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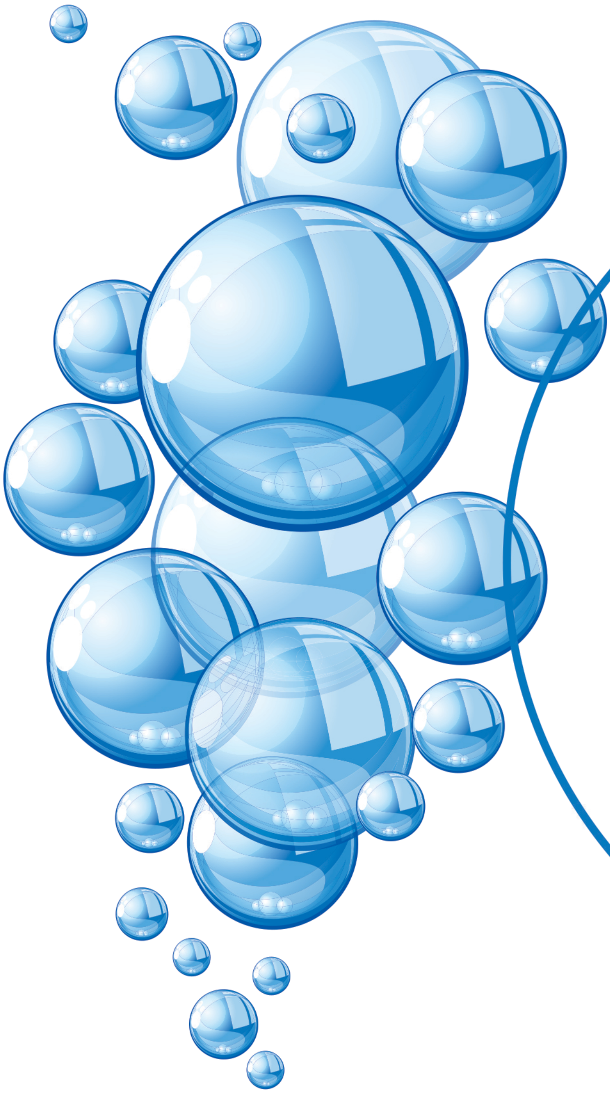

Water Resources Management: New Perspectives and Innovative Practices

PROCEEDINGS BOOK

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Water Resources Management:
New Perspectives and Innovative Practices

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PREFACE

The University of Novi Sad, Faculty of Technical Sciences hosted the **International Symposium "Water Resources Management: New Perspectives and Innovative Practices"** from 23rd-24th September 2021. The Symposium was a part of the activities realized under the CBHE KA2 project SWARM "Strengthening of master curricula in water resources management for the Western Balkans higher education institutions (HEIs) and stakeholders" co-funded by the Erasmus+ Programme of the European Union. SWARM project is implemented by a consortium made up of seven HEIs from the Western Balkan Region and six HEIs from Program Countries: University of Niš, University of Novi Sad, University of Priština in Kosovska Mitrovica, University of Montenegro, University of Sarajevo, Džemal Bijedić University of Mostar, Academy of Applied Sciences of Kosovo and Metohija, University of Natural Resources and Life Sciences from Vienna, Norwegian University of Life Sciences, Aristotle University of Thessaloniki, University of Architecture, Civil Engineering and Geodesy from Sofia, University of Rijeka, Faculty of Civil Engineering, Universidade de Lisboa, and Public Water Management Company "Vode Vojvodine".

The main objective of the SWARM project is the education of water management experts in the Western Balkan Region in accordance with the national and European Union policies. This objective is further broken down into the following specific objectives:

- To improve the level of competencies and skills in higher education institutions by developing new and innovative master programmes in the field of water resources management in line with the Bologna requirements and national accreditation standards.
- To design and implement new laboratories in Western Balkan HEIs, in cooperation with project partners from Program Countries.
- to develop and implement LLL courses for professionals in water sector in line with EU Water Framework Directive.

