers of soil. Most pollution is found in the top levels. The mass spectrometer gas-chromatography apparatus (GC-MS (Agilent, USA) HP6890) was used to evaluate the organic components at the samples, while the AAS method ZEEnit 700 P was utilized to quantify the amount of heavy metals present.

The pH, electrical conductivity, temperature, dissolved oxygen, dry residue, and electrical conductivity of natural water samples collected from the Zikh lake region were measured using the "Water Quality Meter" 850081 brand instrument.

ANALYSIS OF RESULTS

Findings of an analysis of water samples collected from Zikh lake

Table 1

Physical-chemical characteristics of samples of lake water

Sampling station(s)	**Unit**	**S1**	**S2**	**S3**
pH		7,45	7,5	8,38
Dissolved oxygen	mg/l	3,7	4,2	4,8
NO_3^-	mg/l	38,12	28,46	32,22
NO_2^-	mg/l	0,25	0,26	0,34
NH_4^+	mg/l	5,98	4,86	2,59
PO_4^{3-}	mg/l	0,72	0,36	0,48

The table shows that the nitrite, ammonium (thickness tolerance 0.4 mg/l), and phosphate (thickness tolerance 0.2 mg/l) ion concentrations in lake water samples are higher than the thickness tolerance. Nitrate ions and dissolved oxygen do not surpass the limit threshold.

Table 2

Quantity of heavy metals in samples of lake water

Sampling station(s)	**Unit**	**S1**	**S2**	**S3**
Arsenic (As) (thickness tolerance 50)	mkg/l	34,27	41,25	9,69
Mercury (thickness tolerance 0,50)	mkg/l	5,78	6,67	1,16
Cadmium (thickness tolerance 1)	mkg/l	166,5	176,3	648,8
Copper (Cu) (thickness tolerance 1000)	mkg/l	42,59	332,5	171,4
Cobalt (thickness tolerance 100)	mkg/l	1,31	1,26	1,25
Lead (thickness tolerance 30)	mkg/l	455,2	495,6	493,7
Nickel (Ni) (thickness tolerance 100)	mkg/l	479,5	839,4	369,2
Zinc (thickness tolerance 1000)	mkg/l	128,4	142,02	10,49

The table shows that the concentration of heavy metals in the lake water samples was several times higher than the thickness tolerance. This water is particularly contaminated and toxic since it contains far more mercury, copper, lead, and nickel than is acceptable for its thickness.

Table 3

PAH content in water samples drawn from Zikh lake

Sampling station(s)	**Thickness Tolerance** mkg/l	**Unit**	**S30**	**S31**
Naphthalene	0,02	mkg/l	<0,02	<0,02
Acenaphthylenes	0,006	mkg/l	<0,02	<0,02
Anthracene	0,02	mkg/l	<0,02	<0,02
Fluoranthene	0,02	mkg/l	<0,02	<0,02
Fluorene	0,006	mkg/l	0,058	0,024
Phenanthrene	0,006	mkg/l	0,203	0,143
Benzopyrene	0,001	mkg/l	<0,02	<0,02
Chrysene	0,003	mkg/l	<0,02	<0,02

The table indicates that the concentration of chrysene, benzopyrenes, phenanthrene, and acenaphthylenes is above the threshold for thickness.

CONCLUSION

International specialists rank Zikh lake among the region's most contaminated lakes. There is currently work underway to improve Zikh lake's biological state and rid it of waste water. This will totally improve the appearance of the lake's surroundings, which are currently contaminated by rubbish and oil. The design phase of Zikh lake's restoration is now underway. Lake and surrounding area water purification will start later.

Concurrently, efforts are underway to eliminate and balance the impure sediments that have gathered at the lake's bottom for over a century. More than 10,000 cubic meters of silt in a 0.8 million cubic meter volume should be cleaned during the project's initial phase. It is important to prevent home and construction waste from contaminating the lake and its shorelines. By doing this, the water level will be controlled, the ecosystem will be revived, and the lake will resume its normal historical course. The activity completed in a short amount of time will positively alter the dynamics of water quality indicators.

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Environmental protection

CONCENTRATION OF LEAD (II) AND ZINC (II) IN RIVER WATER WITH A SORBENT BASED ON A COPOLYMER OF MALEIC ANHYDRIDE WITH STYRENE

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Annotation. This paper discusses the results of a study on the extraction and concentration of trace amounts of lead (II) and zinc (II) with a polymer chelating sorbent. For the sorption-photometric determination of lead (II) and zinc (II), a modified sorbent based on a copolymer of maleic anhydride with styrene was proposed. Optimal sorption conditions were determined. At pH 4, the degree of sorption passes through a maximum. With an increase in the concentration of lead (II) and zinc (II) in the solution, the amount of absorbed metal increases, and at a concentration of $8 \cdot 10^{-3}$ mol/l, it becomes maximum. The dependence of sorption on time and ionic strength of the solution was studied. The effect of different mineral acids (HClO4, H2SO4, HNO3, HCl) with the same concentrations on the desorption of lead (II) and zinc (II) from the sorbent was studied. The experiment showed that the maximum desorption of lead (II) and zinc (II) occurs in perchloric acid. The sorbent extracts lead (II) and zinc (II) from solutions with a recovery rate of 95-97%.

Keywords: lead (II), zinc (II), sorbent, concentration, photometric determination.

INTRODUCTION

The analysis of natural objects of complex chemical composition containing traces of lead (II) and zinc (II) belongs to the most labor-intensive procedures of analytical chemistry and is an urgent task of modern analytical practice. Direct determination of traces of lead (II) and zinc (II) in natural and technical objects in the presence of macro quantities of interfering background elements leads to a significant decrease in the accuracy and sensitivity of the determination with modern physicochemical methods of analysis. This makes it necessary to develop highly selective, highly sensitive, and rapid methods for determining these elements. In this regard, research aimed at increasing the sensitivity and selectivity of sorption-spectrophotometric methods of analysis is promising. A successful solution to such problems can be achieved by a combination of preliminary selective isolation - concentration of elements with polymer complexing sorbents. The concentration of trace elements has now occupied a significant place in the system of methods of analytical chemistry. It facilitates the preparative production of necessary components and the removal of harmful ones from solutions. There are many known methods for concentrating trace amounts of elements. To concentrate and separate lead (II) and zinc (II), methods of evaporation, sublimation, and sorption, especially ion exchange, are used. In the presented work, we concentrated lead (II) and zinc (II) with a polymer complex-forming sorbent.

EXPERIMENTAL PART

Solutions, reagents, sorbent. Chemical grade reagents were used, or ch.d.a. A solution of lead (II) and zinc (II) was prepared by dissolving an accurately weighed portion of the metal salt in distilled water [1]. Working solutions were prepared by diluting the original solution. The required pH values were maintained with HCl, NaOH, and ammonia acetate buffer solutions. Ionic strength was created with calculated amounts of KCl. Determination of the concentration of lead (II) and zinc (II) was carried out using the photometric method. The work used a polymer chelating sorbent based on a copolymer of maleic anhydride with styrene. The sorbent was synthesized according to the method [2]. The resulting sorbent was dried at 50-60°C.

Equipment. The optical density of solutions was measured using a KFK-2 photo calorimeter. The acidity of the solution was controlled with a glass electrode using a PHS- 25 ion meter.

Experimental technique. Sorption was studied under static conditions. When studying the sorption of lead (II) and zinc (II) under static conditions, a metal solution was introduced into a graduated test tube with a ground stopper, and an ammonia acetate buffer solution was added to create the necessary acidity to a volume of 20 ml. 0.05 g of sorbent was added, the test tube was capped, and left for 3.0 hours. Then the solution was decanted. The developed scheme involves the use of various methods for the final determination of lead (II) and zinc (II). We used the spectrophotometric method. The concentration of lead (II) and zinc (II) was calculated using a calibration graph, and the results obtained were processed statistically.

RESULTS AND ITS DISCUSSION

Effect of pH on sorption. The dependence of the sorption capacity on the acidity of the solution was studied. Metal sorption was performed from a volume of 20 ml of solution. At pH 5, the degree of sorption passes through a maximum. The sorption capacity of the sorbent is studied under static conditions. A metal solution is added to 50 mg of sorbent and left in a buffer medium at pH 1–8. The mixture is filtered and then measured. The amount of remaining metal in the solution is found based on the curve of optical density versus concentration, and the amount of sorbed lead (II) and zinc (II) ions is calculated accordingly. A study of the influence of pH (in the range of 1–8) on the preliminary concentration of lead (II) and zinc (II) ions under static conditions shows that quantitative removal of metal ions is achieved at pH 5. Additionally, it was found that at pH 5, the maximum sorption of the metal occurs when using 30 mg of sorbent. All further studies were carried out at pH 5.

The influence of the concentration of lead (II) and zinc (II) on the sorption process. To determine the optimal conditions for the sorption of lead (II) and zinc (II) with the resulting sorbent, a study of the dependence of the sorption capacity (CE) on the metal concentration was carried out. With an increase in the concentration of lead (II) and zinc

(II) in the solution, the amount of sorbed metal increases, and at a concentration of 8•10-3 mol/l it becomes maximum.

It is known [3] that the ionic strength of a solution significantly affects the flexibility of the solid-phase matrix and the state of the functional groups of the analytical reagent. Therefore, the dependence of the analytical signal on the concentration of the solution in the presence of KCl in the range of 0.1-1.2 M was studied. A negative effect of increasing the ionic strength of the solution on the properties of the sorbent was noted, which is explained by the screening of coordination active groups by electrolyte ions [3]. All further experiments were carried out in solutions with an ionic strength of 0. 6.

Sorption equilibrium is achieved within 3 hours of contact of the solution with the sorbent. Further increasing the sorption time does not change the characteristics of the sorbent.

Study of desorption: The effect of different mineral acids (HClO4, H2SO4, HNO3, HCl) with the same concentrations on the desorption of lead (II) and zinc (II) from the sorbent was conducted. The experiment showed that the maximum desorption of lead (II) and zinc (II) occurs in perchloric acid.

The developed method was used to determine trace amounts of lead (II) and zinc (II) in water taken from an Agstafa river. The analysis was performed as follows: 30 ml of the filtered test sample was adjusted to the desired pH value by adding HNO3 and left for 3 hours in a round-bottom flask with 100 mg of sorbent. The sorbed metal ions were eluted with 5 ml of 2 M HClO4. The concentration of lead (II) and zinc (II) in the eluate was determined by the photometric method. The correctness of the methodology was checked using the ICP-OES thermo ICAP 7400 DUO method.

Table

Results of determination of lead (II) and zinc (II) in river waters (n=5, P=0.95)

Metal	Found (by sorption-photometric method), mg/l	Found (ICP-OES thermo ICAP 7400 DUO) mg/l
Pb	0,0037±0,0005	0,0038±0,08
Zn	0,293±0,004	0,291±0,003

CONCLUSION

Thus, the study showed the possibility of using a sorbent-based copolymer of maleic anhydride with styrene for the sorption-photometric determination of lead (II) and zinc It can be reused after regeneration.

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Water management

WATER TOURISM IN AZERBAIJAN

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Annotation. The development of water tourism in Azerbaijan is seasonal, which lasts from May to October. During this period, in addition to the development of beach, medical and health tourism, water sports tourism on rivers is also developing. There is an opportunity to go diving, kitesurfing, scooter riding, rafting tourism on mountain rivers and organize various tours. In the Caspian Sea, diving is also used in the Mingachevir, Gey-Gol, Sugovushansky, and Khanbulan reservoirs. One of the types of water sports tourism that has become widespread in the Caspian Sea in the summer season is jet skiing.

In Azerbaijan, where there are many rivers and reservoirs, you can also go kitesurfing (riding a board with a kite), which is a type of jet ski and is an active water tourism. Azerbaijan has the necessary resources for the development of various types of water tourism.

Keywords: water sports, diving, rafting, kitesurfing, scooter, jet ski.

INTRODUCTION

There are up to 8,350 rivers in Azerbaijan. The length of only 22 of these rivers is 100 - 500 km, and the length of two rivers - the Kura and Araz - is more than 1000 km. Unfortunately, most of these rivers are not used for tourism purposes.

The Kura River originates from Mount Kyryl-Gedik in Turkey at an altitude of 2740 meters. Passing through the territory of the republics of Georgia and Azerbaijan, it flows into the Caspian Sea [1, 170].

The Mingachevir reservoir is located on the Kura River. You can practice water sports in Mingachevir all year round. In the summer season, the urban population and the population of surrounding villages organize recreation here, engage in water sports and fishing [2,296].

We bring to your attention some information about rivers and water sports suitable for the tourism industry in Azerbaijan.

MAIN PART

Wakeboarding is a combination of water skiing, snowboarding, skating and surfing. A motorboat tows an athlete standing on a short and wide surfboard. A motor boat moving at a speed of 30-40 km/h and with additional cargo on board creates a wave behind it, which the athlete uses as a springboard. During the jump you need to perform several tricks. Wakeboarding began to grow faster in the early 1990s.

Water skiing is one of the most popular types of active sports tourism. Water skiing was first invented in 1922 by American Ralph Samuelson. He decides to experiment with regular winter skis and use them on the water. He's experimenting at Lake City by tying two wide spruce trees together. This sport began to develop rapidly. Currently, water skis are made from foamed plastics - polyurethane foam. This is done to ensure easier and better glide.

Kayaking is one of the fastest growing types of water tourism. Kayaking can be done alone or in a group. In modern kayaking, 3 main directions are developing - paddle slalom, rodeo and flow. Slalom is based on the ability to maneuver the kayak while feeling the kayak and the water. Rodeo, unlike slalom, is distinguished not only by its high level of technology. Performing various tricks on a kayak using the features of the river topography. A kayaker's equipment includes: kayak, helmet, life jacket, rubber shoes and paddle.

Rafting is an active form of recreation in mountain rivers with fast currents. There are many fast mountain rivers in Azerbaijan for rafting tourism. Ganikh, Airichay, Katekh, Gusarchay, Gudialchay, Velvelichay, Vilashchay and others are among the mountain rivers of the Greater and Lesser Caucasus. Currently, some travel agencies organize various tours in this direction.

Those involved in diving tourism should first of all undergo serious training. diving is one of the exciting types of active recreation. Diving tourists are interested in diving to the bottom of seas rich in flora and fauna.

Surfing is a type of water sports tourism. Athletes surf the waves on a cork or foam board. It was first widely distributed in the USA, Latin America, Australia and New Zealand [3,128].

Most of the types of water sports tourism mentioned above can be developed on rivers flowing through the territory of Azerbaijan. In this regard, Kura, Araz, Ganikh, Gabirri (Iori), Airichay, Turianchay, Goychay, Agstafa, Kurekchay, Tarter, Khachinchay, Karachay, Arpachay, Bazarchay, Gekari, Kendalanchay, Samur, Gusarchay, Gudialchay, Sumgaitchay, Pirsaat. The rivers Ganja, Nakhchivanchay, Girdimanchay and other rivers will be economically useful for the tourism industry.

Azerbaijan, which has rich natural resources, is also rich in its healing reservoirs. Absheron, Shabran, Guba, Shamakhi, Ismailli are highlighted with medicinal resources nsky, Gakh, Naftalan, Shusha, Kelbajar, Masalli, Lankaran, Nakhchivan regions. These treatment facilities serve patients from many parts of the world.

The development of water tourism in Azerbaijan is more favorable in the warm season. This season you can widely use beach tourism, diving, kitesurfing, scooter riding and other types of water recreation. You can engage in rafting tourism along the flowing mountain rivers of the Greater and Lesser Caucasus and even organize various tours to this area.

Diving tourism can also be used in the Caspian Sea, lakes Mingachevir, Gey-Gol, Khanbulan and Sugovushan.

One of the types of water sports tourism that has become widespread at sea is jet skiing. Used for recreation, for sporting purposes, for rescuing people and law enforcement. Fans of extreme tourism can use jet skis in Azerbaijan, where there are many rivers and reservoirs.

One of the types of active water tourism is kitesurfing, that is, riding on water waves. This sport is active near the coastal settlements of the Caspian Sea. One of the most popular types of water tourism is SUP surfing. For SUP surfing, tourists paddle quietly while standing on a board in calm weather.

There are many ways to develop beach tourism in countries located on the sea and river coasts. The coastal zone of Azerbaijan is 825 km. Despite all these opportunities, we cannot use beach tourism at the required level. One of the most profitable areas in the tourism industry is beach tourism.

In most countries of the world, people like to relax by the sea on hot days. We have up to 95 beach areas in coastal areas to develop tourism in the Caspian coastal areas belonging to Azerbaijan. The creation of beaches and recreation centers in these territories, as well as tourism infrastructure in general, is one of the most important tasks. If such conditions are created, the number of foreign tourists coming to our country will increase. In this area, we can take advantage of the experience of Turkey, as well as countries where beach tourism is developing.

Using the Caspian Sea, it is possible to increase the number of tourist routes to surrounding settlements and islands near the Absheron Peninsula. For example, Baku-Lokbatan, Baku-Denizkanari (coastal village), Baku-Neftdashlari, Baku-Chilov Adasi, Baku-Pirallahi, Baku-Gum Island, etc.

At the same time, through the Caspian Sea, tourists will go to northern Baku-Sumgayit, Baku-village Zeynalabdin Tagiyev, Baku-Shurabad, Gilazi, Shabran, Khachmaz and the southern regions of Azerbaijan to Baku-Gobustan, Baku-Alat, Baku. -Neftchala, Baku-Lankaran and Baku-Astara regions may open routes.

60% of Azerbaijan's mineral water reserves belong to the Nakhchivan Autonomous Republic. Some mineral waters are important for healing. Darydag arsenic water is used to treat many diseases. Carbonated “kidney water” in Nakhchivan, similar to radon and sulfur waters, can be found in foreign countries. There are more than 250 mineral water sources in Nakhchivan.

7 sources of mineral water were identified, discovered in 1969 in the territory of the village of Galaalty, Shabran region. Local residents call this water, important for healing, “Naftsu”. This mineral water contains bicarbonate, calcium and sodium.

The Absheron Peninsula is also rich in mineral waters. The mineral waters of the capes Surakhany, Sabunchi and Shykh have great medicinal value. Many sanatoriums have been built on the mineral springs of Absheron, rich in iodine, bromine and other chemicals.

Karabakh, located in the southeast of the Lesser Caucasus, has many mineral waters. These include the mineral springs Turshsu, Shirlan, Cheraktar, Kolatag.

CONCLUSION

In the Lachin-Kelbajar region Upper Istisu, Lower Istisu, Koturlu, Iligsu, Turshsu; in the Shamakhi region, thermal waters with nitrogen and sulfur-oxygen properties Khaltan, Chagan, Chukhuryurd; in the Gabala region Bum and Khalkhal; in the Gakh region Ilisu, Oglan spring and Maiden spring; in the Salyan region, calcium mineral spring Babazanan; in the Lankaran, Astara and Masalli regions there are up to 157 sources of mineral waters containing nitrogen and methane. From these materials it is clear that Azerbaijan has the necessary resources for the development of various types of water tourism.

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Water management

ISSUES OF PROTECTION AND PURPOSE USE OF THE "TRCHKAN" WATERFALL IN THE REPUBLIC OF ARMENIA

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Annotation. Water bodies are an important component of ecotourism, providing a platform for eco-friendly travel that highlights the beauty and importance of aquatic ecosystems. The aquatic environment offers unprecedented opportunities for eco-conscious travelers to connect with nature. Participating in activities such as sustainable fishing, boat tours, bird watching and nature walks in these aquatic landscapes allows travelers to appreciate the interconnectedness of nature and society. By integrating water features into ecotourism programs, we can promote environmental conservation, support local economies, and develop a sense of stewardship of these vital resources.

Keywords: water, ecotourism, stakeholders, waterfall, protection of water bodies.

INTRODUCTION

Water bodies serve as a fundamental component of ecotourism, offering travelers a wide range of recreational and educational opportunities. From the tranquil beauty of lakes and wetlands to the dynamic ecosystems of rivers and coastlines, aquatic environments offer a rich range of experiences for visitors.

In contrast to tourists who tend to spend extended periods in Yerevan, the capital city, eco-tourists contribute significantly more to local communities and expend greater financial resources in the regions. Consequently, to foster community-based tourism initiatives, it is imperative to prioritize the further advancement of ecotourism, including the development and management of appropriate routes & capacity building [1].

By including water features in ecotourism initiatives, we can raise awareness of conservation, support local communities and create memorable adventures that prioritize water conservation. One of the main challenges in this matter is the pollution of water sources, which can affect the state of ecosystems and lead to a decrease in the attractiveness of places for tourism. Increasing levels of tourism can also strain local infrastructure and threaten the natural environment. However, with proper management and awareness, ecotourism can serve as a tool to support sustainable use of water resources and improve the health of aquatic ecosystems. The development of ecotourism can also promote awareness of the importance of preserving aquatic ecosystems.

With growing global interest in sustainable travel practices, ecotourism presents a promising avenue for promoting conservation efforts while simultaneously providing socio-economic benefits to local communities. Armenia's nature characterized by their rich biodiversity and unique landscapes, offer an ideal setting for ecotourism initiatives, however, challenges such as inadequate infrastructure, limited visitor facilities, insufficient marketing strategies and absence of data analytics hinder the realization of ecotourism potential [1].

MAIN PART

Trchkan Waterfall (Fig. 1) – a natural wonder located in Armenia.

Fig. 1. Trchkan Waterfall

On the border of Shirak and Lori regions there is one of the picturesque waterfalls in Armenia. Located on the Chichkhan River, the left tributary of the Pambak River, the Trchkan waterfall has been included in the list of natural monuments of the Republic of Armenia since 2008, and since 2011 a special protected zone has been established. The waterfall, falling from a height of 23.5 m, is the highest and most abundant waterfall in RA. Trchkan Waterfall is also known as Chichkhan Waterfall and locals call it Chran. It is located in the administrative district of the village of Mets Parni, approximately 10 km northwest of the village of Shirakamut [2].

This waterfall is a popular attraction for tourists and nature lovers, offering a serene and picturesque setting. The cascading waters of Trchkan Falls create a tranquil atmosphere, making it a tranquil place to visit and enjoy the beauty of nature.

Waterfalls, which are a complex hydrological and geomorphological phenomenon, form an integral part of the river network of natural landscapes in mountainous and foothill areas. They have important environmental, recreational and therapeutic significance for humans. Rational use of waterfalls (with the necessary environmental protection measures) is possible only on the basis of a comprehensive analysis of the conditions of their occurrence, water flow regime, geological structure of the watercourse bed, and terrain [3].

Protecting waterfalls is important to protect nature and preserve their beauty. Some administrative ways in which the safety and preservation of waterfalls can be ensured are given below:

- Creation of protected areas;
- Implement and enforce rules for visiting waterfalls;
- Monitor for signs of erosion, other negative phenomena and develop measures to prevent degradation of waterfalls;
- Developing school educational programs and excursions to increase student awareness;
- Collaborate with local communities, environmental organizations and government agencies to develop environmental strategies and sustainable practices;
- Regular maintenance of aquatic ecosystems. Conducting monitoring to eliminate any threats to the safety of water bodies;
- Developing a sustainable tourism strategy based on the experiences of visitors to the waterfalls.

Waterfall conservation involves understanding the physical, biological and chemical processes that affect water bodies and their surrounding environment. Some necessary activities are given below:

- Hydrodynamic studies. Conducting studies of water flow through a waterfall can help assess the effects of erosion and sediment transport, allowing for the development of more effective management strategies to protect the structural integrity of the waterfall. Applying the principles of hydraulics can help optimize the flow of water through a waterfall, ensuring minimal disruption to the natural ecosystem and preventing excessive erosion. Using the principles of fluid dynamics, physicists can analyze the flow patterns of water over a waterfall to identify areas of high turbulence or erosion. By optimizing the flow and potentially controlling the redirection of water, the impact on the structure of the waterfall and the surrounding ecosystem can be minimized;
- Construction design. Use the principles of physics to design and implement structural reinforcement, such as retaining walls or erosion control measures, to prevent the waterfall from collapsing under the forces of water flow;
- Hydraulic engineering studies. Physical principles such as soil mechanics and sediment transport can be applied to the design of erosion control structures such as gabions or retaining walls to protect a waterfall from erosion caused by the force of the water flow;
- Hydrological studies. Using physics-based hydrologic models, such as rainfall and runoff modeling, scientists can predict water flow patterns and potential changes in waterfall hydrology due to climate change, which helps in proactive conservation planning;
- Climate change modeling. Using physics-based climate change models can help predict how changes in temperature and precipitation patterns may affect water availability and the health of waterfalls, allowing proactive conservation measures to be taken;
- Energy saving. Adopting energy-efficient methods, such as using waterfall-generated hydroelectricity, can help reduce the overall environmental impact and promote sustainable development;
- Structural analysis. Techniques such as finite element analysis can help identify weak points that may be vulnerable to collapse, allowing targeted strengthening efforts to be made;
- Control and measuring equipment. Physical sensors and instruments such as accelerometers and flow meters, etc. can be used to monitor factors such as water speed, sediment transport and structural vibrations, providing real-time data for early warning systems and adaptive waterfall management;
- Vibration analysis. By applying the principles of vibration analysis, it is possible to evaluate the effect of water flow vibrations on the stability of a waterfall and its surroundings;
- Sound analysis. By analyzing the sound waves and frequencies generated by a waterfall, changes in flow speed, erosion patterns and structural integrity can be monitored, providing valuable information for conservation efforts;

- Thermal imaging can be used to monitor changes in temperature patterns around a waterfall. This can help identify changes in water flow, detect leaks in the natural aquifers feeding the falls, and assess potential stress on the ecosystem due to temperature fluctuations, helping conservation efforts;
- Physics-based geomorphological modeling can be used to model erosion processes affecting waterfalls over time. By analyzing factors such as sediment transport, bedrock composition and flow dynamics, researchers can predict how the waterfall's landscape may change and take targeted measures to mitigate erosion and preserve the natural beauty of the waterfall. Incorporating geomorphological modeling into conservation strategies will help determine the long-term effects of waterfall erosion and take preventive measures to protect these natural wonders;
- Aerodynamics assessment. Applying the principles of aerodynamics can help understand how air flow patterns interact with the dynamics of water flow at waterfalls. By studying the effects of wind on water mist and spray, potential erosive impacts on surrounding vegetation can be assessed and informed decisions can be made to minimize environmental disturbances. By assessing aerodynamics, insight can be gained into the complex interactions between air and water in waterfalls, facilitating more effective environmental practices;
- Sediment transport analysis. Physical principles can be applied to study the movement of sediments;
- Acoustic monitoring. Physics-based acoustic monitoring techniques can be used to study the sounds produced by waterfalls. By analyzing sound frequencies and patterns, changes in the water can be assessed.

CONCLUSION

The targeted use of waterfalls involves a comparison of public and scientific-applied efforts in order to ensure their protection and uninterrupted functioning for a long time. Permanent monitoring of physical, biological and chemical processes at waterfalls will allow us to determine the possible consequences of erosion and other negative phenomena and take preventive measures to protect these wonders of nature.