The International Symposium was an interdisciplinary forum where the research results and best practices in the field of Water Resources Management were shared with all SWARM fellows and stakeholders from the entire world. At the same time, the event was the place for the promotion of the SWARM results to a wider audience.

We would like to express our sincere thanks to all session chairs, keynote speakers, presenters, Organizing and Scientific committees, as well as to many others who contributed to the success of this Symposium.

We are confident that the solid foundation created by the SWARM project will continue to build up and strengthen our unique international network.

In Novi Sad, September 2021

Symposium Chairs

Maja Petrović

Milan Gocić

CONTENTS

STRENGTHENING WATER RESOURCES MANAGEMENT IN THE WESTERN BALKANS

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Abstract:There is an evident need for capacity building in higher education in the Western Balkan (WB) region in various scientific fields. Towards this direction, the European Commission under the Erasmus+ program for the higher education and key action 2 (KA2) funds projects related to the constant improvement of the educational process. This paper highlightsthe main achieved results and made conclusions during the implementation of one of the awarded Erasmus+ projects titled Strengthening of master curricula in water resources managementfor theWesternBalkans HEIs and stakeholders, with acronym SWARM.Special emphasis is put on innovative practices, competence-based curricula and acquiring new teaching and learning methods through theme-based training, lifelong learning courses (LLL), dissemination, exploitation and communication activities. SWARM's goal is to improve and build WB educational capacities, cooperation and competencies focused on water resources management issues through the implementation of various new and improved academic courses and seven new LLL courses intended for students and professionals in the water sector.

Keywords:higher education,innovative practices, lifelong learning, sustainability, water resources management, Western Balkan.

INTRODUCTION

Innovative solutions and interdisciplinary approaches should be applied to ensure water as a resource. According to the newest Intergovernmental Panel on Climate Change (IPCC) sixth assessment report, the water cycle is highly impacted by faster global warming. Therefore, strong cooperation between the academia and the water sector is needed to respond to the future challenges caused by climate change and its impact on this natural resource. On the other hand, the Western Balkan (WB) countries should harmonize procedures in the field of water resources management (WRM) in line with Chapter 27 of the European Union's (EU's) water management requirements. Higher education institutions (HEIs) in the WB region can help through the improvement of the existing curricula and the development of lifelong learning (LLL) courses for water professionals (Gocic, 2020).

The European Commission has funded strengthening the capacity of HEIs and their researchers through different types of programmes such as Erasmus+, Horizon 2020, and now through Horizon Europe. Erasmus+, as one of the three key actions,fosters cooperation for innovation and exchange of good practice in various scientific fields such as natural disasters risk management, water resources management, geoinformatics, geospatial data analysis (Hadzić et al., 2019, 2020). One of the projects selected for funding in the year 2018 is the SWARM (Strengthening of master curricula in water resources management for the Western Balkans HEIs and stakeholders, www.swarm.ni.ac.rs) project (Filkov, 2019; Karleusa, 2019; Skoulikaris and Ganoulis, 2020).

The overall goal of SWARM is to educate experts in the field of water resources management in WB in accordance with EU and national policies.This goal was complemented by the realization of thefollowing specific goals that are fully compliant with the priorities of capacity building projects in higher education:

- Improvement of the level of competences and skills in the WBHEIs by modernizing or developing new and innovative master programs in the field of water resources management in compliance with Bologna's requirements and national accreditation standards.
- Modernization of seven laboratories in WB HEIs in cooperation with the partners from theprogramme countries.
- Development and implementation of LLL courses in the water sector in accordance with the EU Water Framework Directive.

This project was realized by six partners from programme countries (Austria, Greece, Norway, Bulgaria, Croatia and Portugal), eight from the Western Balkan region and four associated partners. The achieved SWARM results are summarized in the next sections.