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Earth sciences

EVALUATION OF THE INTENSITY OF EROSIVE PROCESSES IN THE TERRITORIES OF VILLAGE GLDANI AND RECOMMENDATIONS OF MEASURES TO COMBAT IT

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Annotation. The article analyzes the causes of erosive processes in the surrounding areas of Tbilisi bypass. The stages of development of cracks formed as a result of these processes are studied and the erosion class is determined. In order to regulate them in the future, it is recommended to carry out complex hydrotechnical and phyto amelioration measures (for example, equal planting of tree-shrub type crops on the entire area of catchment basins, terracing of slopes, arrangement of horizontal collecting ditches and storage systems, etc.), which leads to surface water runoff on slopes, reduction of intensity and elimination of shrill-producing processes.

Keywords: soils, pits, erosion.

INTRODUCTION

One of the most pressing issues for Georgia is the protection of international and domestic highways from the negative process of erosion.

According to the frequency of formation of erosive foci, the stages of development and the damage caused by them, the area around the Tbilisi bypass can be classified as one of the most difficult sections in Georgia (Fig. 1).

Fig. 1. Schematic illustration of eroded sections of the Tbilisi bypass

The Tbilisi bypass, built for transit traffic, starts from Zahesi township and ends at the 18th km of the Tbilisi-Tsiteli Khidi highway (the total length of the road is 49 km). Its safe operation is of great importance, because it represents the connecting artery of several states, including Georgia, Azerbaijan, Armenia and Turkey, and contributes to the establishment and development of common economic interests.

It can be seen from Figure 1 that the highway of international and domestic importance on the sections of Zahesi-Gldani and Norio-Martkopi passes through ecologically unstable mountain slopes, because there are active processes of soil depletion, overwashing, formation of gullies and formation of pits. This is facilitated by such natural factors as: the slope of the slopes and the lithology of the igneous rocks, the geomorphology of the area and the Engineering-geological conditions, the humid climate - with moderately cold winters and quite hot summers, the high amplitude of diurnal and seasonal temperature variations, the water supply in the snow cover, the altitude In different areas, higher than average precipitation rates, strong winds, which create suitable conditions for intense physical wear of rocks.

In order to study the erosion processes in the described area and to develop countermeasures, a vulnerable slope was selected (Fig. 2), at coordinates: 41°49'21.68"N; 44°48'53.85"E. It is located on the southern slope of the Saguramo ridge at an altitude of 600-630 meters above sea level, the length of which is 240 m.

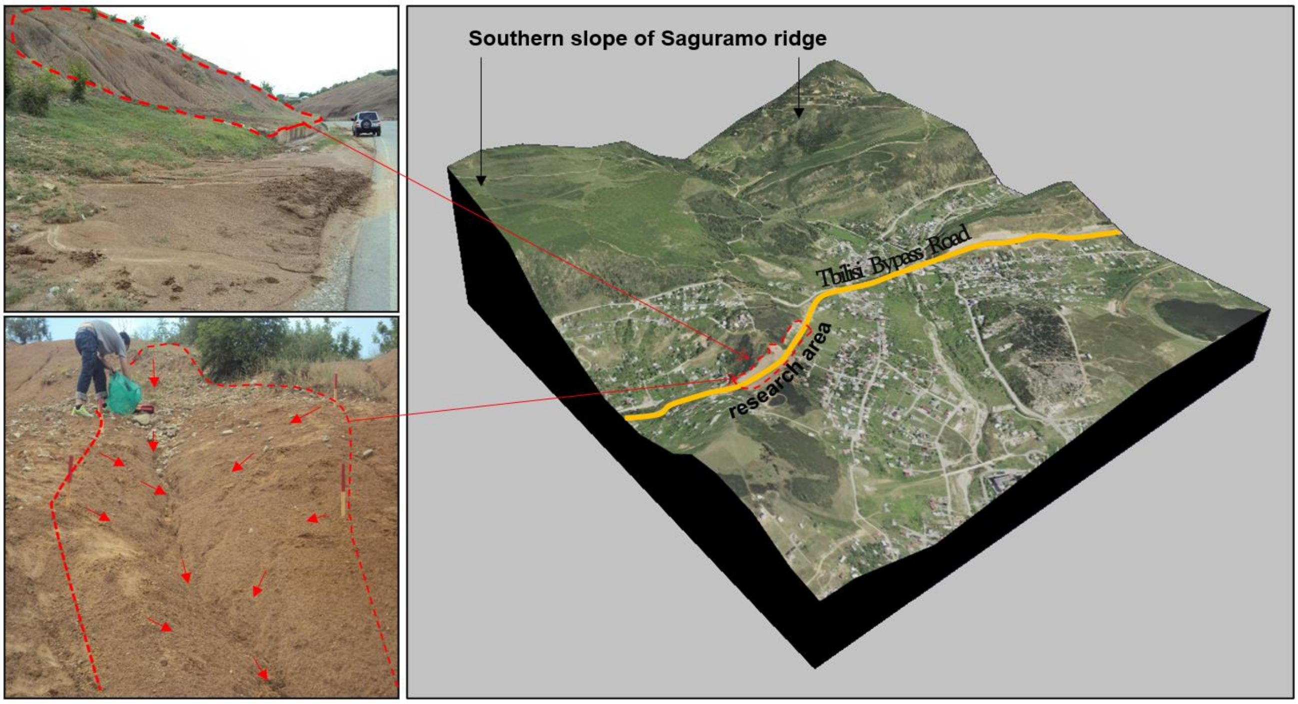


Fig. 2. Schematic ortho and photo illustration of the study area located on the Tbilisi bypass

It can be seen from number 2 that erosion processes are actively taking place in the selected area. Highly depleted thin clays and sandstones are spread there, on top of which are developed yellowish-brown dusty, easily washed clays of various thicknesses (0.2-1.5 m). In the upper part of these loams there is a humus layer and it is covered with a soil layer 0.1-0.2 m thick. On the surface of the soil, devoid of vegetation cover and exhausted, grooves created by small streams are formed as a result of rains. Their formation takes place on a slope with a large slope (the slope varies from 40^0 to 70^0 in some sections), which creates a prerequisite that erosion processes will develop even more intensively during the rains.

MAIN PART

On the mentioned slope, scientific field-experimental checkpoints (polygon) were organized in three cross-sections, where the depths and widths of washing were studied and determined as a result of monitoring studies (Fig. 3).

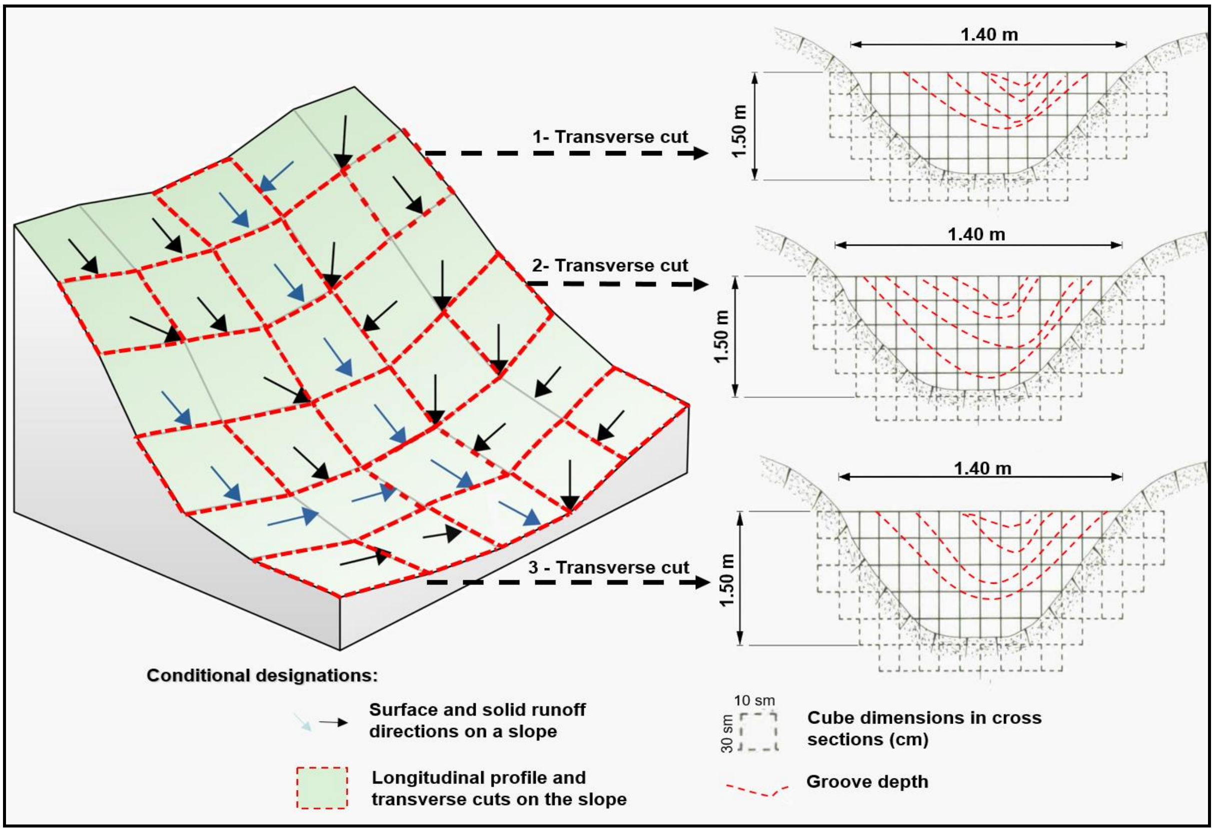


Fig. 3. Schematic illustration showing erosion processes in the directions and sections of the surface runoff on the selected research slope

At the initial stage of the research (2021), the maximum width of the groove formed as a result of erosion in the first section was H=17 cm, and the width B=20 cm, in the second section the depth H=30 cm, width B=31 cm, in the third section the depth H=15 cm, Width B=21 cm. In 2022, the maximum depth of the erosive groove in the first transverse profile was H=25 cm, the maximum width B=23 cm, in the second section depth H=41 cm, width B=60 cm, in the third section depth H=35 cm, width B=36 sm. In 2023, respectively, these values amounted to: H=61 cm; B=65 cm. H= 90 cm in the II transverse profile; B=100 cm. III in the transverse profile H= 75 cm; B= 87 cm, and the expedition research conducted in 2024 showed us that the maximum widths and depths of the erosive gully have changed significantly and amounted to: H=75 cm in section I; B=91 cm; in the II section - H=127 cm; B=146 cm; in the III section - H=91 cm; B=120 cm. Although the maximum depth of the gully in section III is reduced, it is due to the fact that the eroded gully has increased in depth.

As a result of carrying out field-reconnaissance works and on the basis of graphic processing of camera material, the total area of the research area was determined, which does not exceed F_0 =7.53 km^2. From here, the area of the yellowish-brown dusty and loamy layer on the exposed slope is F_1=1.16 km^2 (Fig. 4). Aggregate structure with increased porosity is well defined in this highly exhausted and easily washable layer. The growing processes of natural and artificial denudation taking place in different altitude zones are obviously accompanied by changes in the physical and mechanical properties of the rocks forming the slope, which is mainly facilitated by the climatic conditions of the region.

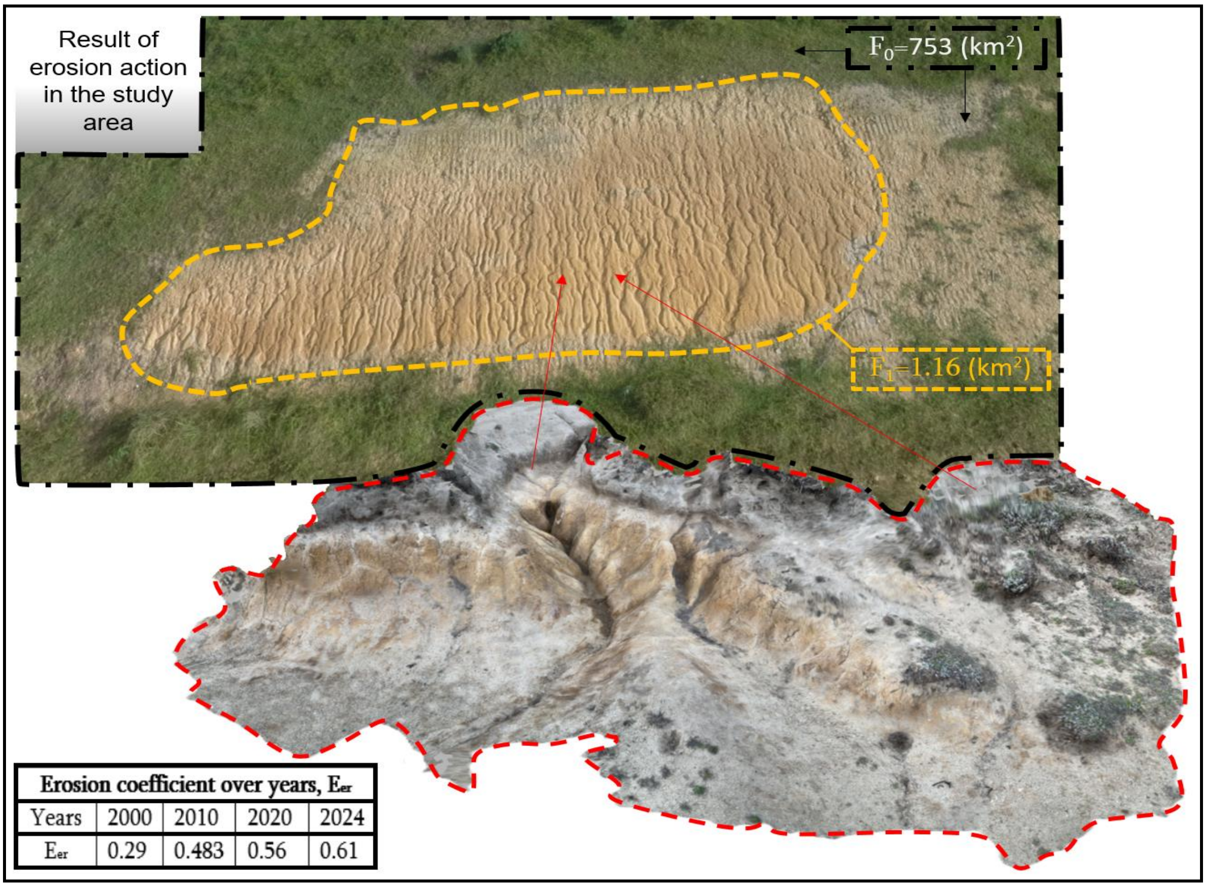
During the research period, the erosion coefficients of the mountain slopes were determined (on the example of the selected research polygon), for which the empirical approach adopted by academician Givi Gavardashvili was used [1].

The accounting attitude has the following form:

$$E = \left[0{,}58 + 1{,}40\left(\frac{F_1}{F_0}\right)\right]\left(\frac{t}{T}\right)^{0{,}21} \tag{1}$$

where, E is the characteristic magnitude of erosion processes; F_1 is the area of the exposed area in the river basin (km^2); F_0 - the total area of the river catchment (in our case, a dry ravine) basin (km^2); t - research time interval (year); T - total period of observation (in our case equal to 30 years).

The erosion coefficients calculated by the mentioned formula according to the years are presented schematically in Fig. 4.



Erosion coefficient over years, E_{er}				
Years	2000	2010	2020	2024
E_{er}	0.29	0.483	0.56	0.61

Fig. 4. Erosion of the mountain slopes in the erosive gully collection basin in the study area Values of the coefficient

In the mountain slope erosion class and table 1 and schematic fig. The connection established between the characteristic of erosion given on **№** 4 was evaluated by academician G. Gavardashvili's methodology [1] and professor R. according to the Morgan scale [2].

Table 1

Quantitative characteristics of the current erosion processes on the research slopes

№№	The area of the catchment basin (km^2)		Erosion rate (E_{er}) by 2024	Erosion class	Erosion intensity per year (t/ha)	Amount of waste material accumulated along eroding areas (t/year)
	Whole F_0 (km^2)	Eroded F_1(km^2)				
	1	2	3	4	5	6
1	7.53	1.16	0.61	4	10-50	1160-5800

Because there is a frequent network of connected and continuous gully runoff every 5-10 meters, and the origin of ditches is noted every 20 meters, therefore this area belongs to the fourth class of erosion according to the evaluation criteria, which is quantitatively equivalent to the denuded mass of 1160-5800 t/ha per year, which in the future may cause a delay in the movement of vehicles on the Tbilisi bypass.

From the data obtained as a result of the conducted field-expedition research and the analysis of camera material, it is clearly visible the scale of the erosion processes taking place in the selected sensitive area (polygon) on the bypass of Tbilisi (Fig. 5).

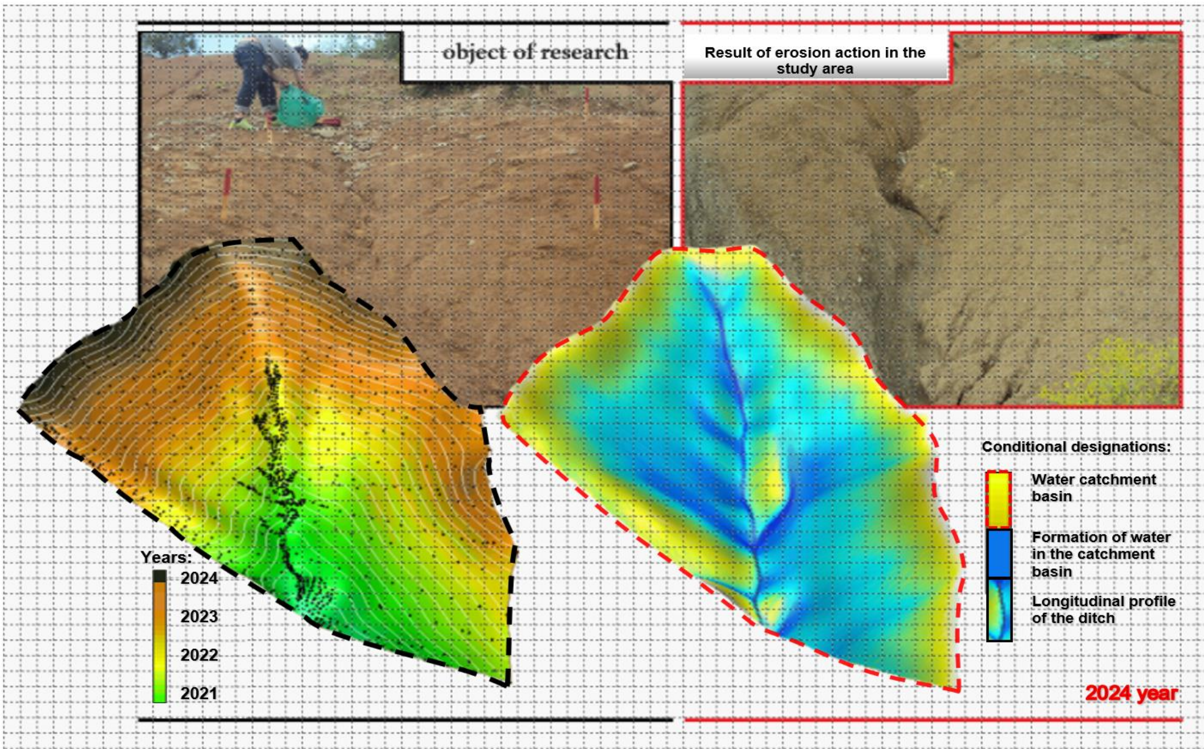


Fig. 5. Schematic 2D illustration showing the process of the formation of soil and the growth of its water catchment as a result of water erosion in the study area (2021-2024)

All of the above indicates the need for multi-faceted study of eroded grooves and ditches and the eroded slope of similar areas on the highway, for which it is necessary to carry out detailed complex studies both in the field and in the laboratory.

The ongoing global warming will have a negative impact on the natural conditions of the study area, and erosion processes will proceed at an even faster pace.

CONCLUSIONS AND RECOMMENDATIONS:

1. The field-expedition and scientific research carried out in the selected areas allowed us to determine the intensity of erosion processes of the selected area over time. According to the results of the study, it was revealed that if the maximum depth of the ditch on the selected slope in 2021 (at the beginning of the study) was equal to H=35 cm and the maximum width did not exceed B=35 cm, as of April 2024, it amounted to: H=75 in section I cm B=91 cm; in the II section - H=127 cm; B=146 cm; in the III section - H=91 cm; B=120 cm.
2. The selected area, in terms of erosion processes, belongs to the 4th class of erosion, which quantitatively corresponds to an eroded mass of 1160-5800 tons per hectare per year. Such an amount of eroded mass is significant in terms of erosion and can potentially lead to restrictions on traffic flow on the highway in the future.
3. In the selected area (bank) and similar eroding sensitive areas, it is recommended to carry out complex hydrotechnical and phyto amelioration measures for future regulation of erosion processes (for example, equal planting of tree-shrub type crops on the entire area of catchment basins, terracing of slopes, arrangement of horizontal collecting ditches and storage systems etc.), which leads to a decrease in the intensity of surface water runoff. It is possible to recommend and cultivate such special plants as vetiver, pampas, etc., which have been tested in the world today, to regulate the current erosion processes and restore biodiversity on the vulnerable mountain slopes.

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COMPUTATIONAL ANALYSIS OF WAVE MOTIONS NEAR THE ESTUARIES ALONG THE RIONI RIVER

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Annotation. Permanent ecological and geomorphological issues have plagued Poti and its surrounding sea region for more than a decade. These issues stemmed from the region's history of failed attempts to develop and implement hydro-engineering structures for a variety of uses.

When the Rioni stream was completely thrown over to the north of the city in 1939, the Poti coastal strip's geomorphological difficulties started. While the city was spared from repeated flooding, the surrounding area lost an invaluable amount of alluvium that forms beaches. The Poti coastal strip washed away and tragically withdrew several hundred meters as a result of the sea. The paper proposed methods for determining the wave regimes in the coastal zone of the Black Sea in the area of Poti.

The Crank-Nicholson scheme and the finite element approach were used to numerically solve the fundamental water discharge equations. Computational experiments were conducted based on the model. The transverse and longitudinal sea currents, as well as variations in the free surface elevation, were calculated. The wave mode in deep water under identical boundary circumstances was calculated in this region during the model testing. The computations' outcomes match the data's established analytical solutions.

Keywords: wave motion, sediments, coastal erosion, numerical model.

INTRODUCTION

Locations of geomorphological and hydro-engineering problems existing in Poti sea region are schematically given in Fig. 1.

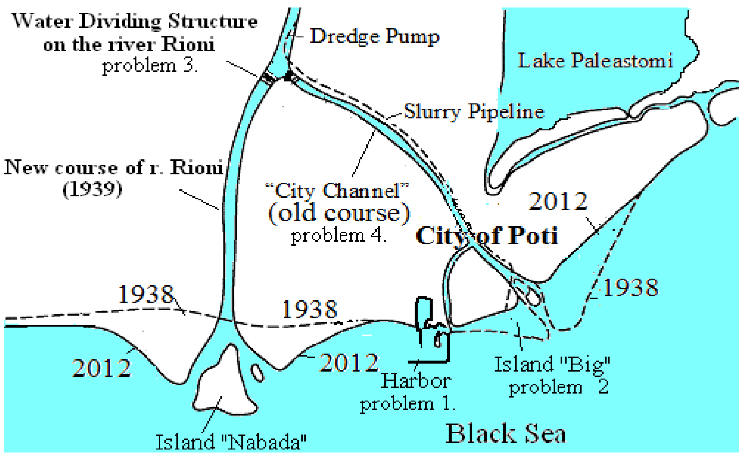

Fig. 1. Schematic map of Poti sea region
--- coastal shore line in 1938; — coastal line in 2012

The serious environmental problems started in Poti after transfer of the main flow of the river Rioni to the north. As a result, the flooding of the city stopped, however the reduction of water consumption in the city channel, caused a decrease of the sediments carried away by the river, what leads to coastal erosion (Fig. 1).

The coast changes are connected with the movement of the waves and currents in the coastal part of the sea. Consider wave movements in the coastal zone of the sea in the Poti region.

Numerical Model of Wave Motion of the Sea.
Basic Equations.

The basic equation of wave motion is [1,2,3]:

$$\begin{gathered}\frac{\partial \vec{Q}}{\partial t}+\frac{c^2}{n}\vec{\nabla}(n\varsigma)+f\vec{Q}=0,\\ \frac{\partial \varsigma}{\partial t}+\vec{\nabla}\cdot\vec{Q}=0.\end{gathered} \tag{1}$$

where $\vec{Q}$ is the vector fluid flow $\vec{Q}=\int_{-h}^{\zeta}\vec{u}dz$; $\zeta(t,x_1,x_2)$- the free surface of the calm sea level elevation; n- the group velocity; C_g related to the phase velocity C; f - coefficient of bottom friction; h - water depth. The following relations hold [2,3]: $\sigma^2=gk\cdot\tanh(kh)$, $C=\frac{\sigma}{k}=\sqrt{\frac{g}{k}\tanh(kh)}$, $n=\frac{C_g}{C}=\frac{1}{2}(1+\frac{2kh}{\sinh(2kh)})$, where $\sigma=\frac{2\pi}{T}$ is the angular frequency; $k=\frac{2\pi}{L}$ -wavenumber; T, L - respectively, the period and wavelength.

According to the above mentioned, we use the following equations:

$$\begin{gathered}\frac{\partial \vec{Q}}{\partial t}+\frac{C^2}{n}\vec{\nabla}\xi=0\\ \frac{\partial \xi}{\partial t}+n\vec{\nabla}\cdot\vec{Q}=0\end{gathered} \tag{2}$$

where the function $\xi(t,x_1,x_2)=n(x_1,x_2)\cdot\zeta(t,x_1,x_2)$ adjusted increase of sea free surface.

Let us formulate the boundary conditions. On the part B_1 of the common boundary B of the integration domain, a vector function - $\vec{Q}^*(t,x_1,x_2)$ is given, on the part B_2 is a function $\xi^*(t,x_1,x_2)$.

Finite element formulation.

The boundary value problem for equation (2) with the corresponding boundary conditions is equivalent to the variation problem of the form:

$$\begin{gathered}\int_S(\frac{\partial \vec{Q}}{\partial t}+\frac{c^2}{n}\vec{\nabla}\xi)\cdot\delta\vec{Q}dS=\int_{\Gamma_2}\frac{c^2}{n}(\xi-\xi^*)\vec{N}\cdot\delta\vec{Q}dB,\\ \int_S(\frac{\partial \xi}{\partial t}+n\vec{\nabla}\cdot\vec{Q})\delta\xi dS=\int_{\Gamma_1}n(\vec{Q}-\vec{Q}^*)\cdot\vec{N}\delta\xi dB,\end{gathered} \tag{3}$$

where $\delta\vec{Q}$ and $\partial\xi$ are variations meet the boundary conditions for the flow and elevation, $\vec{N}$ is the unit vector of the outer normal to the boundary of the integration region. Integration in the left-hand sides of the equations is carried out over the entire region of *S*, in the right-hand sides by the corresponding parts of the boundary.