SHARING INNOVATIVE PRACTICES FROM THE EU WATER SECTOR TO WESTERN BALKANS

Water-related issues have become more complex and challenging in recent years, requiring more effective and efficient solutions to overcome these problems. Innovative solutions and valuable experience were gathered in academia and professional bodies alike, which are of great importance for future water resource managers. Therefore, cooperation between the educational sector and water management professionals is indispensable; an issue that was also presented by the programme countries. Several examples of innovative practices established in the EU and Norway, successfully tackling water-related issues and future challenges, were collected in a workshop held in the scope of the SWARM project in May 2019 in Vienna. The study cases covered various different aspects of water management in the SWARM partner countries, including trainings of professionals. As water resources management represents a wide field with no commonly acknowledged clear delineation of boundaries, this summary of the workshop, based on the corresponding report by Glock et al. (2019), aims at developing a view of exemplary approaches towards innovations in terms of tackling various regionally different issues:

In Austria, aformalised training system for operators of waste water treatment plants of different sizes and sewage systems was implemented. The system includes a special course for operators of small waste water treatment plants < 50 PE that has shown to be successful in greatly enhancing the skills of participants. Moreover, innovative sediment management methods for anthropogenically influenced surface water bodies have been studied in the course of the Christian Doppler Laboratory for Sediment Research and Management at BOKU Vienna. The project consists of three modules, tackling current issues in (i) sustainable hydropower, (ii) sediment management in river engineering and (iii) issues on the global scale.

In Bulgaria, a research project on water consumption of different crops in various climatic regions with different irrigation methods was carried out. This allows the Water Management directorates to issue permits for a suitable amount of water to be extracted for irrigation. Moreover, an optimization tool for efficient use of water was developed for the river basin management directorates. A research project on circular economy in the area of waste water treatment was carried out focusing, among others, on the reuse of sludge. Also challenges in using solar pumps for irrigation were investigated in order to make their use more practical.

In Croatia, the Faculty of Civil engineering as part of the University of Rijeka wereexplicitly promoting partnership and exchange between public institutions and private companies in water resource management.

The Norwegian partners in the SWARM project presented an innovation in water resource management by using DNA for biomonitoring of water quality. Moreover, the use of satellite data for monitoring coastal waters and lakes was studied. A non-targeted approach for studying organic substances in water was implemented. This should facilitate to also detect substances which were not initially anticipated.

In Greece, river basin and flood risk management plans have been developed for each of the 14 water districts aiming at the integrated management of the available water resources and of the derived challenges. The Nexus approach is applied taking into account the interdependencies between water resources, energy and food production. Moreover, a telemetric monitoring system providing real time data in flood events has been established.

Finally, SWARM partners from Portugal reported good practices in place for tackling water resources management challenges: (i) identification of vulnerable zones, (ii) assessment of the concentration of pollutants in water bodies and (iii) identification of groundwater dependent ecosystems.

In order to suggest which innovations should be addressed in terms of curriculum development as well as LLL activities, an analysis of strengths, weaknesses, opportunities and threats (SWOT) in terms of water management in the Western Balkans was performed within the scope of the workshop (Tritthart & Gocic, 2021). Besides noting that not all present weaknesses can be addressed in curricula, a relevant finding of this activity was the need for integrating soft skills (e.g. management, communication) in the process of curriculum content design.

HARMONISING WATER RESOURCE MANAGEMENT CURRICULA BETWEEN EU AND WESTERN BALKANS

The strategy for harmonization of WRM curricula between EU and WB Universities is presented based on the analysis and assessment of the various curricula in EU and WB Universities within the SWARM project.

A Catalogue of competences was developed which was used to make the appropriate links among subjects and competencies. A holistic approach to WRM requires professionals with multiple competencies. The catalogue summarizes two types of competencies: 1) generic (key, cross-curricular, core or transferable competencies across study areas) and 2) subject-specific competencies (competencies specific to a subject area).

There is global demand for effective water resources managers and consultants with an appreciation of the challenges of effective environmental management within a range of sectors. Successful water management is dependent on the development of integrated solutions. This requires social, political, institutional, legal, and financial, as well as scientific, technical and environmental awareness and understanding.