From the Eq.3 we obtain:

$$\begin{aligned}
&\int_S \left(\frac{\partial \vec{Q}}{\partial t} \cdot \delta \vec{Q} - \xi \vec{\nabla} \cdot (\frac{C^2}{n} \delta \vec{Q}) \right) dS + \int_{B_2} \frac{C^2}{n} \xi^* \vec{N} \cdot \delta \vec{Q} dB = 0 \\
&\int_S \left(\frac{\partial \xi}{\partial t} \delta \xi - \vec{Q} \cdot \vec{\nabla}(n \delta \xi \right) dS + \int_{B_1} n \vec{Q}^* \cdot \vec{N} \delta \xi dB = 0
\end{aligned} \qquad (4)$$

We divide the domain of integration into finite elements of $S = \bigcup S_e$. On each finite element S_e we use the following function approximations [4]:

$$Q_i(t, x_1, x_2) = Q_i^N(t)\psi(x_1, x_2);\ \delta Q_i(t, x_1, x_2) = \delta Q_i^N(t) \cdot \psi(x_1, x_2);\ \left(\frac{C^2}{n}\right) = \left(\frac{C^2}{n}\right)^N \psi(x_1, x_2);$$

$$n(x_1, x_2) = n^N \psi(x_1, x_2) \ldots$$

where $\psi(x_1, x_2)$ are local interpolation (basis) functions.

When solving the Cauchy problem for the system Eq. 4, one can use the method of finite differences. On the time axis t we take the discrete set of points $t_0, t_1, t_2, ..., t_{i-1}, t_i, ...$ with step Δt and use the Crank-Nicolson scheme [5]. On the basis of (4) we obtain a system of linear algebraic equations:

$$\begin{aligned}
&\sum_{(e)} \overset{(e)}{\Omega}{}_{\Delta}^{K} \left[\frac{a_{NK}}{\Delta t} Q_{1(i)}^N + b_{NMK1} \left(\frac{C^2}{n}\right)^M \frac{\xi_{(i)}^N}{2} \right] = \sum_{(e)} \Omega_{\Delta}^{K} \left[\frac{a_{NK}}{\Delta t} Q_{1(i-1)}^N - b_{NMK1} \left(\frac{C^2}{n}\right)^M \frac{\overset{(e)}{\xi}{}_{(i-1)}^N}{2} + \left(\frac{C^2}{n}\right)^M \frac{\xi_{(i)}^{*N} + \xi_{(i-1)}^{*N}}{2} p_{NMK1} \right], \\
&\sum_{(e)} \overset{(e)}{\Omega}{}_{\Delta}^{K} \left[\frac{a_{NK}}{\Delta t} Q_{2(i)}^N + b_{NMK2} \left(\frac{C^2}{n}\right)^M \frac{\xi_{(i)}^N}{2} \right] = \sum_{(e)} \Omega_{\Delta}^{K} \left[\frac{a_{NK}}{\Delta t} Q_{2(i-1)}^N - b_{NMK2} \left(\frac{C^2}{n}\right)^M \frac{\overset{(e)}{\xi}{}_{(i-1)}^N}{2} + \left(\frac{C^2}{n}\right)^M \frac{\xi_{(i)}^{*N} + \xi_{(i-1)}^{*N}}{2} p_{NMK2} \right] \Rightarrow \qquad (7) \\
&\Rightarrow \sum_{(e)} \overset{(e)}{\Omega}{}_{\Delta}^{K} \left[\frac{a_{NK}}{\Delta t} \xi_{(i)}^N + b_{NMK1} n^M \frac{Q_{1(i)}^N}{2} + b_{NMK2} n^M \frac{Q_{2(i)}^N}{2} \right] = \\
&= \sum_{(e)} \overset{(e)}{\Omega}{}_{\Delta}^{K} \left[\frac{a_{NK}}{\Delta t} \xi_{(i-1)}^N - b_{NMK1} n^M \frac{Q_{1(i-1)}^N}{2} - b_{NMK2} n^M \frac{Q_{2(i-1)}^N}{2} + n^M \left(\frac{Q_{1(i)}^N + Q_{1(i-1)}^N}{2} N_1 p_{NMK1} + \frac{Q_{2(i)}^N + Q_{2(i-1)}^N}{2} N_2 p_{NMK2} \right) \right].
\end{aligned}$$

At time t_0, the values of nodal flows $Q_{1(0)}^N, Q_{2(0)}^N$ and the elevations of the free surface $\xi_{(0)}^N$ are give the initial conditions. To find the wave field at the i-the time step, we must solve the system of equations (7) with respect to the unknowns $Q_{1(i)}^N, Q_{2(i)}^N, \xi_{(i)}^N$, taking into account the boundary conditions.

Computational experiments.

To study the coastal wave mode in the area of the city of Poti near the Rioni river south estuary, consider a section of the sea in the plan of 700×600m, adjacent to the Poti port (Fig. 2).

Fig. 2. Field of research seashore

The domain of integration was divided into triangular finite elements, the steps of the partition were taken as follows: along the axis $x_1 - \Delta x_1 = 5$ m, along the x_2 axis - $\Delta x_1 = 5$ m Number of nodes along the first axis – 141 $i = 1 \div 141$, along the second – 50 $(j = 1 \div 13)$.

The parameters of waves in deep water are as follows: the direction of propagation is the west; wave height - $H = 1$ m; wave period - T=4s.

When performing calculations in the equations of motion of a mathematical model, an additional term corresponding to the energy dissipation due to wave embedding, when approaching the shore, is introduced [1]. Therefore, the amplitudes of the oscillations, of the elevation of the free surface immediately near the shore decrease. For the purpose of testing the model, algorithm and program, computation was made of the wave mode in deep water in the region under consideration of the same boundary conditions. The results of computation completely correspond to known analytical solutions [1,6] .

The results of the numerical solution of the model are shown in Figures 4-8.

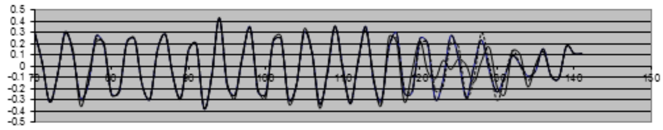

Fig. 4. Changes in the elevation of the free surface of the sea near the shore

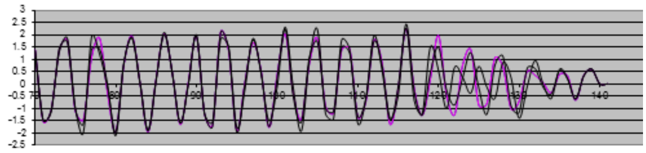

Fig. 5. Changes in the transverse flow near the shore

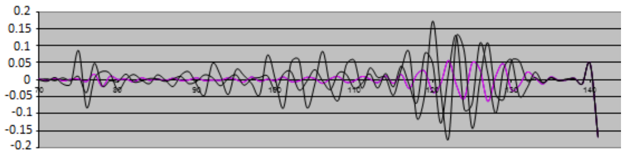

Fig.6. Changes in the alongshore flow near the shore

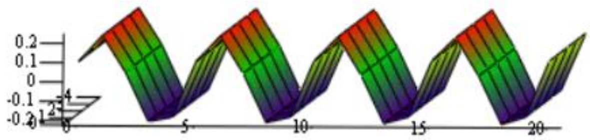

Fig. 7. Fragment of the wave pattern in deep water

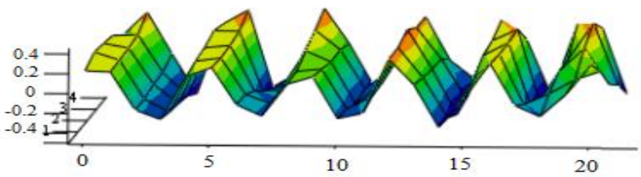

Fig. 8. Fragment of the wave pattern with the existing bottom profile

Figures 4 - 8 show the changes in the elevation of the free surface of the sea ξ (Fig. 4), the transverse q_1 (Fig. 5) and the alongshore flow q_2 (Fig. 6) of the flows in the region $(i = 70 \div 141,\ j = 1 \div 4)$ for the moments of time corresponding to phases - 180° and 225° of one wave period. In Fig. 4-6, the scale lengths along the vertical and horizontal lines are different, the length of the section for the range is 350 m.

CONCLUSIONS

A mathematical model of wave motions of the sea in the coastal zone of the Poti region of the Black Sea has been developed. To solve the basic equations of the model, the finite element method is used. When solving the Cauchy problem, we use the finite difference method and the Crank-Nicolson scheme. A program was developed for the numerical solution of the equations obtained. As a result, changes in the height of the free sea surface ξ, transverse flow q_1 and alongshore flow q_2 were obtained. For the purpose of testing the model, algorithm and program, computation was made of the wave mode in deep water in the region under consideration of the same boundary conditions.

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Hydrology and meteorology

CREATION OF AN IRRIGATED BIOENERGY AGROECOSYSTEM IN THE DRY STEPPE OF UKRAINE

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Annotation. The potential of a basic enterprise in the Dry Steppe zone of Ukraine for creating an irrigated bioenergy agroecosystem and proposing promising agricultural production systems is investigated. The relevance of the study is explained by rising temperatures and water shortages. The methods used include analysis and modeling of enterprise development options. The results indicate the possibility of producing more products and offer balanced options for the production of plant and animal food, industrial raw materials and bioenergy. The study uses a combination of different methods, from general scientific to special methods, such as hypothesis, observation, analysis, synthesis, as well as field data and analytical methods. Dispersion, correlation, regression, and variation methods of analysis, as well as the method of multivariate computer simulation modeling, were used. To model the development options, the parameters of the enterprise's production activity, climate change trends, and agrometeorological resources of the region were analyzed. With the help of multivariate computer simulation, the author proposes the principles of forming a balanced production of plant and animal food, industrial raw materials and bioenergy on the example of 11 models.

Keywords: agroclimatic resources, agricultural production, bioproductivity potential, development scenarios.

INTODUCTION

The main task of each agroecosystem is to ensure the food security of the state while preserving the environment. Given that the agroecosystem is a set of abiogenic and biogenic components that interact with each other in a certain territory, it is advisable to model the options for the development of the sectoral structure of agricultural enterprises by region in order to find and establish a rational combination of sectors, optimal use of available resources, further forecasting of performance and ensuring their sustainable development. The expediency of the modeling carried out in this paper on the example of a basic farm in the Dry Steppe zone of Ukraine is explained by the development of management decisions before the actual implementation of complex systems for which physical (natural) experimentation is difficult or even economically unprofitable. The purpose of this study is to propose promising systems of agricultural production for the State Enterprise "Andriivske" in Bilhorod-Dnistrovskyi district of Odesa region with the restoration of reclamation systems, balanced transformation of biomass into energy resources, high-quality and affordable food, raw materials for technical needs and organic fertilizers. To achieve this goal, the task was also to determine the organizational and economic conditions for achieving high economic efficiency, environmental sustainability and social attractiveness of this agricultural enterprise.

Analysis of recent research and publications. Promising options for the development of the sectoral structure in the steppe zone should be developed taking into account the availability of significant thermal resources with a tendency to their growth [1]. Under these conditions, the main factor limiting the productivity of agricultural land is moisture conditions [2]. At the same time, the production costs of irrigation are quite high and, depending on the cost of water, electricity, the condition of the irrigation system (depreciation) and other components, can reach 1 thousand or more USD per hectare [3]. Therefore, in order to obtain acceptable economic indicators for sprinkling, it is necessary to have a high level of agricultural technology and crop yields: winter wheat - at least 6 t/ha, corn - 7 t/ha, soybeans, rapeseed, sunflower - 3 t/ha, tomatoes - 60 t/ha [4].

Intensive drip irrigation technologies provide an average 5-fold increase in the productivity of vegetable and melons and potatoes, 3.4-fold increase in corn, 2.2-fold increase in soybeans, 2.4-fold increase in sugar beet, and almost 4-fold increase in medicinal raw materials compared to rainfed growing conditions [5]. The net profit can reach 700 or more USD/ha. In addition, it may be economically feasible to grow vegetables, industrial hemp, a number of medicinal plants, tobacco, lavender, rose essential oil, etc. [6,7,8]. On the other hand, the construction or reconstruction of irrigation systems requires significant capital expenditures, which can reach 2-3 thousand USD/ha [9]. Therefore, with a purely crop-based industry structure and the current practice of grain production, it is problematic to restore irrigation systems. This is due to the rather long payback period of the attracted financial resources, in particular during the period of establishing the effective operation of the reclamation system [10]. In such circumstances, agricultural producers are looking for more appropriate and economically attractive areas. For the most part, this process is realized intuitively, based on existing experience or accidentally obtained information. In addition, the management staff of agricultural enterprises, as a rule, focuses on the current elements of technological processes in the production system without analyzing the prospects for their development based on long-term planning with high accuracy and predictability. As a result, a narrow sectoral focus is usually not sufficiently justified for economic, environmental and social reasons. Therefore, in the irrigation zone, the development of agricultural production systems that will ensure the transformation of bioproductivity potential into products with a high level of liquidity and profitability is currently relevant.

MATERIALS AND METHODS OF RESEARCH

The object of research is the State Enterprise "Experimental Farm Andriivske" of Bilhorod-Dnistrovskyi district of Odesa region, which is part of the National Academy of Agrarian Sciences. The area of arable land in the enterprise is 5124 hectares. Climate change in the region was assessed by the indicators of average annual and monthly air temperature, precipitation, hydrothermal coefficient (HTC), standardized precipitation index (SPI), and climate water balance (CWB). Computer multivariate simulation modeling was carried out using the Agroecosystem program module of the Agroresources complex. The following options for enterprise development were considered:

Model №1 - "Modern practice without irrigation".
Model № 2 - "Model № 1 + processing of livestock products".
Model №3 - "Model №2 + cow productivity of 10 thousand liters of milk".
Model № 4 - "Model № 3 + cattle density of 0.4 head/ha".
Model № 5 - "Model № 4 + cattle density 0.6 head/ha".
Model №6 - "Irrigation of 3030 hectares - sunflower, soybeans, corn".
Model №7 - "Model №6 + maximum possible cattle density".
Model №8 - "Model №7 + biogas plant".
Model №9 - "Model №8 + sugar beet".
Model №10 - "Model №9 + irrigation of 5124 hectares".
Model №11 - "Model №10 + organic farming"

The economic efficiency of the models was determined by the following indicators: capital expenditures for infrastructure, technological production costs, gross income from the sale of products, and net profit.

RESEARCH RESULTS

With the systematic increase in temperature in most agricultural areas of Ukraine, moisture conditions are deteriorating, which is accompanied by a decrease in the sustainability of agriculture. This is especially true for the southern regions, in particular the Dry Steppe of Ukraine. Compared to 1961-1990, in 1991-2021, the average annual air temperature in this area increased by 1.3°C. The average annual precipitation for 1961-2021 in the southwestern part of Odesa region was 497 mm. Generalized data indicate that sustainable high-performance agricultural production in Ukraine is possible when this indicator is at least 600 mm. This amount of precipitation has been observed in the region over the past 30 years in only four cases, i.e. with a probability of only 13% or once every 10 years. At the same time, a steady increase in temperature leads to increased evaporation with a constant deterioration in moisture conditions. One of the main indicators for assessing moisture supply, which takes into account precipitation and temperature, is the Selyaninov hydrothermal coefficient (HTC). If in 1961-1990 the average value of the HTC was 0.87, in 1991-2021 it was 0.74, i.e., it decreased by 15%, while the amount of precipitation for the specified period decreased by 10%.

Another common indicator of precipitation and drought assessment recommended by the WMO is the Standardized Precipitation Index (SPI). This indicator is calculated over a long period of time in the context of a one-month or more interval. Usually, one-, three-, six-, and twelve-month intervals are used. A monthly assessment of moisture conditions throughout the year using the SPI index shows a significant decrease in cases of extremely wet conditions (by 63%) and a 2.5-fold increase in cases of severe drought. Given global and regional climate change, which is accompanied by a deterioration in the moisture supply of Ukraine, the main measure is the artificial regulation of the water-air regime using reclaimed systems. In this case, we are talking about the Bilhorod-Dnistrovska irrigation system, which includes a diversified agricultural enterprise whose land was formerly irrigated. This land use is currently undergoing the restoration of on-farm irrigation infrastructure. Optimization of moisture conditions will significantly increase the productivity of arable land, and the introduction of a bioenergy system of agricultural production will be accompanied by a dramatic increase in the efficiency of the use of existing agricultural resource potential.

Numerous options exist for enhancing the production structure of the Andriivske farm. Yet, the proposed considerations offer insight into the capabilities of modern information technologies, notably, operational multivariate computer modeling of agricultural production systems. These technologies provide an objective assessment and facilitate comprehensive solutions to three primary objectives: significantly boosting enterprise profitability, achieving ecological balance within the agroecosystem, and enhancing the quality of life for rural inhabitants.

Model №1. In the structure of the company's sown areas, the share of winter cereals in the last 5 years has fluctuated between 35-50% and sunflower - 25-35% and the rest are other crops. Comparison of these indicators with the average regional indicators shows that the current practice of agricultural production of individual agricultural enterprises differs little and is characterized by the use of crop rotation: 1, 2 - winter cereals; 3 - sunflower; 4 - legumes and other crops. This is due to the high risks of obtaining a positive effect when growing corn, soybeans, vegetables, and rapeseed in conditions of unstable moisture. Winter cereals make good use of autumn and winter precipitation, while sunflower is resistant to moisture deficit and is almost always profitable even with low yields. As the heat regime warms up, winter peas and rapeseed could be promising. Yields of winter wheat and barley at Andriivske ranged from 12.7 to 40.7 c/ha and averaged almost 29 c/ha, including winter wheat - 13.9-46.8 with an average of 38 c/ha, sunflower - 4.0-15.7 with an average of 11.9 c/ha, peas - 4.8-23.1 with an average of 10.9 c/ha.

Currently, in order to provide a dairy herd of 80 cows with a productivity of 4 thousand liters of milk per year with the appropriate number of calves and heifers with the necessary amount of feed at an average yield of 120 c/ha of green mass over 5 years, 250 hectares of arable land must be used annually.

Model №2. According to the calculations, the existing cattle population allows us to produce more than 300 tons of milk and about 50 tons of live weight of fattened bulls and cull cows annually. As an example, it is assumed that the result of milk processing will be hard cheese with 30% fat content and cream with 20% fat content. If the fat content of milk is 3.5% and the distribution between cream and cheese is 1.2 and 2.3%, respectively, the output will be 21 tons of cream and 27 tons of cheese. The production of beef and veal will be 20 tons.

Model №3 - "Model №2 + cow productivity of 10 thousand liters of milk". To reach the level of 9-10 thousand liters, the first condition is to purchase breeding stock or organize targeted breeding work. In addition, it is necessary to select special animal feeding rations. It should be borne in mind that if a dairy cow produces, for example, 4 thousand liters of milk per year, approximately 1 unit of feed is consumed per liter, if it produces 6 thousand liters per year, 0.8 units are consumed, and if it produces 10 thousand liters of milk per year, 0.6 units are consumed. For example, if the production target is 30 thousand tons and the animal productivity is 6 thousand liters, it is necessary to build a complex for 5 thousand heads of dairy herd, and if the productivity is 10 thousand liters, it is necessary to build a complex for 3 thousand heads. In general, an increase in the productivity of the dairy herd to 10 thousand liters of milk per year will increase milk production from 300 to 800 tons, cream yield will increase to 50 tons, and cheese to 60 tons.

Model 4. This scenario is considered to compare the profitability of crop and livestock production, prioritize livestock development, or create an irrigation system. If the funds allocated for the reclamation system are used to develop the dairy farming infrastructure, the number of dairy herds will increase to 830 heads. This will increase gross milk production to 8,000 tons, with a live weight of cattle reaching 280 tons and a yield of 500 tons of cream, 600 tons of cheese, and 100 tons of veal and beef.

Model №5. The scenario is considered to assess the possibilities of the maximum development of animal husbandry with regard to the potential of obtaining fodder from the entire area of arable land without irrigation. With the current yield of cultivated crops, the obtained biomass, provided optimal feeding rations of animals and their high productivity, will make it possible to maintain 1,200 dairy cows, 600 heifers and about 1,700 calves. Accordingly, it will be necessary to expand all components of the infrastructure: livestock farms and equipment, facilities for storing fodder and organic fertilizers, modules for processing raw materials, warehouses, etc. This will make it possible to transform plant biomass into 720 tons of cream, 910 tons of cheese, and 160 tons of meat at the final stage of the production cycle.

Model №6. This option is considered for the analysis of the effectiveness of the implementation of irrigation under the plant-based sectoral structure of agricultural production. According to "Irrigator Ukraine" LLC, which comprehensively designs and builds reclamation systems, the area of land suitable for irrigation in the enterprise is 3,030 hectares. It is believed that the most effective use of reclaimed land is possible with the help of a combined irrigation system: integration of sprinklers (2430 ha) and drip irrigation (600 ha). With sprinkler irrigation, the planned yield of corn is 10 t/ha, soybeans – 4 t/ha, sunflower – 3.5 t/ha. It is assumed that when using drip irrigation, the yield of these crops will be 1.5 times higher than with sprinkler irrigation.

Model №7. It is considered to determine the possibilities of expanding the livestock industry in accordance with the maximum production volumes of basic and concentrated fodder for both 3030 hectares of irrigation and 2094 hectares of rainfed land. As a result, the gross production of milk will reach 36 thousand tons, the live weight of cattle - 1260 tons. After processing, it will be possible to receive 2.3 thousand tons of cream, 2.9 thousand tons of cheese, and 500 tons of meat products annually.

Model №8. It is clear that for the load on 1 hectare of arable land, 3 conditional head of cattle will accumulate significant amounts of animal husbandry waste in the enterprise. If we assume that approximately half of the dry matter of fodder is transformed into manure, then taking into account the surplus of straw and the main fodder spoiled during storage (20%), its annual volume at 75% humidity will reach 130,000 tons or 26 tons/ha. 10-12 t/ha is enough to ensure a deficit-free balance of humus. On the other hand, fresh manure is a valuable raw material for obtaining heat and electricity. This option is being considered precisely to assess the feasibility of supplementing the infrastructure with a bioenergy complex. During gas generation, biomass will be transformed into 12 million m3 of biogas. When it is burned at a three-generation thermal power plant, 2.4 kWh of electricity and 2.8 kWh of electricity are obtained from each m3. heat or cold, and from all available energy raw materials, respectively, 30 million kWh of electricity and 35 thousand Gcal of heat. At the same time, approximately half of the dry matter of all waste remains undecomposed and will be used as an organic fertilizer (distate or biohumus) in which all the macro- and microelements removed from the soil are concentrated.

Model №9. The scenario is being considered to assess the feasibility of introducing sugar beets into the crop rotation and involving a mini-sugar factory in the infrastructure. The yield of this crop under drip irrigation exceeds 120 t/ha of root crops. For calculations, we assumed a productivity of 80 t/ha when using irrigation. At the fodder value of corn for silage of 0.18 c.units/kg, approximately 14 tons of c.units/ha will be obtained from 1 ha. Similar in total nutrition will be obtained from one hectare of ghee, pulp and molasses with additional sugar production. Therefore, this scenario provides for the involvement of 200 tons of root crops per day in the infrastructure of the sugar factory. This will make it possible to obtain 7.0-7.2 thousand tons of sugar in addition to the assortment provided by Model №. 8.

Model №10. This option envisages the extension of the reclamation system to all 5124 hectares of arable land at the expense of subsurface drip irrigation. Of these, 2200 hectares will be used for grain, 1644 hectares for fodder, and 1280 hectares for sugar beet. This will help expand the livestock feed base and increase the number of dairy cows to 6.7 thousand. Gross milk production will reach 65 thousand tons and live weight of cattle will be 2.1-2.2 thousand tons. It will be possible to produce 1.3-1.4 thousand tons of oil, about 12 thousand tons of sugar, almost 10 thousand tons of dairy products, and 0.8-0.9 thousand tons of veal and beef annually.

Model №11. If the above sectoral structure is implemented, only fats, proteins, and carbohydrates, which are mainly carbon, oxygen, hydrogen, and nitrogen (components of atmospheric air), will be removed from the enterprise with the finished product. Their content of mineral macro- and microelements is negligible, and almost all of them are returned to the soil with organic fertilizers after gas generation. For example, the recycling rate of phosphorus and potassium in such a production system will be 95 and 99%, respectively. In addition, perennial legumes will account for at least 20% of the sown area, which, given the nitrogen content of organic fertilizers, will ensure a significantly positive balance of this element without the use of mineral fertilizers. Crop rotation with optimal predecessors (the share of legumes soybeans and alfalfa is 30-35%), complete disinfection of all waste in the process of methane fermentation will be accompanied by a systematic improvement of the phytosanitary condition of the agroecosystem. This will make it possible to abandon mineral fertilizers and introduce a system of biological plant protection. Such a provision would make it expedient to make a transition to organic farming and production in general, with appropriate certification and labeling of the products. At the same time, certification and sale of organic products compared to standard technologies will significantly increase the profitability of agricultural production without additional capital expenditures.

Numerous options exist to enhance a company's production activities. However, the 11 selected models stem from years of experimental and theoretical research, modern technological advancements, and financial resource utilization. According to the State Statistics Committee, the average selling price of milk and live cattle weight over the past 5 years stands at $327 and $1215 per ton respectively, with costs at $1926 and $257 per ton respectively. Hence, dairy farming yields zero net profit. Crop production, based on average long-term yields, estimates profitability at $190 per hectare. Thus, with current practices (Model №1), the annual net income averages around 1 million currency units, serving as the benchmark for comparing more intricate enterprise development scenarios. According to Model №2, a module for processing milk with a capacity of 1 ton per day is required, which also involves the installation of a storage room with temperature control during the storage of finished products. The minimum capacity of the meat processing plant is 3-4 cattle per day. However, the maximum live weight gain at the enterprise was 28 tons in 2019, which makes the organization of meat processing impractical at this stage. Under this scenario, the estimated total capital expenditures for these components were assumed to be 100 thousand USD. It is estimated that 1.4 thousand USD per year is spent on keeping one dairy cow with a train. Taking into account the costs of milk processing, overhead costs and VAT, annual production costs will amount to 200-210 thousand USD, gross income from livestock farming will be 280 thousand USD, ensuring its profitability at the level of 70-80 thousand USD.

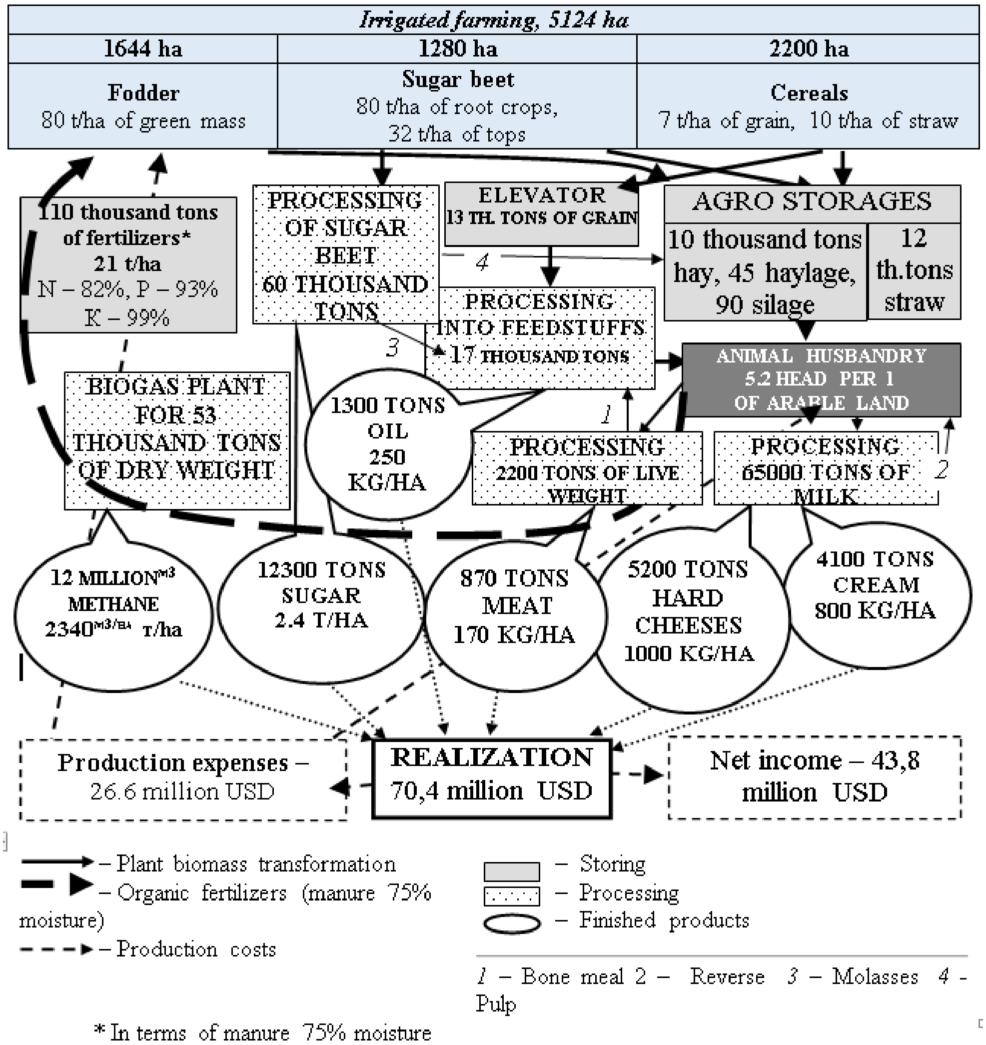

Fig. 1. Diagram of one of the promising options for the branch structure of Andriyivske State Farm

In order to significantly increase the productivity of the dairy herd, the financial costs for the purchase of 80 highly productive animals will be 220-225 thousand USD. Current production costs will remain at the level of the previous model - 2.4 million USD. At the same time, gross income from crop production will be 3 million USD and from livestock production - 0.6 million USD. Net profit will increase from 1.0 to 1.3 million USD or from 190 to 250 USD/ha. This demonstrates the economic significance of a significant increase in the productivity of the dairy herd (Model №3) - at relatively low costs, the profitability of production will increase by 50-60 USD/ha with a short payback period.

According to the business plan developed by Irrigator Ukraine LLC, almost 5.4 million USD will be required to create an irrigation system at SE Andriyivske on an area of 3300 hectares. This level of investment will allow to build a fully equipped cattle complex for 2 thousand head worth 2.6 million USD, purchase 850 heads of highly productive breeding cattle worth 1.6 million USD, supply modules for the production and storage of meat and dairy products with a capacity of 8 thousand tons of milk and 0.3 thousand tons of live weight of cattle worth 0.8 million USD, and build storage facilities worth 0.4 million USD. Sales of the products will bring in USD 7.7 million, while production costs will amount to USD 2.8 million. Thus, investing in dairy farming will increase net income to USD 4.8 million or almost USD 1,000/ha with a payback period of 2 years. If the livestock infrastructure is expanded in line with the current potential for plant biomass production (without irrigation), the economic performance of the enterprise can be improved to a greater extent (Model №5). Such a situation will ensure an increase in the profitability of the enterprise to the level of 6.3 million USD or 1230 USD/ha with a payback period of 2 years. Taking into account the investment of 5.4 million USD in the irrigation system (Model №6). Current annual costs for livestock production are about 200-220 thousand USD. On irrigation, the cost of corn at a yield of 110 t/ha is expected to be 146 USD. /t, soybeans at a yield of 4.0 c/ha - 349 USD/t, sunflower at a yield of 3.5 t/ha - 312 USD/t, winter grains at a yield of 3.0 t/ha - 146 USD/t, the selling price is expected to be 200, 470, 500 and 200 USD/t, respectively. With such indicators, the gross income of the enterprise will be 7.8 million USD, production costs - 5.3 million USD, net income - 2.5 million USD or 480 USD/ha, payback period of capital costs - 4 years. From the analysis, it can be concluded that, given the availability of financial resources at the level of 5.4 million USD, at this stage it would be more expedient to invest them in the development of livestock production with a profitability of 900 USD/ha of arable land and a payback period of 2 years. At the same time, investing in the creation of a land reclamation system will allow to receive only 500 USD/ha of net profit. If an irrigation system is created, the potential of the company's fodder base will allow it to keep 3.9 thousand dairy cows with a productivity of 10 thousand liters of milk with an average load of 3 conventional heads per hectare (Model №7). In other words, the cattle complex should be designed to keep 9.2-9.3 thousand conventional heads. The total capital investment for the creation of such infrastructure can be estimated at 36 million USD, including 5-6 million USD (15%) for the reclamation system, 11-12 million USD (31%) for the cattle complex, 7 million USD (20%) for the cattle herd, 3-4 million USD (9%) for the livestock products processing modules, and 9.0 million USD (25%) for the storage facilities for feed and organic fertilizers. Production costs are expected to reach 14-15 million USD, gross income will amount to 31-32 million USD, and the company's profitability will reach 17 million USD or 3-4 thousand USD/ha (previous version - 0.5 thousand USD/ha).

Such a system will accumulate approximately 140 thousand tons of livestock waste. The cost of the bioenergy complex of the above capacity will be quite high - at the level of 8 million USD. Its involvement in the infrastructure will increase gross income by 6.5 million USD, production costs for its maintenance will be approximately 0.1-0.2 million USD per year, which, together with other technological processes and expenditure items, will amount to 14.6 million USD. As a result, the profitability of the enterprise will increase to 23.2 million USD or 4.5 thousand USD/ha Model №8.

Involvement of sugar beet in irrigated crop rotation will require the construction of a sugar factory with a capacity of 60 thousand roots per year (Model №9). With a sugar content of 12%, the volume of sugar production will be 7.2 thousand tons worth 3.3 million USD. In general, the gross income of the enterprise will reach 45 million USD, production costs will amount to 17 million USD, and net income will be 28 million USD or 5.4 thousand USD/ha.

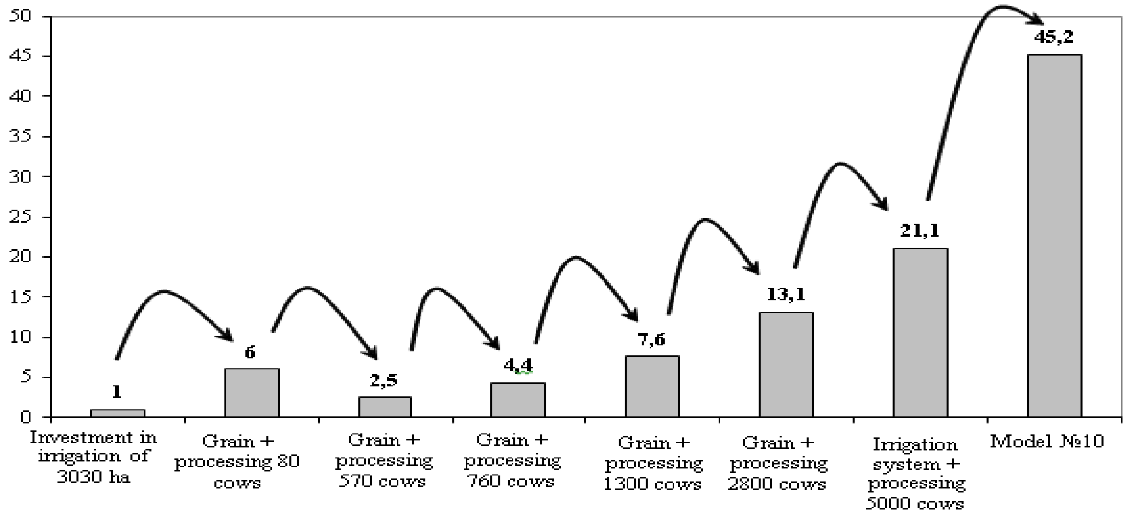

Fig. 2. Targeted use of net profit for the development of the company's infrastructure

Next year, the further development of livestock production at the expense of net profit should be aimed at increasing the dairy herd by another 760 heads with a net profit of 7.7 million USD. In the future, the number of cows can be expected to increase to 2.6 thousand heads with the company's profitability at the level of 13 million USD. These funds will be enough for a drip irrigation system on an area of 2094 hectares, as well as storage facilities for feed and organic fertilizers. As a result, the scenarios envisioned in Models №10 and №11 will be put into practice.

The paper also considers Model 11 of the formation of an organic agricultural production system on the basis of the Andriyivske farm. The calculations were based on retail prices in the Natur Boutique organic store chain, excluding the trade margin: meat - 5.9, sour cream - 3.0, 45% cottage cheese - 12.1, sugar - 1.5 USD/kg, oil - 5.2 USD/kg. If the planned production volumes of these products are realized at these prices, the net income can reach more than 8 thousand USD/ha without additional capital expenditures. There is an alternative option. Assuming that the enterprise manages to establish an efficient irrigation system and launch a mini dairy and meat processing plant, this would be accompanied by an increase in its profitability to 2.5 million USD or 480 USD/ha. With the targeted use of these funds, next year it will be possible to increase the dairy herd by 350 heads with a corresponding increase in livestock processing capacity. The following year, their implementation will allow to receive more than 4 million USD, which, together with grain and oil, will provide a gross income of 10 million USD. Production costs for growing grain, keeping animals and processing products will amount to 5.8 million USD with an increase in the company's profitability to 4.4 million USD and a payback period of 1 year.

CONCLUSIONS AND RECOMMENDATIONS

It's been found that without irrigation, high temperatures and increased evaporation prevent realizing crop productivity potential. Multivariate computer modeling is essential for optimizing resource combinations, including chemical and biological elements. Therefore, to enhance the production structure of the State Enterprise "Andriivske" farm in the Dry Steppe of Ukraine, options were proposed and elaborated through 11 models. One model focuses on developing a bioorganic farming system, minimizing agrochemical use and emphasizing environmental labeling for top-quality, low-carbon products. Developing reclaimed areas in the Dry Steppe Zone for bioenergy agricultural production can integrate crop and livestock products, technical materials, and bioenergy. Around $80 million is required to establish a highly efficient bioenergy production system, with an expected profit of $9-14 thousand per hectare and a 2-year payback period. Developing the production system's profitability through reinvested profits is estimated to take 8 to 10 years. An analysis of the enterprise's resource potential using computer modeling helps to identify internal production reserves.

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Environmental Protection

DETERMINATION OF HEAVY METALS IN SURFACE WATER AND SOIL ADJACENT TO INDUSTRIAL REGION

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Annotation. The paper discusses the impact of mining and processing production on the environment, using the example of the Kazreti deposit. A 6-month cycle of conducted studies and presented 4 heavy metal content in both water and soil samples.

The results of the analysis show that the content of heavy metals (Cu, Pb, Cd Zn) is significantly increased compared to their background content and is also much higher than the maximum allowable concentration.

Keywords: ore, pollution, heavy metal, water, soil.

INTRODUCTION

According to the World Health Organization, an ecosystem is considered polluted if, as a result of human economic activities, its composition changes to the point that it becomes less favorable for plant and animal organisms.

Industrial enterprises release millions of tons of heavy metals into the ecosystem every year, which, according to the intensity of their entry into the environment, form the following order: Cu, Pb, Co, Fe and Zn. From 1980 to the present, more lead has been released into the atmosphere by industry and motor vehicles than during the rest of history. All existing natural sources of pollution (volcanoes, forest fires, etc.), in comparison to human activities, have moved to the second place, since they emit 18.3 times less lead, 8.8 times less cadmium, 7.2 times less zinc [1].

The intensive extraction of useful minerals pollutes the environment so much that the food products grown on the surrounding soils are often very harmful to the human body.

MAIN PART

From this point of view, one of the most important deposits in Georgia is the Kazreti deposits, which are located in the Bolnisi region, on the right and left banks of the Mashavera River. These copper-containing sulphide deposits, which are developed in an open-pit manner, cause intense environmental pollution with toxic metals [2].

Dozens of studies show that soil and water pollution in this region has been significantly higher than normal for years. The polluted Kazretula River contains a large amount of such harmful elements as: cadmium, lead, copper, zinc, iron, nickel, manganese and arsenic. Among the elements mentioned above, three are particularly noteworthy: cadmium, lead and arsenic, which have a harmful effect on the human body. Horticulture is developed in the region, and Mashavera and Foladauri rivers polluted by production waste are used in the reclamation system. Vegetables absorb a large amount of cancer-causing heavy metals - lead and cadmium. This problem poses a great threat to both local and urban populations that are supplied with these vegetables. In the vicinity of the enterprise there are agricultural fields where vegetables and grain crops are grown, it is known that vegetables are particularly sensitive to heavy metals and absorb them directly [3;4].

The agricultural plots of Kazreti, Javakhi-Ratevani, Rachisubani, Mtsneti, Khidiskuri and Nakhiduri villages were selected as test sites. We took soil samples from the territory of the villages: Ratevan, Nakhiduri and Balichi and determined the content of copper, cadmium, zinc and lead in them. The obtained results are presented in Table 1.

Table 1

Soil analysis results

Village	Cu, mg/kg	Cd, mg/kg	Zn, mg/kg	Pb, mg/kg
Ratevani	1735	117	5565	9
Nakhiduri	222	35	3765	15
Balichi	101	43	163	18

During the experiment, chemical analysis of irrigation water was carried out systematically. The obtained results are presented in Table 2.

Table 2

Results of river water analysis

River	Place of sampling	pH	TDS, mg/l	Cu, mg/l	Cd, mg/l	Zn, mg/l	Pb, mg/l
Kazretula 50 m from dam	March April May June July August	7,8 7.9 8.2 7.5 7.6 7.7	1600 1200 980 885 1005 989	1.3 1,5 1.4 0.99 1.7 1.6	8,9 9.2 9,3 9.1 9,3 9,3	324 320 335 340 327 317	0.04 0.035 0,024 0.025 0.04 0.04
Mashavera	March April May June July August	7.7 6.8 7.1 6.7 7.2 7.9	880 970 794 875 990 890	1.5 1,8 1,3 1,7 1,6 1,6	0.3 0.2 0.3 0.3 0.2 0.2	25.5 23.5 26 24.8 24,3 25.1	0.001 0,001 0,002 0,002 0,002 0,002
Mtskneti irrigated water chanel	March April May June July August	6.7 6.5 6.7 6.8 6.5 6.5	960 899 930 920 940 970	0.3 0.25 0,34 0,4 0,36 0,4	0.05 0.035 0.04 0.04 0.05 0.05	1.7 1.1 1.8 1,5 1.7 1.6	0,001 – – – 0,001 0.001
M. A. C.	–	–	–	0.001	0,005	1	0.1

CONCLUSION

The paper presents the results of the research conducted in Bolnisi region, in particular in the area polluted by the influence of the Kazreti field. In particular, the results of soil analysis of some Bolnisi villages and the water analysis of rivers Kazretula, Mashavera and irrigation canal are presented.

The results of the analysis show that the content of heavy metals (Cu, Pb, Cd Zn) is significantly increased compared to their background content and is also much higher than the maximum allowable concentration.

Taking into account that the mentioned surface waters are used for irrigation of agricultural fields, we continue our research in the direction of studying vegetable crops.

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Hydrology and meteorology

SCIENTIFIC RECOMMENDATIONS FOR PROTECTION AGAINST CAUSES OF THE NATURAL EVENTS THAT OCCURRED IN TSALKA REGION ON JUNE 8-12, 2023

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Annotation. The paper presents the causes of the devastating natural disasters that occurred in the Tsalka region on June 8-12, 2023, and based on the results of field reconnaissance and camera work carried out by the authors, relevant scientific recommendations for mitigating the damage caused by natural disasters are presented.

On the river Ktsia is calculated the maximum cost of the predicted flood on the site with a recurrence of 100 years, which should be taken into account when designing and constructing hydrotechnical structures on it.

Keywords: flood, flood, catastrophic water consumption.

INTRODUCTION

Recently, in many countries of the world, including Georgia, the number and scale of destructive natural events has increased significantly. The facts of floods, landslides and mudslides are especially frequent, which cause great damage to the economic and ecological situation of the countries, and human casualties are also frequent [1].

This year, almost all regions of Georgia have experienced several devastating natural disasters that have caused great damage to the country and, what is most alarming, have claimed the lives of dozens of people. The natural events that happened in Tsalka region on June 8-12 were catastrophic, the main cause of which was a large amount of precipitation in the form of rain. It continued with variable intensity for several days, which caused devastating floods and landslides as the river. on Ktsia, as well as on its first and second order tributaries or ravines.

MAIN PART

In order to determine the causes of the natural disaster and mitigate its devastating consequences, we carried out field reconnaissance work in Tsalki municipality. As a result of field studies, many important problems caused by natural disasters were revealed. River Ktsia swelled as a result of havey rainfall. The river completely destroyed the bridge which built in the middle ages and become inoperable Kushi-Artsivani-Avralo highhwey (photo1). Also village In Avranlo, it overcame and in some sections breached the embankment reinforced with concrete blocks on the right bank (about 100 m long), while the river crossing from the left bank changed its bed and currently flows through the homesteads of the population.

Photo 1. Destroyed river on the river Ktsia and Kushi-Arwivani-Avralo highway which left nonfuction

Left tributary of Ktsia, river Gumbati was destructive for village Gumbati. River damaged the embankment stone gabion on the left bank of the road bridge on the road connecting to the district center. Disrupted and rendered it inoperable, the flow of water damaged the left abutment of the aforementioned bridge, in particular, partially washing it away and making it unsafe to travel on the bridge. Also, the water and sediment overflowing from the bed blocked the road connecting Ashkala-Gumbati villages and agricultural fields were destroyed.

The disaster also damaged the bridge on the road connecting Rekha-Khando villages. The swollen Gujarati river washed away its right footing and threatened the operation of the bridge. It also damaged the right retaining wall, moved from its bed and flooded the farmsteads, agricultural fields of the villagers and killed the poultry and livestock.

River Saponauri which is the left side tributary of river Gujareti, divdides the village Rekha into the almost two equal part, caused great damage to the villagers and the administrative infrastructure. The river swelled as a result of intense rain, carried a large volume of inert material and wood, which could not be safely transported by the bridge of internal importance of the village, rose from its bed and flooded the residences and auxiliary buildings of the surrounding population, farm plots, destroyed crops and killed domestic animals and birds (photo 2).

Photo 2. River bad was filled by a river Saponauri as a result of flooding in village Rekha

Rainfall of a large volume and intensity in the villages of Arsivani and Kizil-Kilisa caused a large volume of surface runoff. The torrential rains on the highways damaged the road surface, making it impossible to move on the roads connecting the villages of Kizil-Kilisa and Tabatzkuri (about 2 km) and internal (total length of about 1 km).

We calculated the river. Ktsia, village Maximum expected flood cost up to Kush Bridge. For which V.I. was used. The formula proposed by Rostomov [2].

$$Q = 1{,}5\left[\frac{\Omega^{0.56}\times K^{1.55}\times \tau^{0.88}\times \bar{I}^{0.125}}{(L+10)^{0.44}}\right]\times \Pi \times \sigma \times \lambda \ (m^3/s) \quad (1)$$

Where ,

Q is The maximum cost of exploration water;

$\boldsymbol{\Omega}$ - Area of the catchment basin;

K - Climatic coefficient;

$\boldsymbol{\tau}$ - Insurance ratio (in our case, 100 years);

$\bar{I}$ – Water catchment area;

L – Length of the catchment basin bed;

Π - Soil characteristic parameter;

$\boldsymbol{\sigma}$ - Shape coefficient of the catchment basin;

$\boldsymbol{\lambda}$ - Coefficient of the watershed.

As a result of the relevant hydrological report, the maximum consumption of 1% water supply was determined for the river. in Ktsia, near the Kush hydro-station, which amounted to $Q_{1\%} = 175$ (m^3/s).

As a result of the analysis of the natural events (flood, landslide) that occurred on June 8-12, 2023 in Tsalka region, the negative results caused by it, field reconnaissance works and camera calculations, we can present the following scientific recommendations.

1. The collapse of the bridge built in the middle ages near Village Kushi was caused by the flooding by river Ktsia.
2. The bridge on the river Gumbati, which is located between in the village Gumbati, and the district center is in an emergency condition and needs rehabilitation works. The dangers on the bridge were caused by the overflowing river. The failure of the stone gabion built in 2016 by the Gumbati in the upper side of the bridge, during the construction or design of which the hydrological data of the river and the peculiarities of the bed were not taken into account. In order to protect the foundations of the bridge, it is necessary to build a new protective wall, the hydrological regime of the river and the depth of washing of the bed will be taken into account during its design. Here, in the lower section of the bridge, the river makes a left turn and loses speed, due to which inert material is intensively deposited in this section and, accordingly, the level of the bed bottom increases. Due to this, the existing concrete protective wall is almost completely covered, which no longer fulfills its function. It is necessary to periodically clean the bed or build a new wall to protect the existing population and homesteads, which may be in danger in the near future [3].
3. The river Gumbati created a danger to the road connecting Ashkala-Gumbati villages at the exit of the village of Gumbati. The swollen river carried a large amount of inert material accumulated in its bed, mainly boulders and large stones, which were deposited and suspended as it approached the village, where the river bed slope decreases and the water velocity and energy decrease accordingly. It was the sedimentation of the transported inert material in the bed that caused the bed to sink, as a result of which the river flowed out of the bed and made several branches, thereby damaging the surrounding area as well. Despite the fact that due to the relief conditions in this place it is difficult to carry out bed cleaning works using machinery, it is still necessary to periodically clean it and return the river to its original bed.
4. The swollen river Gujarat threatened the right footing of the bridge on the road connecting Rekha-Khando villages. The reason for this is that the foundation concrete wall, which has been out of order since 2016, is not functioning at all, and the temporary stone pile embankment built in its place could not adequately protect the foundation of the bridge and posed a threat to the operation of the bridge. It is necessary to arrange the protective walls of the bridge bases, the parameters of which will be calculated taking into account the hydrological regime of the river and the depths of washing the bed.

5. Village Rekha - ტhe main reason for the damage caused by the flood of river Saponauri is the construction of a new bridge over it in 2020 on the territory of the village and the reconstruction of the bed. In our opinion, the new existing bridge was built without considering the hydrological regime of the river. The swollen river, due to its nature, carried a large volume of inert material and timber. Depending on the property, a large volume of inert material and timber was taken. When entering the village area, where the slope of the bed decreases, sedimentation of inert material took place in the bed and, accordingly, its cross-section decreased, and the transported logs and branches got stuck under the bridge, the carrying capacity of which is artificially reduced. As a result, the river Saponauri rose from its bed near the bridge and flooded the surrounding area and the population. It is necessary, taking into account the hydrological regime of the river, to determine the overall dimensions of the bed in the village and arrange it accordingly, as well as to reconstruct the above-mentioned bridge and increase its carrying capacity [4.5].
6. Village Avranlo damage caused by Ktsia was mainly caused by the inert material filling of the mdianari bed over time. It is necessary to carry out cleaning works (deepening of the bed) of the river bed on the territory of the village, as well as rehabilitation of the damaged right embankment wall and construction of the left embankment wall.
7. High-intensity precipitation in the villages of Arsivana and Kizil-Kilisa produced a large amount of surface runoff, and given that there is no drainage system on the highways, or it is out of order, it was concentrated on the roadway. The surface water flow was so strong that it damaged and bent the carriageway on steep sections of the road, and deposited entrained road pavement and inert material on less steep sections of the road. Due to this damage, it became practically impossible to move on these sections of the highway. On this and other similar sections of the road, it is necessary to arrange a drainage system taking into account the quantitative characteristics of surface runoff.

CONCLUSION

Based on the results of our field research work and calculations, it is possible to conclude that the main cause of the damage caused by the natural disaster that occurred in the Tsalki region on June 8-12, 2023 is the failure of the coastal protection and infrastructural facilities, which is mainly caused by the incomplete rehabilitation of the amortized and damaged protective structures, and in some cases by their incorrect design and construction. It is these problems that manifest themselves acutely when rivers and ravines overflow, and in the case of their critical costs, we get tragic and destructive results.

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Construction

GREEN BUILDING CERTIFICATION: BASIC ASSUMPTIONS AND SELECTED APPLICATION RESULTS

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Annotation. Human activity, since the industrial revolution, has contributed to very adverse changes in the natural environment. This is especially true in urban areas. and industry. Aware of the threats to our civilization, scientists, universities and institutions point to the need to introduce sustainable development. Successively, also in the European Union, regulations are being introduced to contribute to the gradual improvement of the natural environment. These activities also assume the creation of more and more friendly living and working conditions for people. In the area of construction, the principles of creating green buildings and green infrastructure with a minimized impact on the natural environment are being introduced. This is related, m.in other things, to the fact that the construction industry is responsible for about 39% of global CO_2 emissions (28% from operating emissions, energy needed for heating, cooling and powering them, and the remaining 11% from materials and structures). Construction consumes 50% of the world's natural resources.

Sustainable development of civilization will be possible with an increase in energy demand in construction. At the same time, this must be accompanied by a gradual reduction in the rate of CO_2 and other air pollutant emissions, improvement of the comfort of building use and ensuring environmental safety. It is necessary to reduce and rationally use water, collect and use rainwater, increase the area covered with vegetation around and on buildings, take care of reducing the amount of waste and its proper processing.

One of the ways to promote and implement sustainable development in construction is to carry out assessments of buildings and various technical infrastructure accompanying buildings, according to the principles of green building certification. Such building rating systems have been developed in several countries and are used in many countries. These are not systems required to be used obligatorily, but only at the request of the investor or building manager. However, they often form the basis for the creation of selected legal regulations.

In Poland, regulations are being developed to stimulate the processes of implementing sustainable, green buildings. The article presents selected certification principles and the results of their application. Georgia, like other countries, is also making efforts to implement energy-efficient, ecological, green buildings with biologically active areas in the building structure.

***Keywords**:* green buildings; sustainable buildings; sustainable development; green certification

INTRODUCTION TO GREEN BUILDING CERTIFICATION

Green building certification, combined with such terms as: Green Construction, Green Building, Sustainable Building, is designed to promote architectural, structural, installation, technological and organizational solutions that are friendly to people and the natural environment. It is made voluntarily, at the request of the property owner or his manager, in order to check whether the design assumptions have been achieved or at what level they have been achieved. Often, the assessment of a building must take into account the full technical life cycle of the building. Starting with the materials used for construction, as far as possible, ecological, and ending with the demolition of the building after the end of its assumed service life and possible reuse or disposal of materials from demolition.

This action, if taken on a large scale, together with other pro-ecological activities, should contribute to reducing the negative impact of construction on the environment. Of course, a positive effect from such facilities can be achieved if their users maintain appropriate rules for the organization and operation of these facilities. To a large extent, maintaining the appropriate parameters of energy efficiency, ecology, comfort and others, originally assumed in the project, depends on the awareness and responsibility of people using such buildings.

Selected guidelines and components of sustainable construction:

- minimization of energy consumption, zero emission, close to zero emission of CO_2 and other gaseous pollutants;
- efficient use of renewable energy, water and other raw materials in the construction and operation of buildings;
- minimization of waste generation and pollutants discharged into the environment, minimum burden on the natural environment;
- avoidance of environmentally harmful materials;
- ensuring the health of buildings, or rather creating conditions conducive to the health and proper physical and mental condition of their users, i.e. minimizing the potential of harmful factors for the health of users;
- protecting the health of users and improving the work efficiency of employees, teaching school and university students, etc.
- location of buildings integrated into the surroundings, not disturbing the landscape.

Figure 1 presents the most popular green certification system for buildings, with their assignment to the country in which the system was created.

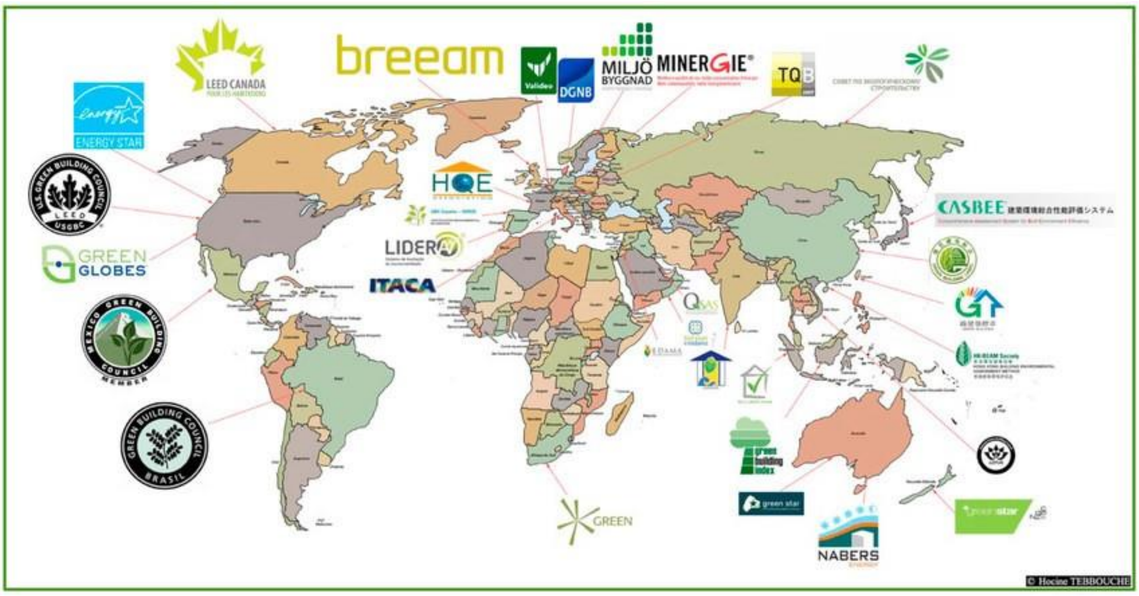

Fig. 1. Green certification schemes indicating the countries in which they have been established [1]

As Green building certification schemes typically take into account partial assessments such as energy efficiency, water savings, acoustic comfort, indoor lighting and air quality, and the use of vegetation. Certification schemes often have different rules and requirements, so it is difficult to compare them with each other.

Table 1 lists the world's best-known green building certification schemes, along with the date they were established and the country(s) in which they were developed. The most popular ones are marked in bold.

Table 1

Names of the main green certification system for buildings, including the date of their establishment and the country/s where they were introduced

Name of the green building certification system	Year of creation of the system	Country of creation of the system
BREEM	**1900**	**Great Britain**
HQE	**1995**	**France**
LEED	**1998**	**USA**
ESCALE	1998	France
ECO QUANTUM	1998	Netherlands
ECO EFFECT	1998	Sweden
ECO PROFIL	1998	Norway
Minergie	1998	Switzerland
NABERS	1999	Australia
CASBEE	2001	Japan
Green Star	2003	Australia
Green Globes	2004	USA
Nordic Swan	2005	Nordic coutries
LBC	2006	USA
DGND	**2007**	**Germany**
WELL	**2014**	**USA**
Active House	2017	Denmark

Table 2 lists the Polish green building certification schemes, with the date of their establishment. Polish ecological certification systems for buildings are not as popular as others, but their creation is a testimony to the fact that there is a lot of interest in this problem and a desire to create their own certification systems.

Table 2

Names of the Polish green certification system for buildings, including the date of their establishment

Name of the green building certification system	Year of creation of the system
E-Audyt	2002
ECO-ITB	2009
GBS - Green Building Standard	2017
Zielony Dom (Green House)	2021

The Intergovernmental Panel on Climate Change believes that the human impact on the Earth's climate is obvious, and that recent anthropogenic greenhouse gas emissions are the highest in its history. Climate change will significantly increase the current threats to both the environment and humans. The scale of the damage caused by climate change will depend on the extent and quality of the international community's response to the process. Climate change mitigation action is urgent and necessary to contain climate change as much as possible and reduce existing environmental and social risks.

The latest report by the World Meteorological Organization indicates that we are halfway through the implementation of the 2030 Agenda for Sustainable Development. Only 15% of the Sustainable Development Goals (SDGs) have been achieved and the global climate goals are still far from being achieved. The 2022 SDG report highlights the increasing impacts of climate change and extreme weather events, as well as other interrelated global challenges that hamper development benefits and jeopardise the full achievement of the SDGs by 2030 [1]

Unfortunately, the realistic assessment of progress in achieving the Sustainable Development Goals in the 2023 report shows significant problems. Of the approximately 140 targets that can be assessed, half of them show moderate or severe deviations from the desired trajectory. Moreover, more than 30% of these targets have made no progress or, worse still, have regressed below the 2015 baseline. This assessment highlights the urgent need to step up efforts to ensure the implementation of the SDGs and progress towards a sustainable future for all [2].

Sustainable development efforts need to be stepped up worldwide, including in Georgia. Significant climate changes have been observed in its area, which have led to many negative effects. In the years 1986-2015, compared to the years 1956-1985, the average annual air temperatures increased almost throughout the country by about 1°C [3].

The average area air temperature in 2023 in Poland was 10°C and was as much as 1.3 degrees higher than the annual long-term average (climatological normal period 1991-2020). The year 2023 should be classified as an extremely warm year, taking into account the average for Poland. Analysis of historical series shows that since 1851, air temperature in selected large cities in Poland has increased by 1.5°C to 2.3°C. It should be emphasized that over the last 40 years, the rate of temperature increase in large urban agglomerations has increased significantly. The average total precipitation in 2023 in Poland was 656.2 mm, which was nearly 107.3% of the norm determined on the basis of measurements in the years 1991-2020. In 2023, precipitation was characterized by strong spatial differentiation. Average area annual totals ranged from over 330 mm to over 1900 mm. In relation to the multi-year norm (1991-2020), precipitation in 2023 ranged between 80% and 130% of the norm [4].

The World Green Building Council points out that cities must first strive to reduce global carbon emissions. This is because half of the world's population lives in cities, accounting for more than 70% of CO_2 emissions. Buildings are the biggest contributors to urban emissions, accounting for 50-70% of urban emissions and 38% of global emissions. About 75% of building emissions are operational emissions generated by building systems (e.g. heating, ventilation and air conditioning, lighting and others). The remaining 25% are embodied emissions, i.e. carbon dioxide generated during the production of building materials, construction and interior design of buildings [5].

Areas and surface overgrown with vegetation on buildings, as well as collection sites and systems using rainwater will play a special role for the proper, sustainable development of urban areas.

In urban areas, it is recommended that CO_2 flows in green infrastructure systems, including buildings with vegetation (green roofs, living facades and living interior walls), should be considered throughout the technical life cycle of buildings [6]. This approach is also used in many green building certification schemes.

Assessing carbon emissions and CO_2 reduction opportunities in green building analyses should be done throughout their life cycle. A very effective way to balance CO_2 emissions and reduce their emissions is to use green, biologically active structures. According to some authors, the full reduction of carbon dioxide emissions for some facilities is achieved even in a very short period of about three years. At the same time, there is a positive impact of these building solutions on human health and well-being, as well as the increase in biodiversity and others [7].

BENEFITS OF A GREEN BUILDING CERTIFICATE

An important benefit of obtaining a green building certificate is the possibility of obtaining a higher sale or rental price of the property or premises, compared to standard facilities.

Owners of such green buildings can obtain certificates. They ennoble one person as a very responsible person who is subject to influence on people and the natural environment. These objects are patterns for use and disclosures where they are alternatives in traditional construction.

A significant marketing effect from the designer, through the printing house, owner, investor, developers, to the end user. Lower costs for energy, water and other utilities compared to standard building solutions. Increased comfort of using rooms.

In ecological certification, special attention is paid to the quality of the internal environment of buildings. An appropriate, optimal ventilation system, adequate natural and artificial lighting, and the elimination of toxic chemicals should be used. Certified buildings create healthier and more comfortable conditions for their occupants. This ensures good health, well-being and higher productivity and quality of work and rest for other users.

These buildings are prepared to implement new technical solutions as new proposals emerge resulting from technical progress in the area of sustainable construction. These solutions should bring further benefits to the owners and users of such buildings.

Main factors taken into account in the design of sustainable buildings

- takes a smart approach to energy
- safeguards water resources
- minimizes waste production, maximizes reuse
- improves the well-being and health of users
- makes it easy for users to get in touch
- adapts to changing conditions
- covers the entire life cycle of a building
- boosts biodiversity

CONSTRUCTION WITH ELEMENTS OF SUSTAINABLE DEVELOPMENT

Activities conducive to sustainable development in construction include the implementation of the principles of energy-efficient construction, buildings with high energy efficiency, structures with green living vegetation, etc.

The latest version of the EU Energy Performance of Buildings Directive (recast) [8] highlights the need for green infrastructure, i.e. living roofs and walls, for urban planning and architectural design. Such actions allow for better adaptation to climate change and mitigation of the harmful effects of climate change in urban areas. It also indicates the necessary actions in the field of energy consumption. Buildings in the European Union must meet zero-emission CO_2 standards:

- from 1 January 2026 – newly designed buildings occupied, operated or owned by public authorities;
- from 1 January 2028 – all newly designed buildings;
- from 2050, all buildings (both new and existing) [9].

On energy efficiency, Georgia is aligned with the Directives on energy labelling and the energy performance in buildings. Fifteen energy efficiency bylaws were adopted in 2022 and 2023. The remainder of implementing legislation is still to be adopted. On energy labelling, the adoption of eleven product regulations is pending, in addition to three that are already adopted. An advanced draft of the long-term building renovation strategy has already been developed [10].

In Georgia, in 2019, significant changes were made to the construction law concerning planning, architectural and construction activities. They define the zones (subzones) of land development and/or the specificity of individual planning units, architectural and planning features as well as spatial and cubature features of buildings, the location of buildings and their parameters. Specific greening coefficients are assigned to each of the zones and the corresponding subzones [11].

There are studies and various publications aimed at architects, builders, developers and other interested parties. Description and analysis of the world's most commonly used green building assessment systems, which aim to assess the quality of the environmental impact of buildings during construction, operation and after their operation [12].

In the case of Kazakhstan, the host of the EXPO2017 Energy of the Future exhibition, the integration of sustainable development principles in various spheres of the economy, including the construction sector, was initiated. The construction industry began to implement m.in environmental certification systems, such as Leadership in Energy & Environmental Design (LEED) and the Building Research Establishment Environmental Assessment Method (BREEAM). Especially in cities such as Astana and Almaty (Fig. Fig. 2, 3). The article [14] examines the factors affecting use, the characteristics of certified buildings, and the potential to promote certification schemes on a wider scale.

Fig. 2. Talan Towers, a social and business complex, Astana, the first completed project in the Kazakhstan to receive LEED Achieved gold certification [13]

Fig. 3. Q-2 Building, Nur-Sultan, Obtained a BREEAM certificate [13]

In Kazakhstan, attempts to implement green building have been made for about 10 years. However, as the analysis of this type of projects shows, there is a noticeable lack of qualified and experienced staff who could design and implement this type of facilities. In the case of Kazakhstan, water efficiency and energy efficiency of buildings were assessed as the most influential factors that should encourage the implementation of green building. The use of technical solutions for high water and energy efficiency in green buildings would reduce life cycle costs by about 40% [15].

EXAMPLES OF GREEN BUILDINGS IN GEORGIA

An interesting example of a building in Tbilisi classified as a green building is the Head Office of ProCredit Bank Georgia (Fig. 4). It is the first building in Georgia to be included in the list of green buildings, whose resource efficiency has been confirmed by the international EDGE Advanced certificate in 2020 [16]. The bank's headquarters is a modern architectural project with high energy, water and material efficiency, which is in line with the pro-ecological philosophy adopted for all buildings of the ProCredit group. The building features a glazed façade and atrium to provide daylight along with the building's energy-efficient partitions. LED lighting with presence and lighting control sensors. High-performance, energy-efficient units for space heating and cooling. ProCredit Bank Georgia has installed Georgia's first rainwater retention system. A system of photovoltaic panels producing electricity for the needs of the building and charging the batteries of the bank's electric cars. ProCredit Bank Georgia plans to gradually complete the next stages of EDGE certification for its headquarters, including reaching the zero-carbon emissions stage, making ProCredit Bank Georgia 100% CO_2 neutral [17].

Fig. 4. ProCredit Bank Georgia's head office in Tbilisi, an EDGE Advance certified building [18]

Another example is the Solar Energy Apartments (SEA) project (Fig. 5), which was presented at the Greenbuild EXPO. The design of the building has been certified in the BREEAM system and entered into the Green Book. Solar Energy Apartments (SEA) is an eight-storey building with 72 apartments. It is an interesting, environmentally friendly and energy-efficient building, using modern materials, technologies and renewable energy [19].

Fig. 5. Solar Energy Apartments (SEA) project implementation stage [19]

CERTIFICATION OF GREEN BUILDINGS IN POLAND

In Poland, the first buildings received LEED and BREEAM certificates in 2010. Since then, a gradual increase in the number of certified buildings has been observed in the following years, as shown by the annual reports of the Polish Green Building Council (Fig. 6). This applies primarily to newly constructed buildings.

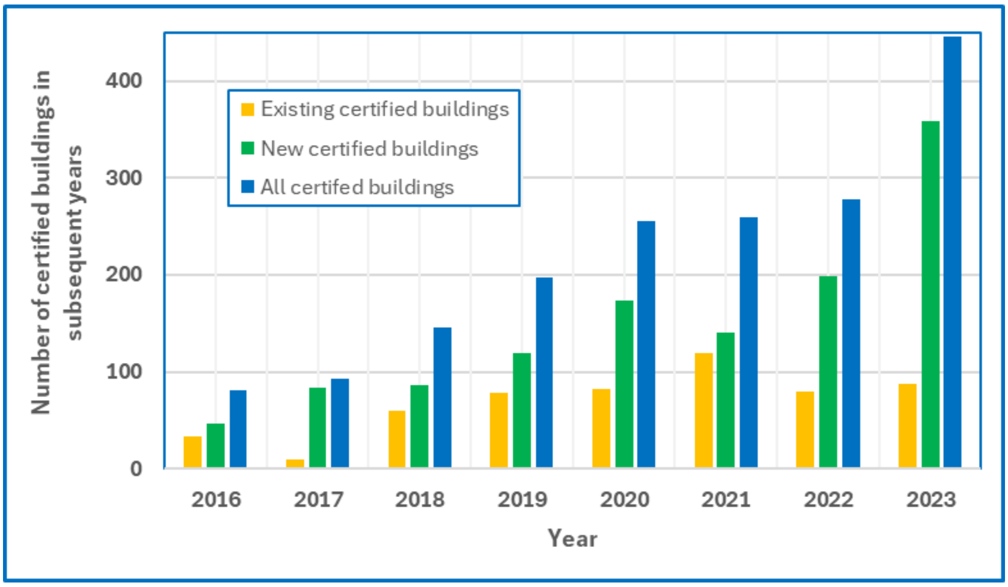

Fig. 6. Number of certified new and existing buildings in Poland in subsequent years

According to data from the 2023 report of the Polish Green Building Council, by 2023 office, warehouse and production buildings received the most certificates, i.e. over 45% (Fig. 7).

According to the PLGBC 2023 report, Poland is the leader in terms of the number of certified buildings in Central and Eastern Europe. Out of 3545 certificates issued, 1637 (46%) concern buildings located in Poland (Fig. 8).

Despite the increase in the number of certified buildings, the usable area of these buildings, especially in 2023, was smaller than in previous years (Fig. 9).

The percentage increase in the usable area of certified buildings in subsequent years in Poland is presented in the graphic list (Fig. 10). This is confirmed by a fairly significant decline in building certification in 2023.

This was influenced by several factors, including the COVID pandemic, the economic crisis, and the geopolitical situation in Polish's environment.

The average usable area of certified buildings in subsequent years is shown in the chart (Fig. 11).

Fig. 7. Industry division of certified buildings in Poland [20]

Fig. 8. The number of certified buildings in Poland compared to other buildings in Central and Eastern Europe [20]

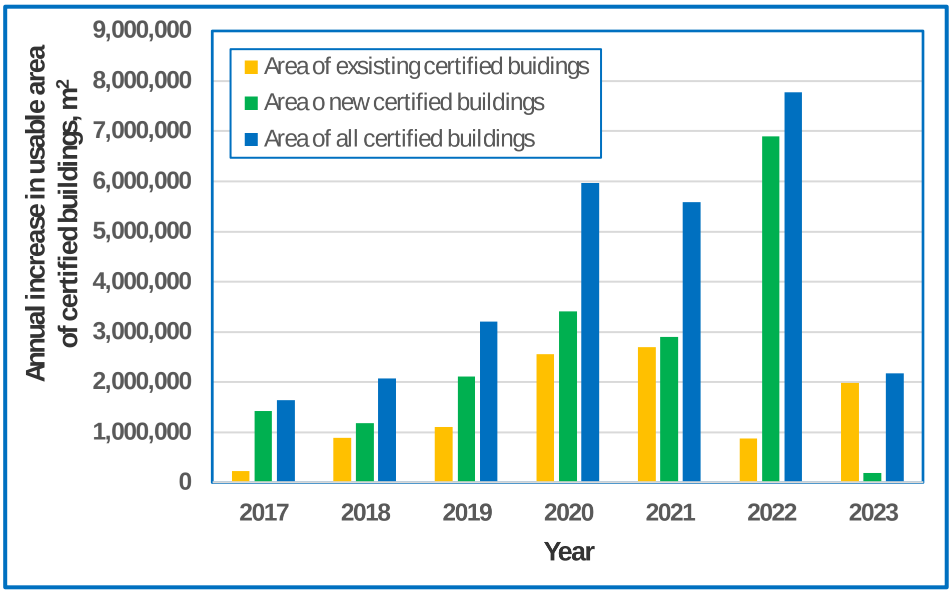

Fig. 9. Annual increase in usable floor area of certified new and existing buildings in Poland

Fig. 10. Percentage increase in the usable area of certified buildings in subsequent years, compared to data from the previous year

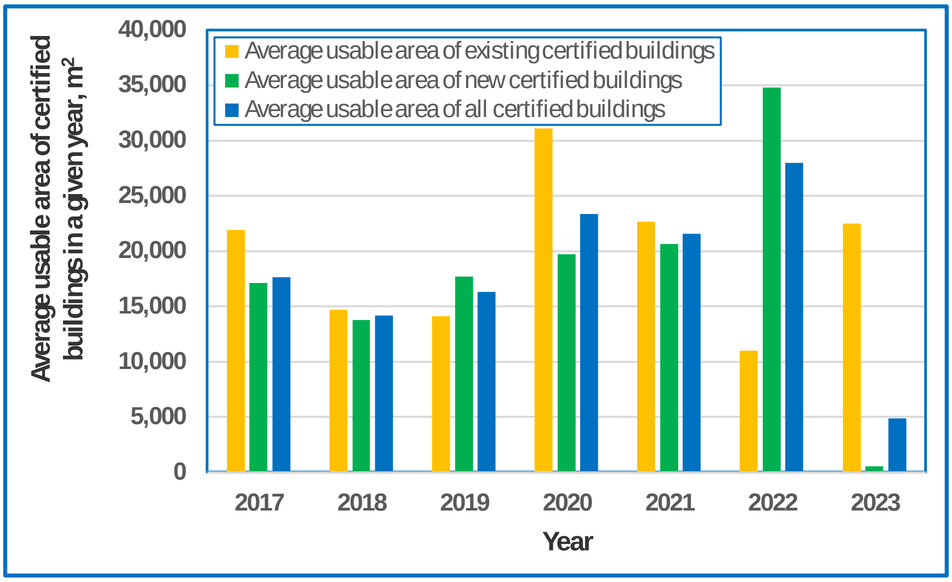

Fig. 11. Average usable floor area of one certified existing, new and total building in subsequent years

An interesting piece of information is the determination of the share of the area of newly constructed certified buildings in the total area of all buildings completed in a given year (Fig. 12). In 2022, it reached this value of 18%, unfortunately, in 2023, due to crisis phenomena, it fell to a value of about 05%.

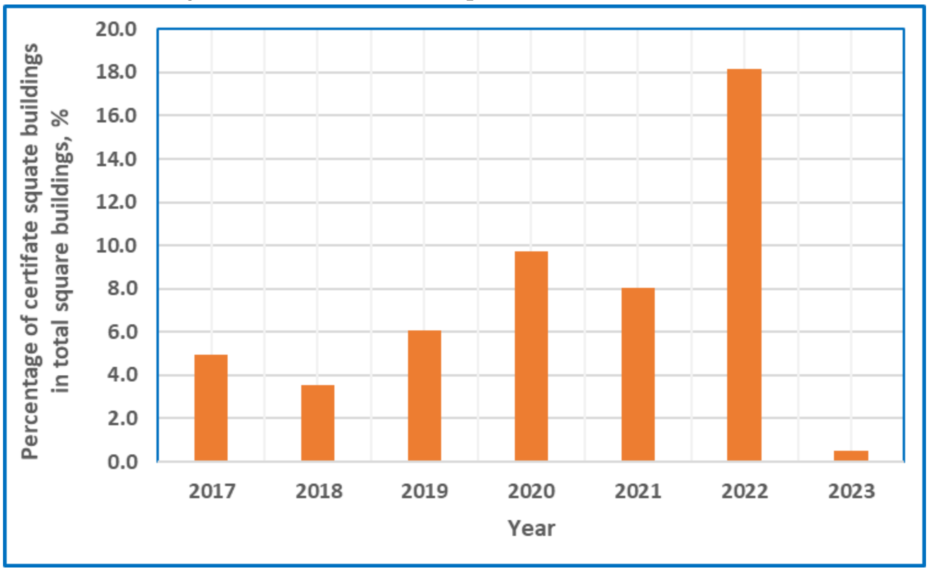

Fig. 12. Percentage share of the usable area of certified buildings in the total area of all buildings completed in Poland in subsequent years

CONCLUSION

Green building certification is an essential step towards creating more sustainable construction and architecture. It indicates models for creating construction that is more friendly to people and the environment.

It is required to improve design and construction guidelines in the construction industry, in the area of creating green buildings.

Such models should be disseminated to make the entire construction industry sustainable.

A valuable fact is that the need for sustainable construction is recognized in various countries. At the same time, it is necessary to intensify the training of building designers and builders in the creation of green buildings.

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Hydraulic Engineering and Irrigation

CONSERVATION OF SOIL AND WATER: A SHARED MISSION IN AN ERA OF CHALLENGES AND CLIMATE CHANGE

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Annotation. The conservation of soils and water remains a key issue in the projects of the Nationwide Recovery Program of Ukraine in the era of challenges and climate change. Irrigation plays a crucial role in achieving maximum efficiency and ecological safety in agricultural production. Its success is determined by the quantity and quality of irrigation water. To align the composition of irrigation water from open and underground sources, an algorithm for selecting designs of drip irrigation systems and water treatment technological schemes has been proposed, depending on the content of suspended particles of organic origin in the water. This approach involves a step-by-step removal of water contaminants, allowing for a flexible and reliable water purification technology with minimal capital and operational costs. The reasoned combination of methods, technologies, and water treatment means, taking into account the quality of the irrigation sources and the requirements for drip irrigation systems, ensures the reliable operation of drip irrigation systems and their elements, as well as a safe impact on soils, plants, and the environment.

Keywords: conservation of soil and water, water quality, drip irrigation systems, technical approaches, algorithm for selecting water treatment equipment.

INTRODUCTION

The water crisis ranks among the top five largest crises recognized by the UN, FAO (Food and Agriculture Organization), Global Soil Partnership (GSP), and the International Commission on Irrigation and Drainage (ICID), which will have the most detrimental impact on global development in the next decade. Climate change, the expanding deficit of natural water supply, and increasing competition for water resources are the primary threats globally to achievements in food security and reducing negative environmental impact [1-7]. Agriculture, which consumes up to 70% of the world's freshwater resources, including irrigation, will be particularly vulnerable. This fact underscores the need for developing effective water resource management strategies and adopting technological solutions to optimize water use for irrigation.

In the midst of Russia's armed aggression, Ukraine faces a significant challenge from escalating threats that demand urgent measures to protect both its population and the environment. This situation underscores the need to establish a stable and food-secure nation. This direction aligns with the broader objectives of the UN's Food and Agriculture Organization (FAO) Strategic Program for 2022-2031 [1]. The program sets out a vision for global development that emphasizes collaborative efforts to achieve the Sustainable Development Goals by 2030. This entails transitioning to more efficient, inclusive, resilient, and sustainable agricultural and food systems. The primary focus is on improving production quality, ensuring better nutrition, conserving the environment, and enhancing the quality of life for all. Irrigation plays a crucial role in achieving maximum efficiency and environmental safety in agricultural production, creating a stable economic foundation for business activities in Ukraine, and ensuring global food security. Its success is determined by the quantity and quality of irrigation water, upon which the productive and ecological functions of soils depend. The operational reliability of irrigation systems and the increase in crop yields of agricultural crops are also essential factors in its effectiveness.

MAIN PART

The call for preserving soil health and improving water quality aligns with the urgent and coordinated actions needed to mitigate the impacts of climate change and ensure sustainable food security [2-3]. According to the conclusions of the UN's Food and Agriculture Organization (FAO) and the International Fund for Agricultural Development (IFAD), global agri-food systems will play a pivotal role in adapting to climate change and alleviating its consequences, protecting and conserving biodiversity, and creating inclusive and resilient means of existence [4-7]. A primary goal in shaping agri-food systems should be the expansion of soil productivity restoration through irrigation. This would reduce the vulnerability of agricultural producers, strengthen integrated water resource management, and minimize climate and ecological risks [4]. In Ukraine, local agri-food systems can serve as effective tools for adapting irrigated agriculture to the new realities of wartime and further development amidst massive destruction of the engineering reclamation infrastructure of the water management complex. This will ensure the country's food security and counteract the degradation of soil cover and its consequences related to the military actions of the russian federation and climate change. Considering the principles of sustainable development, agri-food systems can function as powerful tools to mitigate climate change. Their transformation will play a key role in achieving global environmental goals and Sustainable Development Goals [3].

The increasing demand for irrigation will lead to a rise in situations related to both direct and indirect (recycled) use of water of varying quality from different sources, including unconventional ones. Effective methods for diagnosing and managing water quality will be required, using technical schemes and water treatment facilities with the highest degree of purification and safe use. In Ukraine, drainage waters formed as a result of excess moisture or water drainage (discharge) from reclamation canals, hydraulic structures, and flooded areas are considered the most suitable for irrigation. The reclamation and reuse of drainage water in irrigation systems remain a priority in research. Essentially, these studies aim to address environmental tasks related to reducing overall water pollution for subsequent use, improving and adapting cultivation practices for more resilient crops under any drainage water composition (salt-tolerant, drought-tolerant, etc.), enhancing soil reclamation programs, and refining modeling methods and selecting better approaches and scenarios for using drainage water in various irrigation methods. Researchers have extensively explored these issues, leading to advancements in understanding and application. Notable studies include works by Drury C.F., Tan C.S., et al., 1996; Youssef J. et al, 2017; Reinhart Benjamin D. et al., 2019; Bagheri S., 2022; Radmehr A., 2022). These studies provide insights and guidance on optimizing the use of drainage water for irrigation, addressing ecological challenges, and improving agricultural practices.

To assess the quality of water for irrigation, various methods and techniques allow for separating low-quality water from high-quality water. Depending on the requirements of the crop and soil, this water can be used directly, through mixing, or alternately in different ratios. For drainage waters to meet quality standards, direct use in irrigation systems without restrictions is permissible. For drainage waters with deviations from standards, after proper purification, cyclic water supply is permissible. The choice of options for reusing water is determined by the quality, quantity, and availability of drainage waters, crop tolerance to salinity, soil resistance to irrigation and salt loads, and sufficient volumes of suitable water for irrigation. However, among the conducted studies on these reuse schemes, there are many cautions regarding the safety of their impact on soil, plants, and technical equipment. In most cases, negative effects of water, such as its toxic effect on plants, degradation of soil structure, spread of parasites, and reduced efficiency of irrigation systems, have been proven. Climate change and the destruction of hydraulic infrastructure due to the armed aggression of the Russian Federation have created additional threats and risks for these measures and improving the quality of drainage waters shortly. However, the issue of justifying the use of drainage water should still be considered in strategies as a means of preserving and protecting limited water resources from pollution at the nano- and micro-levels.

Balancing the benefits and risks associated with reusing drainage water is crucial. While drainage water offers a potential resource for irrigation, its quality and potential negative impacts on soil and plants must be carefully managed and monitored. Given the current challenges posed by climate change and geopolitical factors, the sustainable management and use of water resources become even more critical for ensuring food security and environmental protection quality, and potential negative impacts on soil and plants must be carefully managed and monitored. Given the current challenges posed by climate change and geopolitical factors, the sustainable management and use of water resources become even more critical for ensuring food security and environmental protection.

We have developed principles for managing the quality of irrigation water in drip irrigation systems [8]. Its principles are based on the patterns of forming the chemical and biological composition of irrigation water as it is transported through the "irrigation source-irrigation system-soil" chain. We have also identified dependencies of water quality on the efficiency of water treatment equipment and the flow-pressure characteristics of drip emitters in drip irrigation systems. The patterns and dependencies were established through experimental research on operating irrigation systems using irrigation water of different compositions from various sources, including drainage water. The research utilized typical seasonal and stationary drip irrigation systems, ensuring continuous irrigation of vegetable, row, and perennial fruit crops. The irrigation systems included experiments with gravel-sand, disk, and mesh filter stations with manual and automatic flushing, as well as irrigation pipelines with integrated drip emitters from domestic and global manufacturers. These principles and findings help guide the management and optimization of drip irrigation systems, ensuring that water quality meets the required standards and does not negatively impact the irrigation infrastructure or crop health. By understanding the chemical and biological composition of irrigation water and its effects on the system components, we can implement better water treatment practices and maintenance protocols. This ultimately leads to more efficient water use, improved crop yields, and sustainable agricultural practices. Furthermore, the inclusion of drainage water in these studies highlights the potential for reusing this water source in drip irrigation systems, provided it meets certain quality standards and has been properly treated to avoid negative impacts on soil and crops. This approach aligns with sustainable water management practices, promoting the reuse of water resources and reducing the demand for freshwater sources. In conclusion, our research and principles for managing irrigation water quality in drip irrigation systems offer valuable insights and guidelines for optimizing water use, ensuring system efficiency, and promoting sustainable agriculture. Continuous monitoring and adaptation of these principles based on ongoing research and technological advancements will further enhance the resilience and sustainability of agricultural water management systems.

The developed principles form the basis for improving technologies, technological water treatment schemes, technical means, and their designs [9]. Their use ensures increased operational reliability of systems under modern conditions. The main directions for the development of drip irrigation technical means have been identified as addressing their major drawback – dependency on water quality. The selection of the appropriate type of drip emitter based on the specific water composition is recognized as the most effective way to prevent clogging and prolong system operability when using water from non-traditional sources. To enhance the clogging resistance of emitters, scientists from the Institute of Water Problems and Land Reclamation (IWPLR) of the National Academy of Agrarian Sciences of Ukraine (NAAS) are working on developing drip emitters with various channel sizes and special designs. To reduce the dependency on water quality, an impulse-action drip emitter of an insert and integrated type was developed (Ukraine patent for invention No. 122749 "Impulse Drip Emitter"). Its design is capable of ensuring the effective operation of irrigation pipelines using lower-quality water, which can be incorporated into drip irrigation systems. The new design of the impulse drip emitter provides minimal water flow resistance in the irrigation pipeline, a straightforward manufacturing process, and increased emitter reliability. An algorithm for selecting technological water treatment schemes from open and underground water sources has also been developed.

This algorithm is based on the content of suspended particles of organic origin in the water, aiding in the proper selection of technical means for effective water treatment (see Table 1).

Table 1

Algorithm for selecting water treatment equipment

Type of drip irrigation system	**Placement of irrigation pipelines**	**Characteristics of water emitters**	**Suitability of irrigation water for drip irrigation**	**Technical means of water treatment**				
				water intake filter	**hydro-cyclone**	**sand-gravel filter**	**disc filter**	**mesh filter**
when extracting water from surface water sources								
seasonal, seasonal-stationary	surface	integrated unregulated and regulated	suitable	+	-	+	-	+
			conditionally suitable	+	-	+	+	-
stationary	on the trellis	embedded, integrated, unregulated, regulated	suitable	+	-	+	-	+
			conditionally suitable	+	-	+	+	-
stationary	subsurface	integrated unregulated, regulated, with anti-drainage and siphon devices	suitable	+	-	+	-	+
			conditionally suitable	+	-	+	+	-
when extracting water from underground water sources								
seasonal, seasonal-stationary	surface	integrated unregulated and regulated	suitable	-	-	-	+	+
			conditionally suitable	-	+	+	+	+
stationary	on the trellis	embedded, integrated, unregulated, regulated	suitable	-	-	-	+	+
			conditionally suitable	-	+	+	+	+
stationary	subsurface	integrated unregulated, regulated, with anti-drainage and siphon devices	suitable	-	-	-	+	+
			conditionally suitable	-	+	+	+	+

Note: «+» - recommended for use; «-» - not recommended for use.

We found that a step-by-step removal of coarse and finely dispersed contaminating particles using preliminary treatment means followed by filtration stations ensures a reliable water purification scheme. Based on this, we justified nine water treatment technological schemes that differ from typical schemes by their technological combination and sequential arrangement of technical means for preliminary, coarse, and fine water treatment, along with fertigation preparation nodes, when achieved good results. The economic benefit of implementing improved technological schemes for water treatment and drip emitter design is determined by the cost of drip irrigation systems, seasonal operational expenses, and post-improvement maintenance costs, as confirmed in Ukraine through the example of existing drip irrigation systems in Dnipropetrovsk region covering an area of 35.00 hectares, Vinnytsia region covering an area of 30.00 hectares, and Zakarpattia region covering an area of 30.16 hectares. By optimizing the water treatment processes, such as filtration, the need for frequent system flushing and maintenance is minimized, resulting in cost savings. Additionally, efficient water treatment can contribute to the longevity and reliability of the system components, reducing the frequency of replacements or repairs and further lowering operational expenses.

For the successful resolution of this task, it is necessary to create agri-food systems using modern irrigation systems, the operation of which ensures maximum profit with minimal costs, the ecological integrity of the agro landscape, and increased fertility of irrigated soils. When assessing the suitability of soils for irrigation and creating irrigation areas (irrigation systems), the following principles should be adhered to [10]:

- Direction towards obtaining economically justified and ecologically limited volume of agricultural products.
- Priority of compliance with ecological constraints on the quality of irrigation water, water supply volume for irrigation, natural drainage of the territory, and the ratio of irrigation supply to drainage flow.
- Adherence to ecologically permissible saturation limits of agro landscapes with irrigated lands.

CONCLUSIONS AND RECOMMENDATIONS

Based on the research findings, the following recommendations are made for practical implementation: i) the selection of water treatment technological schemes and equipment should be based on the suitability of the irrigation water, characteristics of drip emitters, placement of irrigation pipelines, and the type of drip irrigation system; ii) the evaluation of the impact of water quality and the suitability of drip emitters should be conducted based on parameters for the content of suspended organic particles, considering the quality requirements for irrigation water according to technical criteria. By following these recommendations, practitioners can make informed decisions regarding the choice of drip irrigation equipment and water treatment schemes, ensuring that the selected components are in line with national standards and suitable for specific irrigation conditions.

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Water management

SCHEME OF IRRIGATION WATER PRICE CALCULATION

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Annotation. One of the most important factors of further development of not only production capacities of national economies, but also survival of mankind itself is the availability of water resources, the deficit of which in the world is becoming more and more tangible every year. Under the conditions of growing deficit, the problem of rational water use, formation of water resources market and accordingly rational tariffs for water resources use becomes more and more urgent. An indispensable condition for the functioning of the water resources market is tariffication of these resources, the diversity of methods of which introduces dissonance in the very concept of tariffs and, accordingly, in determining the most rational directions of its use. In order to unify the calculation of tariffs for irrigation water supply, a standard scheme of such calculations is proposed.

Keywords: water resources, water resources market, irrigation water tariffication.

INTRODUCTION

One of the most important factors of further development of not only production capacities of national economies, but also survival of mankind itself is the availability of water resources, the deficit of which in the world is becoming more and more tangible every year. Under the conditions of increasing deficit, the problem of rational water use, formation of water resources market and, accordingly, rational tariffs for the use of water resources becomes more and more urgent. [1]

MAIN PART

Under current conditions, the creation of water resources market will increase the level of their rational distribution and efficient use. Water trade is an element of adaptation strategy to combat water and product scarcity caused by global climate change, and can become a means of solving geopolitical issues and preventing political conflicts. [2]

An indispensable condition for the functioning of the water resources market is tariffication of these resources, the diversity of methods of which introduces dissonance in the very concept of tariffs and, accordingly, in determining the most rational directions of its use. [3]

In order to unify the calculation of tariffs for irrigation water supply, a standard scheme of such calculations is proposed.

The following scheme of water price calculation implies its use for irrigation, so other water use systems are not considered here; although, if the laws of water use development in other spheres of water management are known, this can be envisaged during tariffication based on the already formulated principles. The scheme under consideration consists of a number of elements.

Division of irrigated area into tariff zones

The division of the irrigated area into relatively uniform zones (especially for large areas) is carried out taking into account agro-economic indicators and location relative to the water source and irrigation system. The purpose of this operation is to separate zones with approximately the same real cost of water in order to avoid large differences between the cost of water and its selling price. At the same time, artificial merging and equalization of tariffs of areas with different production costs is undesirable.

Construction of demand evolution function

Demand evolution function or maximum irrigation water demand is estimated on the basis of crop area structure, crop rotation and soil-climatic (precipitation, evapotranspiration, soil moisture capacity) factors. Demand is estimated by the values of total annual (m3/year) water consumption and instantaneous abonated flow (l/sec). The volume of water consumption during the peak period is also estimated. Between the initial and final points of maximum consumption, a functional curve should be constructed that determines the change in demand over time, obtained by analogy with a neighboring object, and at the same time takes into account the peculiarities (problems of financing, time spent on replacing crops, time spent on planting perennials, size of gardens, etc.). Usually two curves are constructed - an optimal and a pessimistic curve; the calculated curve is interpolated between them.

Estimation of fixed operating costs

Fixed operating costs do not depend on the "produced" amount of water and include depreciation charges and operating costs.

Some principles of tariff formulation for irrigation by closed (pipeline) systems

The problem of water tariffication implies finding a compromise between the interests of the irrigation system and water users on the basis of the above theoretical approach. More often binary tariffication is applied, consisting of a user fee for hydrant use and a proportional payment for each unit volume of water used [4].

The user fee is determined by the requested flow rate, which in turn determines the capacity of the system and its cost. Thus, on the same irrigated area, depending on the demanded flow rate, the cost of using different hydrants can be different. Subscription fee for the whole operation period guarantees minimum income for the operation organization. At the same time, it should be taken into account that the increase in the user fee may cause refusal of small water users from irrigation, although they can cooperate and pay for one hydrant.

Proportional payment for used water can be different in normal and peak periods. Payment for the volume of used water forces water users to use water sparingly and excludes such negative phenomena as groundwater rise, soil salinization, etc.

Usually, the cost of irrigation water for different crops should be different, because the optimum of water consumption is at the point of intersection of the curves of demand and incremental cost. In general, for water-loving crops, the cost of water should be less than for less water-loving crops, although this causes complication of calculations, since estimation of water consumption of different crops is quite a complicated task. This can be solved by assigning a high cost of the first cubic meters of consumed water with its subsequent reduction, which will give an incentive to continue irrigation already started. At the same time, a penalty tariff is introduced to prevent overconsumption when the volume of water used exceeds the rational value.

It is also advisable to introduce seasonal tariffs. In this regard, existing preferential tariffs should be noted, for example:

- A two-rate tariff, the subscription fee of which provides for free consumption of a certain volume of water, on top of which a proportional payment applies;
- Various subscription fee and prorated payment options, and the consumer chooses the most appropriate pairing from among them.

Surface irrigation

With this type of irrigation, the set flow rate is distributed to the consumers in turn. Time of water consumption is proportional to the irrigated area, which indirectly determines the amount of water consumed. It should be noted that the quality of service of water consumers under such irrigation is significantly lower than under irrigation by sprinkling "on demand", which, of course, is reflected in the price of water.

Different types of tariffs are applied for surface irrigation, such as a predetermined hectare tariff, under which the cost is calculated either for the entire field area or for the declared area, the size of which changes annually. The hectare tariff favors wasteful water use and can be applied in well-watered areas.

Binary tariff includes payment for declared flow rate plus payment for consumed water. Taking into account the complexity of systematic flow measurement in open canals, the volume of consumed water is estimated based on the time of use of a given flow rate, which necessitates the presence of a controlling staff to control the specified time, opening and closing of outlets. This significantly limits the application of this tariffication method.

A three-rate tariffication can be used, which includes:

- Annual depreciation charges calculated in proportion to either the irrigated area (constant) or the declared hydromodule (increasing);
- Annual fixed hectare costs, which can also be fixed or increasing depending on the hydromodule;
- Annual variable costs,

CONCLUSION

1. Under current conditions, the creation of water resources market will increase the level of their rational distribution and efficient use. Water trade is an element of adaptation strategy to combat water and product scarcity caused by global climate change, and it can become a means of solving geopolitical issues and preventing political conflicts.
2. All the principles of creating a tariff grid for irrigation water cost can be grouped into four main concepts: tariffication based on socio-political criteria, tariffication based on "yield", tariffication based on average cost, tariffication based on incremental cost.
3. The scheme of water price calculation implies division of irrigated area into tariff zones, construction of demand evolution function, estimation of fixed operational costs, and estimation of variable costs.

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Hydraulic engineering and irrigation

ASSESSMENT OF THE TECHNICAL CONDITION OF THE TYASMYNSKA PROTECTIVE DAM OF THE KREMENCHUK RESERVOIR

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Annotation. The technical condition of the Tyasmynska dam was examined, and the method of field survey was given. The characteristics of the object of research, engineering-geological and engineering-hydrological conditions were given. The design of the protective dam, which consists of the lining of the upper and lower slopes, and the drainage design are given.

When conducting field surveys, the following were subject to examination: the presence and the areas of destruction of reinforced concrete lining plates and joints between them, and the nature and sizes of cracks. The results of field surveys conducted in 2007 and 2020 are given. The filtration regime of the dam was analyzed and the drainage system operation was evaluated. The proposals to increase the stability of the Tyasmynska protective dam were developed.

Keywords: *drainage runoff, protective dam, curve of depression, assessment of technical condition, destruction, cracks.*

INTRODUCTION

Some territories and settlements in the territory of Ukraine are protected against flooding by embanking with protective dams. In particular, during the construction of the Dnieper cascade of reservoirs, embanking was constructed to protect an area of 197,000 hectares, where 13 settlements with a population of about 600,000 people are located [1]. These dams operate under conditions of constant water pressure that complicates their operation, unlike flood protection dams. In addition, most dams are in operation for about 50 years, which corresponds to or exceeds their maximum design service life. Conducting field studies on the technical condition of protective dams is necessary not only to prevent possible catastrophic flooding in large areas but also to reduce annual crop losses as a result of agricultural land flooding and to decrease the operating costs of pumping and compressor stations of the Interregional Office of the Dnieper Reservoir Protection Areas, which operate around the clock throughout the year and annually pump out 2 - 3 km^3 of water [1].

The Tyasmynska Dam is located in the valley of the Tyasmyn River 20 km from its mouth between the northern outskirts of Stetsivka village and the northern part of Vitove village, at a distance of 30 km west of the Kremenchuk HPP (Poltava region of Ukraine). The dam is intended to protect the valley of the Tyasmyn River (Fig. 1).

Fig. 1. General view of the protective dam

In the section 13 km from Chyhyryn town to the dam, the Tyasmin River flows to the east parallel to the Dnieper, forming a watershed with a reservoir up to 11 km wide. The channel width at the crossing of the river with a protective dam is about 30 m; the depth is about 3.0 m. The low water line of the river here is 72 m, and the floodwater rises to 75.5 m. The width of the Tyasmyn River valley is 3.6 km.

On the right bank, the width of the floodplain is 600 m. Adjacent to the village of Stetsivka strip with a width of 300-350 m is a partially swampy and peaty lowland. The ground levels of this part of the floodplain are 72.0-74.0 m.

On the left bank, the floodplain is approximately 500 m wide. It is a flat lowland with ground levels of 72.0-72.5 m. Sand mounds reaching elevations of 75.0 m are observed only near the second terrace. Peat bogs are spread from the channel towards the floodplain for 240-300 m.

Hydrogeological conditions in the dam area are characterized by the presence of three aquifers: water from Precambrian rocks, water from the formations of the Buchatsky layer, and water in the alluvial middle, new and modern formations. The groundwater depth varies, depending on the topography and distance from the Tyasmyn River.

Engineering and geological conditions. The protective dam is 3.55 km long; on the right bank, it adjoins the high slope of the fourth terrace, crosses the lower part of the Tyasmyn River valley (the right-bank floodplain, the channel, and the left-bank floodplain), the second terrace and passes to the lowered section of the left-bank fourth terrace, adjoining its higher grounds levels. The water head in the channel part and on the floodplain reaches 9.0 m; on the second terrace it does not exceed 6.0 m, and on the fourth terrace is 1.5 m. The levels of the dam crest on the floodplain and in the channel are 83.5 m. The maximum levels of the dam on the floodplain reach 11.5 m, and in the channel they are 13.5 m.

The dam was constructed on the lowered area of the floodplain and the second terrace (KP31+70-KP45+50) by hydraulic filling and in other areas by raising a bank.

The dam route can be divided into the following main sections by engineering and geological conditions: right abutment; bottom part of the valley (right-bank and left-bank floodplains, and channel); section of the second terrace; section of the fourth terrace; left bank abutment. The slope of the fourth terrace, to which the right shoulder of the dam adjoins, has a steepness of about 10°. From the surface, at the levels of 86.0–91.0 m, the terrace is composed of loess-like soils underlain by alluvial loams, sandy loams, and sands.

The total thickness of the alluvial layer in the abutment is from 7.0 to 12.0 m.

Light loams and homogeneous fine-grained sands with a predominant fraction of 0.25-0.1 mm are the most widespread. The filtration coefficient of fine sand is 6 m/day.

The bottom part of the valley, which includes the floodplain of both banks and the channel, has a total length of 115.0 m. The main criterion for assessing the engineering and geological conditions of the lowland, a significant part of which is swampy and covered with peatlands, is the layer thickness, composition, and physical and technical properties of peaty and muddy soils.

Peat and peat-clay soils differ in the degree of decomposition of plant residues and admixtures of clay particles. The content of organic matter in them varies from 18% to 88% (47.4% on average). Soil moisture is extremely high, more than 200%, and in some places it exceeds 500%.

The dam structure. The Tyasmynska protection dam consists of 3 sections separated by sand mounds, with ground levels from 85.00 m to 95.00 m. The length of the dam is 3.55 km. The width of the dam crest is 11.0 m.

The dam base in the first section consists of loess-like sandy loams with a thickness of up to 5.0 m, and fine-grained sands lie below. The base of the second and third sections (KP31+70-KP39+00 and KP45+00-KP49+00) is represented by fine-grained sands with interlayers of sandy and dusty loams. Between KP39+00 and KP45+00, the base of the dam consists of peat and muddy soils with a thickness of 1.0 - 3.0 m, underlain by sandy, sandy-loam, and loamy soils.

The profile of the dam and its parameters were designed given specific geological conditions and requirements for class III hydraulic structures. The level of the dam crest was determined based on the water level in the Kremenchuk Reservoir, given wave load.

In the floodplain area, the upper slope was constructed with the inclines 1:3.5 and 1:4. It was fixed with monolithic reinforced concrete slabs sized 10x10 m, laid on a layer of crushed stone, which works as a filter. The thickness of the filter layer in the KP37+20- KP34+00 section is 0.25–0.30 m, and in other sections - 0.15 m with increased thickening under the joints up to 0.30 m. The thickness of the reinforced concrete slabs is 0.2 m; it was determined given the wave load of the area, which is affected by a wave up to 1.5 m high (KP31+70-KP34+00). The area, affected by a wave up to 2.5 m high (KP34+00-KP49+35), was fixed with reinforced concrete slabs of 0.3 m thick.

In the right-bank abutment (KP49+35-KP51+00), the reservoir bank is fixed with monolithic reinforced concrete slabs of 0.35 m thick.

Between the reinforced concrete slabs, which fasten the upper slope of the dam, tarred wooden boards were put, under which reinforced concrete slabs sized 2.0 x 0.3 x 0.08 m were laid. The isolation joint boards were fixed with metal staples. A reinforced concrete pressure plate sized 3.5 x 0.3 m was put in the lower part of the lining, along which the stone load was poured.

On the flattened section of the upper slope (KP37+20-KP45+50), at a distance of 70 m from the dam axis, a breakwater made of stone 1.5 m high was arranged to protect its unsecured slope from oblique waves. The level of the breakwater crest is 78.50 m. A parapet of 1.0 m high was built along the edge of the upper slope of the dam channel section.

The lower dam slope was fixed with grass, sown in a soil layer of 0.2 m thick.

In the section of the dam (KP31+70-KP49+00), pipe drainage was made at the ground level 75.00-76.00 m. The pipe drainage consists of reinforced concrete and asbestos-cement pipes with a diameter of 0.4 m and a return filter. Water is drained from the pipe drainage into the dam or supply canal of the pumping station with the help of six asbestos-cement pipelines laid on a rubble layer. Drainage wells made of concrete rings with a diameter of 1.0 m were arranged every 50 m to monitor the operation of the pipe drainage.

A road with a width of 7.0 m was laid along the dam crest. The road topping on the channel section was made in the form of two concrete strips with a width of 3.0 m each. The thickness of the topping is 0.18 m. Between the concrete strips, a rubble coating was made with a width of 1.0 m.

The section of the protective dam (K3P1+70-KP46+00) was built by hydraulic filling when using fine-grained sands with the help of a dredger, with sand compaction to a dry soil density of 1.6 g/cm^3.

Assessment of the technical condition of the upper slope lining. The surveys of the condition of the upper slope lining were performed on October 14, 2007, and October 20-21, 2020 in dry, sunny weather, when the water levels in the Kremenchuk Reservoir were 79.28 m and 79.67 m, respectively. The survey was carried out according to the Methodology for field surveys of earth ridges and protective dams for water management purposes [2].

The presence and scope of plate destruction, cracks in the slabs, and joints between monolithic reinforced concrete slabs were examined.

On-site surveys of the technical condition of the dam showed that the most common types of lining destruction of the upper slope were: joint destruction, cracking, and the destruction of reinforced concrete lining. Table 1 shows the results of field surveys performed by the Institute of Water Problems and Land Reclamation in 2007 and 2020.

As a result of the surveys, it was found that the main type of destruction of the upper slope lining is the destruction of the joints between monolithic reinforced concrete slabs. So, out of 120 examined joints, 100% had destruction.

In our opinion, the source of the destruction of slope joints and lining is the design error in the isolation joints when using metal staples. The staples were corroded and became a catalyst for destroying the concrete in the joint area in the zone of the depression head.

Another type of destruction affecting the technical condition of the upper slope lining is crack formation. On each plate sized 10 x10 m, transverse and longitudinal cracks were observed. The transverse cracks were observed at a distance of 7.0–9.0 m from the upper edge of the protective dam crest along the entire length of the studied area (KP34-KP46).

The crack width ranges from 0.001 m to 0.04 m with a total length of 1741.2 m. The smallest total length of cracks observed in section KP39- KP40 is 96.1 m, while the largest one is 235 m in section KP35-KP36.

The total crack area is 22.5 m^2. The largest number of cracks with an area of 3.02 m^2 was found in the section KP36- KP37, and the smallest one - 0.95 m^2 - in the section KP40- KP41.

The third type of destruction affecting the technical condition of the dam is the destruction of monolithic reinforced concrete. Thus, on KP38, one concrete slab sized 10x12 m was destroyed. The nature of the destruction of the reinforced concrete slabs of the upper slope is shown in Figures 2-3.

Surveys of the technical condition of the protective dam crest showed that due to passing multi-ton trucks along the road located on the protective dam, chuckholes were formed where rain and meltwater collect. The design width of the protective dam crest is 11.0 m. Surveys showed that due to intensive traffic, the protective dam crest expanded to 14.5 m.

Table 1

Survey results of the technical condition of the monolithic reinforced concrete lining of the upper slope of the Tyasmynska protective dam

№	Survey area		Cracks			Joints	
	From KP	To KP	Length, m	Crack width, m	Area, m^2	Total number, pcs.	Destroyed, pcs.
2007							
1	34	35	-	-	-	10	6
2	35	36	-	-	-	-	-
3	36	37	3.4	0.02	0.04	10	10
4	37	38	-	-	-	10	10
5	38	39	-	-	-	10	10
6	39	40	2.5	0.025	0.0675	10	8
7	40	41	-	-	-	-	-
8	41	42	-	-	-	10	9

9	42	43	-	-	-	10	10
10	43	44	-	-	-	10	10
11	44	45	-	-	-	10	10
12	45	46	3.0	0.007	0.021	10	10
In total			**8.9**		**0.093**	**110**	**104**
2020							
1	34	35	171	0.003-0.07	2.25	10	10
2	35	36	235	0.002-0.042	2.76	10	10
3	36	37	220	0.001-0.025	3.02	10	10
4	37	38	151	0.001-0.022	2.32	10	10
5	38	39	146.1	0.002-0.035	1.64	10	10
6	39	40	96.1	0.001-0.035	1.06	10	10
7	40	41	109.5	0.006-0.025	0.95	10	10
8	41	42	107.5	0.005-0.038	1.46	10	10
9	42	43	113.7	0.006-0.028	2.25	10	10
10	43	44	125.3	0.003-0.028	1.76	10	10
11	44	45	145.6	0.03-0.022	1.56	10	10
12	45	46	128.4	0.005-0.032	1.48	10	10
In total			**1749.2**		**22.5**	**120**	**120**

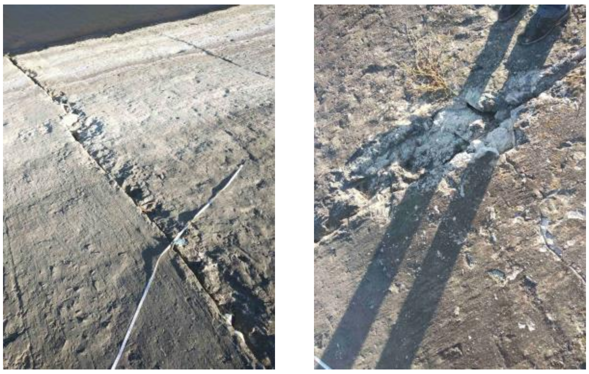

Fig. 2. Destruction of joints between reinforced concrete slabs

Fig. 3. Destruction of the concrete lining of the upper slope

Assessment of the technical condition of the lower slope lining. The lower slope is fixed by sowing herbs in a soil layer of 0.2 m thick, and its length varies from 40.0 m at KP34+00 to 90.0 m at KP43+00.

A visual survey of the lower slope was conducted on October 20, 2020, in sunny and dry weather.

The lower slope was in satisfactory condition. No deformation processes were detected in it. The filtration flow on the slope above the drainage was not observed. Filtration in the form of water saturation, air leakages, and seeping was not detected. Areas of sagging and destruction of the slope were not observed along its entire length.

Filtration regime of the dam. To determine the position of the depression curve of filtration flow, three observation wells were drilled at KP37+60, KP40+75, and KP44+50. By the water levels in the wells, the depression curve was constructed (Fig. 4). For comparison, table 2 shows the calculated pressure gradients as of October 2007.

As can be seen from Table 2, a calculated pressure gradient of the protective dam for the observation periods of October-December 2007 and October 2020 at close NPR marks was not changed. Its value is much smaller than the critical pressure gradient of the flow through the protective dam body [3].

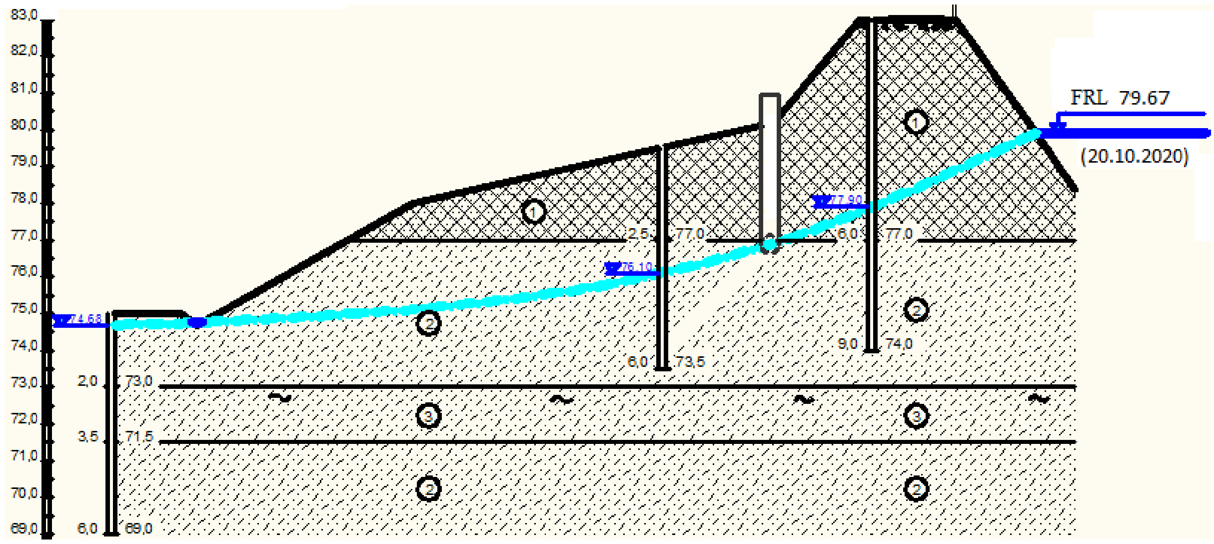

Fig.4. The position of the depression curve of filtration flow at KP44+50

Table 2

Pressure gradients of the filtration flow through the body of the Tyasmynska dam

№	December 2007 FRL (full reservoir level) 79.28 m		October 2020 FRL (full reservoir level) 79.67 m		Average critical flow gradient for the dam body [3]
	Measuring section location	Average calculated pressure gradient of the dam body	Measuring section location	Average calculated pressure gradient of the dam body	
1	KP 36+85	0.05	KP 37+60	0.07	1
2	KP 41+00	0.06	KP 40+75	0.06	1
3	KP 43+35	0.03	KP 44+50	0.04	1

Assessment of the drainage system operation. Flow rates were measured at four water outlets that drain drainage water to determine the flow rate of the drainage system (Table 3).

The water level in the Kremenchuk Reservoir in October 2020 was 79.67 m. The drainage water was transparent, and no soil particles were observed in it, which indicates the absence of mechanical suffusion in the body of the protective dam.

Table 3

Flow rates in the places of drainage runoff discharge

Place of discharge	Flow rates, l/s	
	October, 2007	October, 2020
Supply canal KP46+30	2.14	3.2
Dam canal KP37+50	3.26	1.5
Dam canal KP42+60	0.57	5.0
Supply canal KP47+00	0.17	2.18
In total	6.14	11.88

Thus, it was determined that the drainage flow rate is 11.88 l/s when the water level in the Kremenchuk Reservoir is 79.67 m and has increased almost twice compared to 2007.

CONCLUSIONS AND PROPOSALS REGARDING INCREASING THE STABILITY OF THE TYASMYNSKA PROTECTIVE DAM

1. The survey of the technical condition of the monolithic reinforced concrete lining of the upper slope of the dam showed that the main type of destruction is the destruction of isolation joints between the slabs as a result of wave action, ice load, changes in the temperature regime, as well as the development of both transverse and longitudinal cracking;
2. The filtration regime of the dam is safe since the effective average pressure gradient of the protective dam body is 17-25 times lower than the average critical pressure for the dam body;
3. Given that 100% of the joints of monolithic reinforced concrete slabs were destroyed, the technical condition of the upper slope lining is assessed as unsatisfactory and needs repairing;
4. The applied design of the isolation joint between the reinforced concrete slabs of the upper slope lining when using metal staples for fixing wooden boards leads to the destruction of concrete areas within joints.

Given the above, the following recommendations are proposed for increasing the stability of the Tyasmynska protective dam:

1. It is necessary to repair the road and the ground surface of the protective dam crest since the chuckholes formed on the road and ground surface act as precipitation accumulators;
2. It is necessary to carry out repair work to restore the destroyed joints between monolithic reinforced concrete slabs of the upper slope and in the areas of slab destruction;
3. Given that passing motor vehicles along the crest of the protective dam leads to expanding the dam, and, as a result, lowering the crest level, it necessary to prohibit the use of the crest of the protective dam as a road;
4. To ensure the stability of the structure due to reducing the wave load, it is recommended to install a breakwater made of stone with a fraction of 100-600 mm at the level of the design FRL.

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Hydraulic engineering and irrigation

SCIENTIFIC PRINCIPLES OF RESTORATION OF THE ENGINEERING INFRASTRUCTURE OF THE WATER MANAGEMENT AND RECLAMATION COMPLEX OF UKRAINE

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Annotation. The paper substantiates the expediency and possibility of a significant increase in irrigation (up to 1.1–1.4 million ha) and drainage (up to 1.0 million ha) areas by restoring the technical condition of the existing engineering infrastructure of the water management and reclamation complex of Ukraine. It is possible to increase the area of irrigation and drainage through the implementation of investment projects on the reconstruction and modernization of the existing infrastructure of reclamation systems against the background of the anticipatory implementation of the institutional reform of the water management system and land reclamation by the tasks of the Irrigation and Drainage Strategy in Ukraine until 2030 and the Action Plan for its implementation. Investment projects should be developed based on the data of the engineering infrastructure inventory of reclamation systems and land of inter-farm and intra-farm networks separately, given the available water volumes. These projects should involve improving the efficiency of irrigation water and energy use as well as the environmental safety of irrigation and drainage. Restoring the effectiveness of the water management and reclamation complex in Ukraine will also require involving water resources from the Danube River.

Keywords*:* engineering infrastructure, reconstruction, modernization, institutional reform.

INTRODUCTION

Soil and climatic conditions of Ukraine are quite favorable for the cultivation of many types of crops, which is proved by the centuries-old experience of agricultural development. According to the conclusions of the Food and Agricultural Organization of the United Nations (FAO), Ukraine belongs to the states that in the future can become global food donors, and its agricultural resource potential allows agricultural production in amounts sufficient to provide food for at least 400 million people. Currently, no more than a third of these opportunities are used due to the progressive increase in the deficit of natural moisture supply, resulting from climate change [1,2] and the unsatisfactory operation of the engineering infrastructure of the water management and reclamation complex of Ukraine. The crisis in the use of the engineering infrastructure of the water management and reclamation complex is due to physical wear and the improper operation of state-owned inter-farm networks, as well as the absence of an effective owner due to the legislative uncertainty regarding the ownership of intra-farm networks, which led to their significant deterioration and plundering.

Purpose of research is to develop the scientific basis for restoring the engineering infrastructure of the water management and reclamation complex of Ukraine.

RESEARCH METHODS

Theoretical generalization, statistical, and expert analysis.

RESEARCH RESULTS

According to official statistical data, for today, there are 2.17 million hectares of irrigated land and 3.3 million hectares of drained land with appropriate engineering infrastructure (reservoirs, main and distribution canals, protective dams, pumping stations, pipelines, daily regulation basins, collector and drainage network, and other hydro-technical structures and objects) in Ukraine. According to the Law of Ukraine "On Land Reclamation," the existing engineering infrastructure is divided into inter-farm and intra-farm. Inter-farm irrigation systems include 423 main water intake facilities, 1.730 pumping stations, and 96 reservoirs with a useful capacity of 463 million m3. The length of the permanent irrigation network is 7.3 thousand km, including 3.3 thousand km of canals and 3.9 thousand km of pipelines. By expert assessments, the technical condition of inter-farm networks at the beginning of 2022 was satisfactory for withdrawing and supplying water for irrigation for an area of at least 1.2 million hectares (excluding the Autonomous Republic of Crimea).

Even though the engineering infrastructure of reclamation systems was built in Soviet times, it was mostly (up to 70%) in working condition in the pre-war period. Today, it is technically outdated, energy inefficient, and needs reconstruction and modernization.

The situation with intra-farm reclamation networks is much worse. Due to uncertainty regarding ownership of these networks during the years of Ukraine's independence in the time of land reform, they turned out to be ownerless, which caused their physical deterioration and plundering. Only a part of the irrigated land, where agricultural producers took over the operation of intra-farm networks on their initiative, the technical condition of the irrigation networks is suitable for irrigation. However, the area of such lands in recent years (before the beginning of the full-scale military aggression of the Russian Federation against Ukraine, excluding the Autonomous Republic of Crimea) did not exceed 550 thousand hectares, and in 2023 it was only 100,000 hectares. Thus, there is inconsistency in the capabilities of inter-farm and intra-farm networks regarding irrigation in Ukraine.

The actual irrigation area mainly accounts for intra-farm irrigation networks. There is no reliable data on the technical condition of intra-farm networks that are not currently in use, so the issue of restoring irrigation within intra-farm networks can be relevant only after their inventory and addressing the ownership issue. Given the fact that the operation of inter-farm irrigation systems (networks) during the entire period of Ukraine's independence was carried out in the conditions of chronic underfunding and the lack of reconstruction and modernization in many cases, especially irrigation systems built in the 60s and 70s of the last century (Inguletska, Low-Dniester, North-Rohachytska, North-Crimean Canals, etc.), the technical condition of their engineering infrastructure is critical with the threat of destruction. So, further delay in their reconstruction and modernization poses a severe threat to the possibility of restoring irrigation on such systems. Therefore, the issue of restoring the engineering infrastructure of reclamation systems through developing and implementing projects on reconstruction and modernization of the existing infrastructure has long been on the agenda [3,4,5,6].

However, under the existing system of water and land reclamation management, which in practice remained Soviet until 2021 and combined mutually exclusive functions, in particular, water and reclamation infrastructure management at the background of uncertainty with ownership rights to intra-farm networks, the implementation of such projects is impossible both in the state-owned inter-farm networks and in the intra-farm networks, which for the most part remain ownerless.

Thanks to the direct participation of Ukrainian scientists when involving government officials, agricultural producers, public representatives, and World Bank experts, in 2019, the Cabinet of Ministers of Ukraine developed and approved the "Irrigation and Drainage Strategy in Ukraine until 2030" [7]. In 2020, the "Plan of Measures for the Implementation of the Irrigation and Drainage Strategy in Ukraine until 2030" was approved [8]. These documents at the government level established a new state policy on the development of land reclamation, the main goal of which is to establish an effective and efficient sector of irrigation and drainage services in Ukraine, managed with the participation of water users, which will ensure the sustainability of agriculture in the face of climate change, as well as to specify priority measures, the implementation of which will allow increasing the irrigated area by 1.0–1.2 million hectares and bringing the total irrigated area to 1.5–1.7 million hectares by 2030.

In 2020, the Ministry of Agrarian Policy and Food of Ukraine and the Ministry of Ecology and Natural Resources of Ukraine, when involving scientists and public representatives, started work on the draft Law of Ukraine "On Water Users Associations and Stimulation of Hydrotechnical Land Reclamation" adopted in 2022. [9]. However, the implementation of the Strategy of Irrigation and Drainage in Ukraine until 2030 became much more complicated with the beginning of the full-scale military aggression of the Russian Federation against Ukraine, as a result of which the largest irrigation systems of Ukraine turned out in the temporary occupied by the Russian Federation territories, and continue to suffer significant damage and destruction. Therefore, the restoration of the effectiveness of the water management and reclamation complex of Ukraine is necessary to provide the economy and the population with water resources and create favorable conditions for the socio-economic and ecologically balanced development of the regions as a basis for the sustainable development of the state's economy. According to the World Bank, as of June 1, 2022, the damage caused to the irrigation infrastructure exceeded 200 million dollars, and it continues to grow.

The damage caused to the dams of the Kakhovka HPP (June 6, 2023) is particularly worrying, as a result of which the water level and volume in the Kakhovka reservoir could not provide the required water supply volume to the North Crimean Main Canal. Due to the flooding of the main pumping station, it was impossible to provide the water supply to the Main Kakhovka Canal either. Therefore, the development of a feasibility study for the restoration of the Kahovka reservoir and for attracting water from the Danube River as the main source of water for the restoration of irrigation in the Odesa and Mykolaiv regions, as well as an additional water source for the restoration and development of irrigation and solving the problems of water supply in the settlements of Kherson, Zaporizhzhia, Donetsk, Mykolaiv, Dnipropetrovsk regions and the Autonomous Republic of Crimea is currently relevant and necessary.

Despite that, the temporary loss of control over the irrigation infrastructure located in the temporarily occupied territories is not a reason for failure to fulfill the tasks of both the Irrigation and Drainage Strategy in Ukraine until 2030 and the Action Plan for its implementation. Moreover, the situation created by the full-scale aggression of the Russian Federation requires accelerating their implementation. In these conditions, it is important to have a clear, scientifically based vision of the content and sequence of actions to ensure increasing the irrigation and drainage areas in the territories that were not affected by the aggression of the Russian Federation and on the de-occupied territories after their liberation.

According to preliminary estimates of the Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences of Ukraine on the irrigated land of Ukraine (Kherson, Mykolaiv, Zaporizhzhya, and Dnipropetrovsk regions), the costs for the restoration of the engineering infrastructure of the water management and land reclamation complex range from 91,421 to 117,019 UAH/ha. On drained lands (Volyn, Rivne, Zhytomyr, Kyiv, Chernihiv, and Sumy regions), such costs range from 44,614 to 62,898 UAH /ha.

Together with the experts of the World Bank, the Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences of Ukraine has developed a methodology for rapid assessment and determination of the need for the restoration in the water management and reclamation complex of Ukraine. The overall cost of the specified needs, estimated by the scientists of IWPLR is about 329.12 billion UAH.

In our opinion, first of all, it is necessary to complete the institutional reform of the water and land reclamation management system in terms of the legislative establishment of the institute of national and regional operators of management and operation of inter-farm reclamation infrastructure, including irrigation. It can be done by adopting as soon as possible the Law of Ukraine "On Amendments to Certain Legislative Acts Regarding the Improvement of the Management System of Engineering Infrastructure

Objects of State-Owned Land Reclamation Systems" which also belongs to the priority tasks of improving the legislative support for the development of land reclamation in Ukraine.

It is necessary to emphasize that the absence of provisions on the national operator in this law, as well as emphasizing the significant role of water users in the management of specific irrigation and drainage systems by establishing a quota of their representation in the supervisory boards of the relevant operators as two-third of their composition, will avoid forming necessary prerequisites for attracting investments, especially foreign ones, for the implementation of reconstruction and modernization projects of state-owned inter-farm networks. Given the above-mentioned, the amendments and adoption of this law are a priority task on the way to the implementation of the institutional reform of the water and land reclamation system and have to provide for strengthening the role of the state not only in terms of reclamation infrastructure operation but also in the implementation of reconstruction and modernization investment projects.

The next step should be the completion of transferring engineering water management and reclamation infrastructure from the balance sheet of the State Water Agency to the balance sheet of the State Fisheries Agency. Along with that, all property, equipment, and means of production, which in previous years were in the ownership of regional and interdistrict land reclamation and water management administrations and later in the ownership of river basin administrations, must be transferred. Without this measure, the State Fisheries Agency of Ukraine will not be able to ensure the proper operation of the obtained engineering water management and land reclamation infrastructure. Based on the transferred infrastructure, national and regional (local) operators should be established, the main function of which will be infrastructure operation, as well as planning and implementation of reconstruction and modernization investment projects to provide water supply and drainage services for water users associations, which are established simultaneously by the Law of Ukraine "On Water Users Associations and Stimulation of Hydrotechnical Land Reclamation".

The first step of the newly established water users associations and operators should be an inventory of the infrastructure and land intended for hydro-technical reclamation, registered as property for water users associations and managed by the operators. Such an inventory will involve new methodological approaches that will consider the main provisions of the resolutions of the Cabinet of Ministers of Ukraine "On Amendments to the Procedure for Conducting Land Inventory" and "On Amendments to Certain Acts of the Cabinet of Ministers of Ukraine on Stimulating Land Reclamation" adopted in 2022.

The inventory results of the land and infrastructure intended for hydro-technical reclamation must be sufficient for the registration of property rights to both the infrastructure and land in the State Land Cadastre of Ukraine, as well as contain all the necessary information about the technical condition of reclamation infrastructure objects and the state of land use for developing a feasibility study (FS) for the investment projects on the infrastructure reconstruction and modernization. The inventory results should also be the base for determining the extent of the damage caused to land infrastructure due to the military actions of the Russian Federation against Ukraine.

The extent of damage when developing the feasibility study for reconstruction projects should be determined as a separate cost component to be compensated at the expense of the Russian Federation when implementing such projects. Plans for the post-war reconstruction of irrigation systems must be executed by developing and implementing investment projects for reconstruction and modernization of the existing irrigation infrastructure, which will allow for increasing the irrigated area with lower capital costs compared to new construction. Implementation of such projects is aimed at ensuring significantly higher efficiency of irrigation water and energy use and ecological safety of irrigation.

That can be achieved by the predominant use of drip irrigation, low-intensity, and low-pressure irrigation, the latest types of pumping equipment with adjustable drives, geomembrane anti-filtration coverings of canals, compensatory ecologically safe irrigation regimes, information technologies for controlling water distribution and irrigation processes.

Projects of reconstruction and modernization of inter-farm systems (networks), the customers of which must be relevant operators, must provide for measures aimed at significantly increasing the energy efficiency of water supply, reducing non-productive water losses during transportation, and negative impact on the surrounding natural environment. They should be developed based on inventory data and financial, technical, and energy audits, and they have to include:

- replacement of outdated, energy-inefficient pumping and power equipment with modern, less energy-intensive ones with adjustable drives at the main and intermediate pumping stations;
- installation of anti-filtration linings using the latest geomembrane materials or replacement of open water supply networks with closed ones using glass composite and glass polymer pipes of large (up to 4 m) diameter, which allows for supplying water under a pressure of up to 25 atm and exclude water losses during transportation. At that, the full supply factor (FSF) can be 0.97;
- arrangement of inter-farm networks with systems of automatic water accounting, water distribution, and drainage;
- transition of reclamation infrastructure, when applicable and economically feasible, to autonomous energy supply using renewable (wind, solar) energy sources.

The development and implementation of projects for the reconstruction and modernization of inter-farm irrigation systems must be preceded by an assessment of their water supply, given the impact of climate change on reducing river flow, increasing crop water consumption under irrigation, which, according to preliminary expert assessments, leads to a decrease in the design capacity of irrigation systems built in previous years by 30–40%.

Under the current conditions of the progressive rising territory aridity of Ukraine due to climate change, the amount of the Dnieper water (provided 70% of Ukraine's water needs) accumulated in the cascade of the Dnieper reservoirs and available for use will continue to decrease while the restoration and development of irrigation will require an increasing amount of water. At present, the issue of attracting additional water resources is very decisive in terms of irrigation development and implementation of the post-war reconstruction plans for Ukraine. Therefore, the only possible source of additional water resources for Ukraine is the Danube River.

In this regard, developing a feasibility study for the project on attracting the Danube River water is urgent, as it is provided for in the Action Plan for the Implementation of the Irrigation and Drainage Strategy until 2030.

CONCLUSIONS AND RECOMMENDATIONS

Restoring the effectiveness of the water management and land reclamation complex of Ukraine is necessary to provide the economy and population with water resources and create favorable conditions for socio-economically and ecologically balanced development of the regions as a basis for the sustainable development of the state's economy. Restoration of irrigation and drainage to the extent that will be able to compensate for the negative impact of climate change on the sustainability of agriculture will require involving the water resources of the Danube River and have to be executed by the development and implementation of investment projects for reconstruction and modernization of the existing infrastructure.

The development of these projects must be preceded by the institutional reform of the water and land reclamation management system and the establishment of water users associations and national and regional operators that will operate the existing and restored engineering infrastructure. Projects on increasing water supply and restoring irrigation and drainage have to become a mandatory component of Ukraine's post-war reconstruction plans, as sustainable socio-economic development in the face of climate change is possible only with adequate water supply.

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Environmental protection

THE RESTORATION OF ANTHROPOGENICALLY DAMAGED NATURAL-TERRITORIAL COMPLEXES OF UKRAINIAN POLISSIA IN THE CONTEXT OF CLIMATE CHANGE ADAPTATION AND POST-WAR RECOVERY

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Annotation. The article is dedicated to the challenges of restoring anthropogenically altered natural-territorial complexes of Polissia in Ukraine in the context of adapting to climate change and post-war recovery. A comprehensive analysis of the state of land resources and the land fund of the Polissia zone of Ukraine in six physiographic regions of Polissia has been conducted. The authors have established that the most significant degradation processes in the Polissia zone due to climate change are water and wind erosion of soils, land flooding, acidification, salinization and salinity of soils. One of the key strategies for restoring anthropogenically disturbed landscapes in the Polissia zone of Ukraine is recultivation and renaturalization. This involves the removal of unproductive lands (primarily eroded and economically unprofitable) from the state of actively used lands. These lands are then alkalised, afforested, and some are subjected to different phases of restoration successions to facilitate the return of natural vegetation cover.

Keywords: degradation, land resources, climate change, natural-territorial complexes, rehabilitation, renaturalization.

INTRODUCTION

Anthropogenic pressure on the environment has caused significant technogenic damage to the agrosphere for many decades. Climate change towards aridisation and a decrease in hydrothermal coefficients in the Polissia region of Ukraine are causing dysfunction of the soil profile and failing to ensure the reproduction of groundwater resources. There are harmful environmental consequences for the Polissia region and obtaining a regional character, which, in general, poses a threat to the ecological security of the state and has to be addressed immediately and adaptation measures developed. Gradually, the natural environment is losing the ability to self-regulate.

The Polissia of Ukraine's land resources has a justly high bioproductive potential. Their feature is a high level of wetlands and waterlogging of the territory. Wetlands and waterlogged lands raise over 20% of the region's total area or 44% of the agricultural land area. Land use problems are associated with anthropogenic degradation caused by changes in the conditions of soil formation against the background of intensive drainage reclamation.

As a result of the full-scale invasion of Russian troops, there is a colossal anthropogenic load on the lands of Polissia, Ukraine. Destroyed enterprises, military equipment, and oil products have resulted in significant poisoning of the territory. Currently, about 20% of the land is subject to such pollution.

MAIN PART

Having analyzed the state of land resources and the land fund of the Polissia zone of Ukraine in six physical-geographical regions of Polissia (according to the date of the State Service of Ukraine for Geodesy, Cartography and Cadastre) (Fig. 1), we identified the following features.

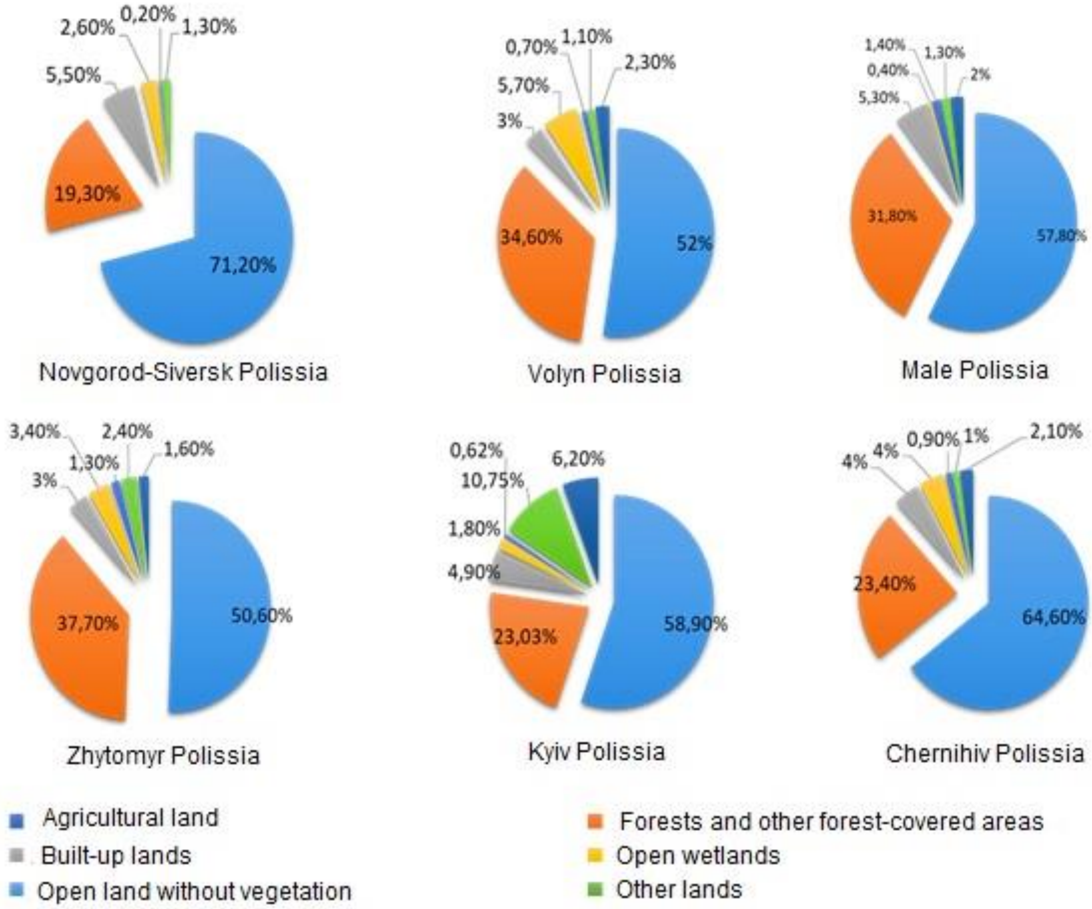

Fig. 1. The structure of the land fund of the Polissia of Ukraine

- The highest level of intensity of use of land resources is observed in Novgorod-Siverskyi Polissia. The share of agricultural land is 71.1% of the total area of Polissia and indicates a high level of agricultural development and excessive plowing of the territory. Of them, arable land is 51.9% (1237.7 thousand hectares), hayfields and pastures 18.2% (434.3 thousand hectares) and perennial plantations 1% (22.7 thousand hectares).
- Zhytomyr Polissia boasts the highest forest cover (37%) and the lowest level of economic development. The current condition of agricultural land soils is quite problematic. It is common for soils to experience erosion, humus loss, salinization, acidification, and compaction.
- Volyn Polissia has the highest concentration of wetlands, with 5.7%, mostly comprised of lowland marshes. In the arrangement of the soil cover, significant areas (1,076.7 thousand hectares or 56.7%) are occupied by hydromorphic soils, among them - meadow-swamp, marsh, peat-swamp and peat - 411.4 thousand ha (21.7%). The amount of anthropogenically altered soils created by drainage is 59.2 thousand hectares.
- The highest percentage of land occupied by water is typical for the territories of Kyiv Polissia, through which the Dnipro River flows with massive areas of reservoirs (Kyiv region – 6.24%, Kyiv city – 8.01%). The reservoirs caused the flooding of approximately 10,000 hectares of agricultural land in the affected areas.

The situation became unstable due to the excessive agricultural development and plowing of the territory, which was a consequence of extensive agricultural production and non-compliance with agro-ecological requirements of land use.

- The land fund of Chernihiv Polissia's structure is dominated by agricultural land. The land fund has a total area of 3,190.3 thousand hectares, and agricultural land is up to 2,060.4 thousand hectares (64.6%). The intensity of agricultural land use in Chernihiv Polissia exceeds the ecologically justified standards almost twice.
- The land fund of Maly Polissia is 2,183.1 thousand ha, which is 3.6% of the territory of Ukraine. Agricultural land covers 1261.5 thousand hectares (57.8% of the total area). They are mainly swampy, unproductive and in need of drainage, the main type of use is pastures (443.5 thousand hectares). A significant share of the land is occupied by forests (694.7 thousand ha). The land supply of Maly Polissia is one of the lowest in Ukraine. On average, one inhabitant has 0.47 hectares of agricultural land, including 0.30 hectares of arable land, which is half as much as in Ukraine. There are also processes of reducing the content of humus in soils, expanding the area of acidic (their share reaches 24%) and eroded soils (41.4% of agricultural land), which, in turn, affects the reduction of the area of agricultural land.

The most large-scale degradation processes of the Polissia zone due to climate changes are water and wind erosion of soils (57%), land flooding (12%), acidification (18%) and salinization of soils (6%).

Military actions also cause mechanical, physical and chemical effects on the soil. Under the influence of the military-technogenic load, the degradation of the soils of Polissia is increasing, namely: loss of humus and nutrients; overconsolidation; siltation and crust formation; water erosion, especially with the formation of ravines and the side effects due to the siltation of water bodies; acidification; waterlogging.

Chernihiv Polissia is one of the regions of Ukraine most damaged by ecocide. According to the Ukrainian Environmental Protection Group, there are some areas where experts have counted approximately 2,052 craters from various shells on just one square kilometer of field, which in terms of soil pollution equivalent means 50 tonnes of iron, a tonne of sulfur compounds and almost 2.5 tonnes of copper. Another effect of military action is the acceleration of climate change through increased emissions of greenhouse gases into the atmosphere [1].

The state of military destruction of soils will determine the most appropriate use of these lands. This will include growing crops that can absorb heavy metals and thus clean the soil; growing bioenergy crops; reforestation; and withdrawal from agricultural use.

Thus, under the influence of agricultural use, climate change and Russian aggression, there have been significant negative landscape changes that require rehabilitation measures. In principle, the following options for the restoration of anthropogenically disturbed natural and territorial complexes of Polissia of Ukraine are possible: conservation, recultivation and renaturalization of lands in the context of adaptation to climate change and post-war reconstruction (Fig. 2).

As a result of the full-scale hostilities, some lands in Novhorod-Siversk, Chernihiv, Volyn and Kyiv Polissia were mined, while others were contaminated with harmful and poisonous chemicals and mechanically deformed as a result of the spontaneous construction of fortifications (trenches, trenches, tunnels) and the movement of wheeled and tracked vehicles.

There are two international practices to address these issues: recultivation and conservation. In line with Article 166 of the Land Code of Ukraine, the reclamation of damaged lands is carried out for their recovery from agricultural, forestry, water management and other purposes [2].

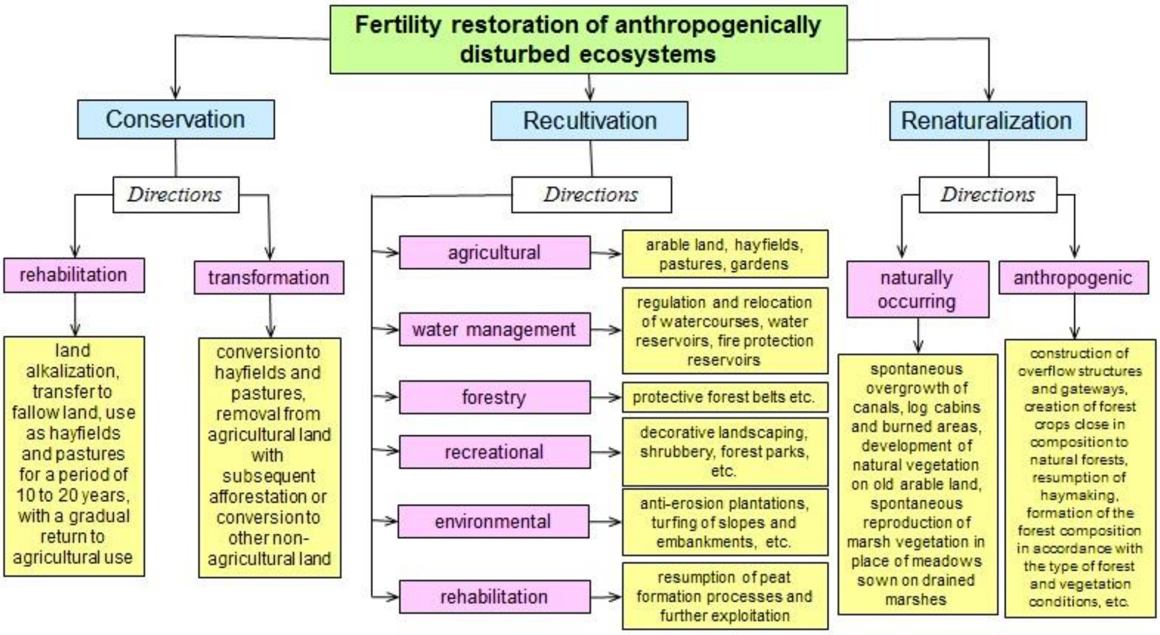

Fig. 2. Methodological approaches to land conservation, recultivation and renaturalization

Currently, approximately 250,000 ha of degraded peat soils and manufactured peatlands are subject to recultivation and renaturalization processes [3]. Ultimate utilization of these lands will be contingent upon the prevailing regional circumstances and the identification of suitable projects. The choice here is wide – nature conservation with the possibility of cultivating swamp plants, creating recreation areas, plant-medicinal and berry plantations, forestry or agriculture, conducting highly productive cultivation, obtaining raw phytomass as an alternative source of energy, etc. The renaturalization direction of the development of degraded peatlands is biospherically significant as it restores the ecological functions of these lands, lost as a result of their land reclamation, irrational use and extraction [4].

Recultivation uses technologies selected according to the type of soil, relief, climatic conditions, and also to cleanse the land of pollution and normalize soil characteristics (Fig. 3). But such technologies are not cheap and can cost $30-300 a square meter of soil. Considering the area of polluted land in Polissia, this approach is hardly feasible on a mass scale.

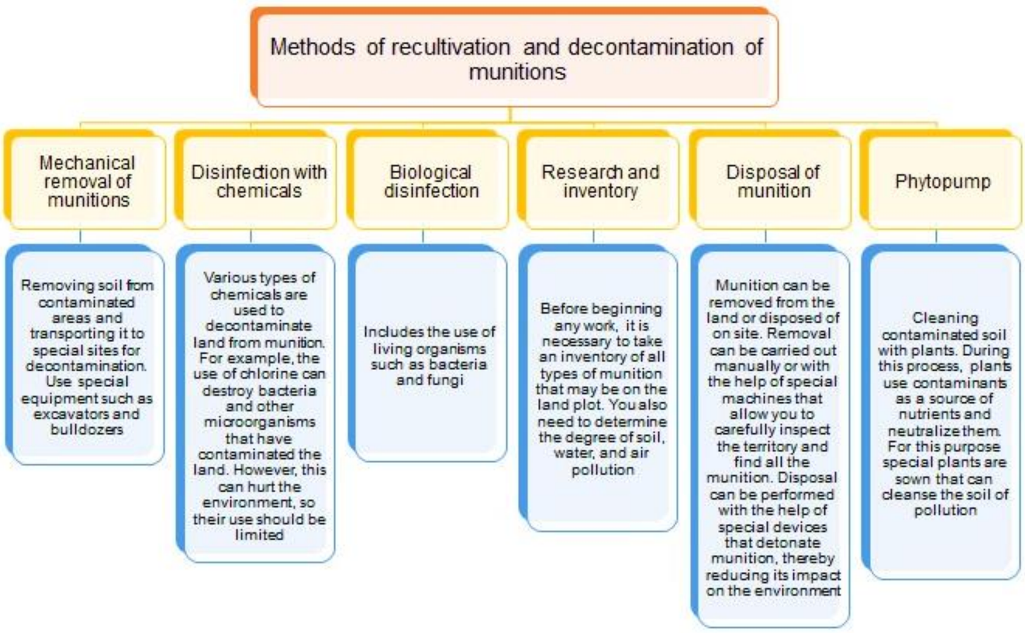

Fig. 3. Methods of recultivation and decontamination from munitions

The degradation of land, which is a consequence of damage, results in a loss of productivity and an increase in the risk of harm to consumers. Accordingly, by Article 172 of the Land Code of Ukraine and Article 51 of the Law of Ukraine "On the Protection of Lands," such lands are subject to conservation. Conservation involves the cessation of the targeted use of land contaminated by hostilities for a certain period with the implementation of reclamation or soil protection measures.

Another approach to the recovery of Polissia lands damaged by military and technological pressure is their renaturalization, which involves the removal of some unproductive lands (primarily those that are eroded and economically unprofitable) from actively used status with their consistent logging and afforestation, and some of them for different stages of recovery succession to return the natural flora [5].

It is important to note that the legislative and regulatory framework for the conservation and rehabilitation of Ukrainian lands has been developed. This base does not yet exist for the renaturalization of lands.

During the renaturalization of lands, it is important to carry out the following complex scientific and practical works, namely: inventory of drained lands; development of a general scheme of land renaturalization; carrying out a complex of engineering-geodetic, engineering-geological, reclamation-hydromechanical, hydrogeological investigations; development of a set of measures to restore water levels both at renaturalization sites and in adjacent territories and assessment of the impact of the planned measures on the environment [6].

The restoration of the natural regime of the renaturalization areas will make it possible to increase the environmental stability of the territory, improve water management, promote the development of territories, and combine the protection and conservation of biological and landscape variety with the creation of conditions for rest, development of green tourism and other types of recreation in combination with the development of livestock, increase the efficiency of organization and management of agricultural production in Polissia of Ukraine.

In the context of the war and global climate change, Ukraine's Polissia is gradually losing its water-regulating capacity, so a set of measures is needed to build adaptive capacity, reduce risks and overcome the expected consequences. The creation of prognoses for the evolution of degradation processes in soils under diverse climatic and anthropogenic stressors will facilitate the formulation of informed management solutions for the rational and balanced utilization of soils or the selection of the most rational direction for the restoration of anthropogenically impacted natural-territorial complexes of Polissia in Ukraine.

CONCLUSIONS AND RECOMMENDATIONS

The land resources of the Polissia of Ukraine exhibit a relatively high bioproductive potential. One noteworthy characteristic of the area in question is its high level of wetlands, which is further exacerbated by the prevalence of waterlogging in the territory. Wetlands and waterlogged lands account for a significant proportion of the total area of the region, representing over 20% of the total area or 44% of the area of agricultural land. Land use problems are associated with anthropogenic degradation caused by changes in the conditions of soil formation. The most significant degradation processes in the Polissia region as a consequence of climate change are water and wind erosion (57%), flooding (12%), acidification (18%), salinization and salinity (6%).

It was determined that military actions cause mechanical, physical and chemical impacts on the soil. Under the influence of the military-technogenic load, the degradation of the soils of Polissia is increasing, namely: loss of humus and nutrients; overconsolidation; siltation and crusting; water erosion, especially with the formation of ravines and the side effects due to the siltation of water bodies; acidification; waterlogging, etc.

It was established that under the impact of agricultural use, climate change and russian aggression, significant negative landscape changes have occurred that need rehabilitation measures. The following options for the restoration of anthropogenically damaged natural-territorial complexes of Polissia of Ukraine are fundamentally possible: conservation, recultivation and renaturalization of land.

The development of forecasts of the development of degradation processes in soils under various scenarios of climate change and anthropogenic load will help to make informed management decisions regarding the rational and balanced use of soils or the choice of the most rational direction for the restoration of anthropogenically disturbed natural-territorial complexes of the Polissia of Ukraine.

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Hydraulic engineering and irrigation

ANALYSIS OF CONSTRUCTION WORKS FOR THE FOUNDATION OF A STEEL COLUMN STRUCTURE

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Annotation. Construction works require proper coordination and organization of the entire project. Starting from the concept, through design and construction, to the use and monitoring of the facility. Special objects are steel poles and masts supporting power traction cabling. This work shows the issues of carrying out construction works in the field on the example of a linear investment. The issue of placing steel masts in the construction of a power line was discussed in detail. The energy industry, as one of the most key and strategic factors of the economy for each country, is divided into many branches. One of them is energy engineering. The construction, modernization and maintenance of power plants and energy networks require the cooperation of engineers from various industries, including: construction workers, surveyors and constructors. The work presents the tasks that engineers must face during the construction of a tower and how their work affects the entire construction process.

Keywords: linear object, steel structure, foundation, earthworks

INTRODUCTION

This work shows the issues of carrying out construction works in the field on the example of a linear investment. The issue of placing steel masts in the construction of a power line was discussed in detail. The energy industry, as one of the most key and strategic factors of the economy for each country, is divided into many branches. One of them is energy engineering. The construction, modernization and maintenance of power plants and energy networks require the cooperation of engineers from various industries, including: construction workers, surveyors and constructors.

The work presents the tasks that engineers must face during the construction of a tower and how their work affects the entire construction process.

Implementation of a linear investment

At the beginning of the investment, thanks to the design documentation, the route of the power line is recreated in the field in relation to the geodetic network. RTK GPS devices are used here [1]. Also, thanks to satellite navigation and instruments for receiving signals and precisely determining coordinates, surveyors mark vertical axes of power pole structures, line axis and points indicating in which direction the arms of these poles are directed [2].

Supplies for high-voltage power lines are most often steel structures mounted on a foundation (Fig. 1). These structures are mounted either on prefabricated or monolithic foundations [3]. The construction of the foundation for the construction of a mesh gate used to connect the overhead power line with the main power supply point is presented in Figure 2 (Fig. 2). In this example, the site includes two "twin" monolithic foundations. They are symmetrically located in relation to the center of the station, i.e. at the same time the vertical axis of the steel lattice column [4].

Fig. 1. Steel structure of a 110 kV high voltage line pole *(own photography)*

Fig. 2. Monolithic foundations intended for a 72-meter-high power pole of a 400 kV line *(own photo)*

In order for the foundation to be built, an excavation had to be made (Fig. 3) and the outline of the foundation body had to be marked. A sketch with the location and dimensions of the foundations allows for geodetic marking [5] and precise excavation for the foundation (Fig. 4).

Fig. 3. Excavation for the foundation *(own photo)*

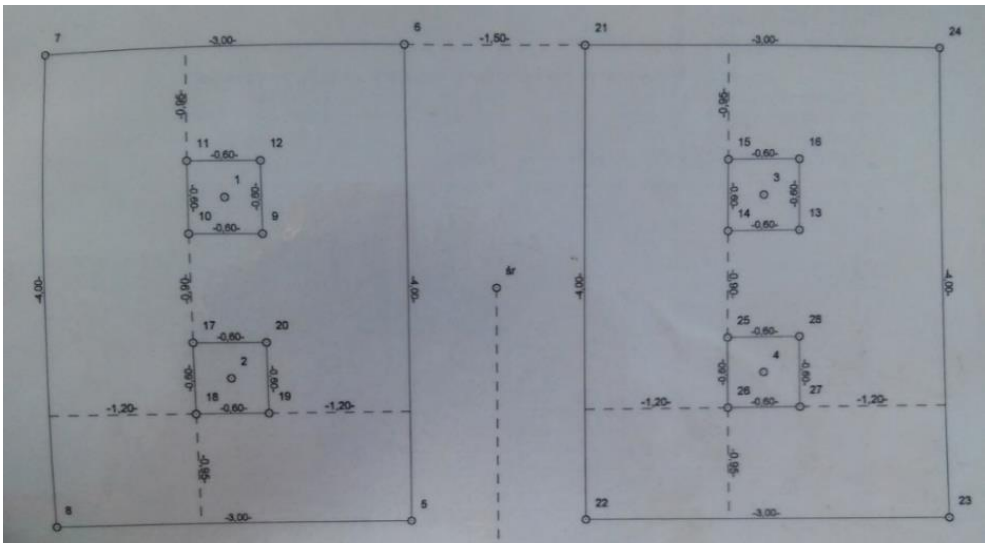

Fig. 4. Dimensioned twin foundations *(own photo)*

The next step was to make a foundation of lean concrete. Bituminous felt is spread and welded onto it, providing moisture insulation. An outline of the foundation footings is made and points for reinforcement and formwork are indicated [6].

Fig. 5. Installation of foundation reinforcement *(own photo)*

Reinforcement works begin with the reinforcement of the foundation footings. The vertical reinforcement of the pillars should be left exposed, from which the anchors and elements on which the steel structures are mounted will protrude on the surface (Fig. 5). When the reinforcement is ready, the foundation formwork is installed [7, 8]. After pouring concrete into the formwork and troweling its surface, downtime is required until the concrete sets (Fig. 6). It is then possible to complete the reinforcement of the columns coming from the footing, formwork them and precisely set the anchors in their upper parts (Fig. 7). Precision is guaranteed by control measurements performed with a total station by a surveyor [9].

Fig. 7. Filling the foundation "chimneys" with concrete mixture. The visible anchors on the gables are connections to the structure *(own photo)*

The use of this instrument and the pole method when building foundations will reduce the time needed to complete them and greatly simplify them. Nevertheless, they require constant attention and concentration. A common mistake made during measurements is inadvertently taking readings when the distance measurement function is incorrectly selected. Measuring distance in a straight line, in the direction in which the total station telescope is directed, is significantly different from measuring the horizon line. In the first phase of setting out the site on the ground surface, the difference in this error may be unnoticeable, but it is there and has a significant impact on the location of the foundation outlines, which will ultimately require correction [10].

Fig. 8. Ready foundations *(own photo)*

After building the foundations (Fig. 8) and installing the steel column structure on them, it is necessary to check whether the structure maintains the verticality of the symmetry axis. It is most often checked using a theodolite. The instrument is positioned in the main axes of the pole and checks whether the telescope's reticle runs along its axis throughout the entire height of the structure (Fig. 9).

Use and monitoring of structures

For documentation purposes, laser scanning of the constructed steel structure is also performed. An example result of a scanner measurement, i.e. a point cloud of a telecommunications mast, is presented in Figure 10 (Fig. 10). This cloud is a three-dimensional reflection of the actual geometry of the measured object. The point cloud obtained in this way allows you to check the correctness of construction and the verticality of the structure. Later, during its use, it enables stability control and monitoring of structure deviations [9].

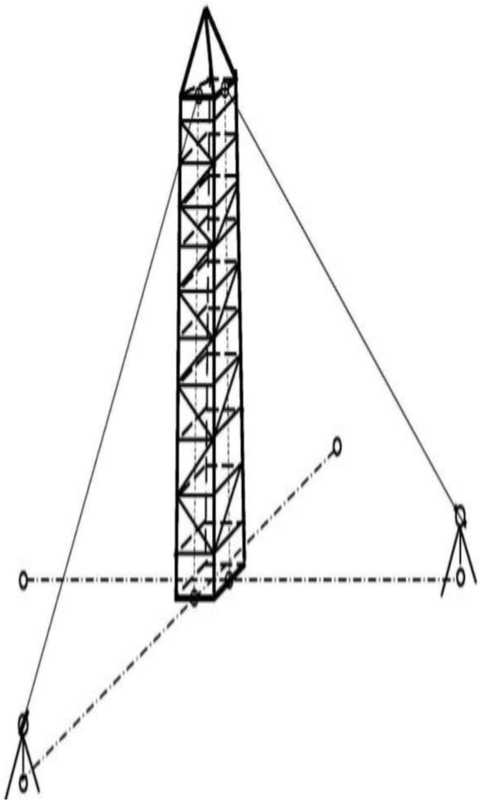

Fig. 9. Verticality control of the structure ***(Gocał 2010)***

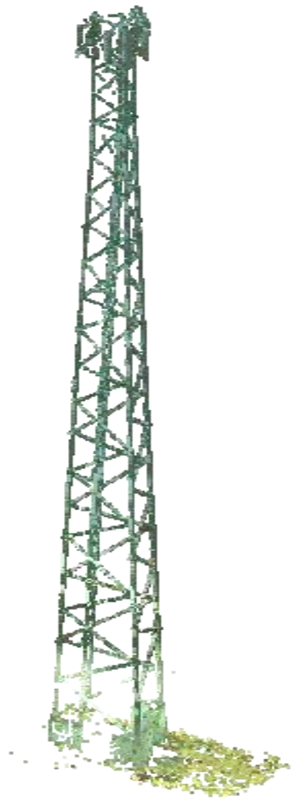

Fig. 10. Point cloud - scanned steel structure ***(own picture)***

Use and monitoring of structures

For documentation purposes, laser scanning of the constructed steel structure is also performed. An example result of a scanner measurement, i.e. a point cloud of a telecommunications mast, is presented in Figure 10 (Fig. 10). This cloud is a three-dimensional reflection of the actual geometry of the measured object. The point cloud obtained in this way allows you to check the correctness of construction and the verticality of the structure. Later, during its use, it enables stability control and monitoring of structure deviations [9].

Another element that requires control are overhead power cables. The measurement can also be performed with a total station or laser scanner. During their use, measurements are taken of the sag of the wire ropes, the vertical distance of the wires from the ground and the mutual vertical distance between the crossing lines. These data are necessary when designing and constructing new engineering facilities such as roads, highways or railway and water lines that run under power lines. Also, for reasons of safety and operational requirements, the designed stresses in the cables should be maintained during installation and throughout the entire period of operation. Therefore, in addition to the implementation of cable sag arrows during installation, inventory measurements must be carried out during the service life of the lines to control their current sag (Fig. 11) [11].

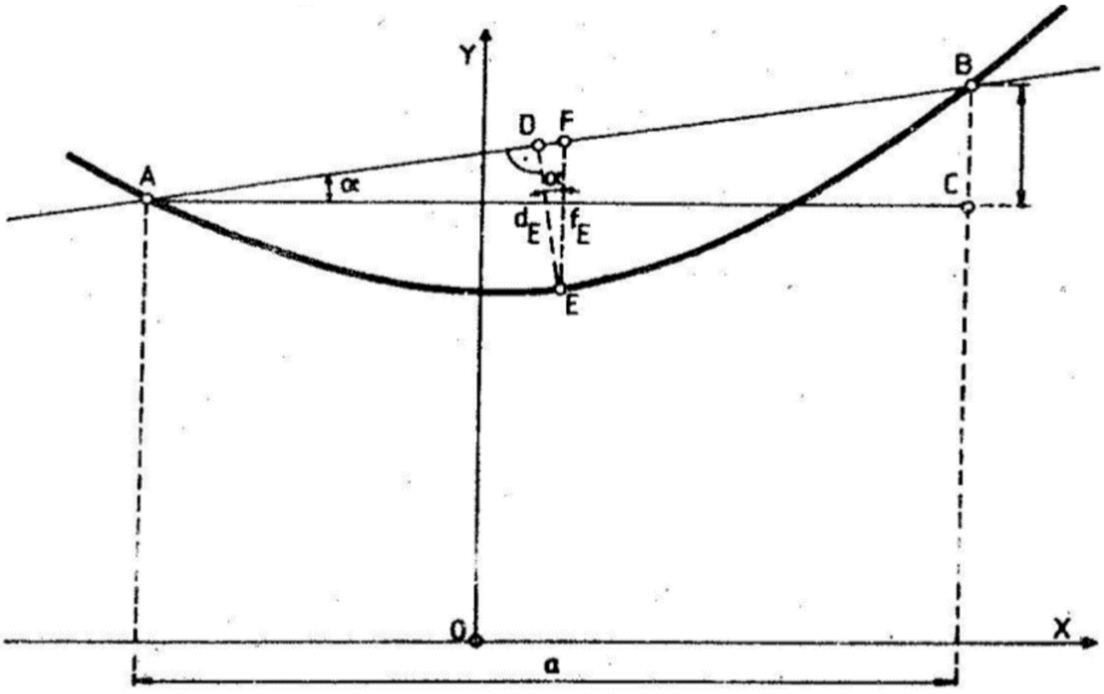

Fig. 11. Sag and deviation arrow ***(Gocał J. 2010)***

SUMMARY AND CONCLUSIONS

Construction works are closely related to the work performed by representatives of other industries. When designing a steel power pole, a constructor must also take into account the fact that the success of his project depends on other engineers. First of all, the success of the investment depends heavily on properly performed surveying and earthworks. Marking out the foundation is the task of the surveyor, but performing earthworks, foundations and reinforcement is essential for the steel structure to perform its functions well. The work presents various examples of tools and methods that are often used in this type of investments. It is important to use these tools skillfully and responsibly. The person responsible for the work must be competent and proficient in carrying out individual construction works. This will allow for safe and long-term use of the structure.

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