The harmonization and the development of the courses' content and the syllabi were based on the following steps which are described briefly as follows:

(1) The EU project partners created a report entitled "EU Universities' Courses and Syllabi". In the report the relevant courses on the thematic of WRM that are within the curricula of the EU Universities were identified and described. The report was used by the WB Universities as a guidance to develop their proposed courses.
(2) The project partners concluded on the new courses as well as the existing courses that wanted to be updated. The outputs of this process, (the proposed number of courses per institution) is summarized in a table (not shown here for the sake of brevity).
(3) A common format for the description of the courses was agreed upon among the WB project partners.
(4) The WB partners proposed the syllabus of the proposed courses. A consolidated document that included all the syllabus was created and was sent to the EU partners for their comments and reviews.
(5) EU partners proceeded in the review of the proposed courses, their content, objective, and teaching outcomes. A consolidated review was sent to the WB project partners.

(6) The WB partners carefully deliberated the revised courses. Many comments were accepted, but there were also a lot of comments that could not be accepted, such as the change of the name of a course, since this is a process that needs approval at the Ministerial level. A final report was produced including all the details for each WB University.

LIFELONG LEARNING – A KEY TO SKILLS UPGRADE IN THE WATER SECTOR

Lifelong Learning was set as a necessary tool for achieving competitiveness and use new technologies in the European region, that is focused on a knowledge-based society, as emphasized in the Prague Communiqué. Since then, the universities were aware of the need to include lifelong learning within higher education, in line with Bologna Process. Also, LLL has a great impact on achieving cross-cutting goals of education as well as a crucial role in meeting the needs of a labor market, as new professions are arising from the fast-changing technologies, and a growing need for new competencies in a changing world. However, in Europe based on the knowledge transfer and cooperation, the universities were given the central role in strengthening regional development by continuous upgrading of competencies and forming the knowledge alliances (2012 Bucharest Communiqué).

To identify topics in the field of water resources management, a comprehensive survey of employees in the water sector in the Western Balkans was conducted. A total of 1,136 respondents participated in the survey. That survey was used to tailor the trainings to meet the needs of each WB country regarding water-dependent jobs. The survey has also provided data on the water sector professionals, and the general but also particular level of knowledge among the participants, and their self-assessment on their skills and competencies. The participants were selected based on the survey and in direct meetings with local, regional and national authorities. This modus enabled obtaining the first step in the implementation of LLL: widening access to higher education as well as improving the recognition of prior learning, including non-formal and informal learning. Based on the received answers, current topics in the field of water resources management were defined, which were marked as the most desirable for the training of professionals in the water sector. The training material should serve as a basis for employees in the water sector who attended courses organized by higher education institutions from the Western Balkans as participants in the SWARM project. This training as a form of LLL helped improving cooperation with employers, especially in the development of educational programmes.

The experience gained in the LLL programmes will be valid for recognizing the needs for improvement of the current courses in different study programmes dealing with water resources, beyond the programmes upgraded in the framework of SWARM, such as crisis management, legal framework, environmental management and renewable energy or construction and civil engineering. In addition, the training material can serve anyone interested in the water sector as a basis for obtaining up-to-date information on legal frameworks, technical and technological processes, IT tools, adaptation to climate change, limited availability of water resources, management of atmospheric water quality, use of used water, management flood and drought risk as well as innovative techniques in water resource management.

EU partners prepared a report regarding LLL courses for professionals in the water sector and briefly described them explaining their organization. This report was used for preparing joint training material for education WB professionals in the water sector. Trainings' material is focused on future-oriented water technology, considering the local needs and capabilities, because training and job qualification are critical success factors for a future-oriented development of sustainable water resources management. The training methodology created more flexible, student-centered modes of delivery.

The professionals from the water sector, but also any interested stakeholders had the opportunity to attend the trainings and reach the following learning outcomes in the wider scope of water resource management and adaptation to the climate change. After getting a basic understanding of climate change and its impact on water resources, and the EU Water policy, the trainees got the skills to apply the best practices in water-saving and water use, advance techniques for water and wastewater treatments and measures for adaptation to the climate change in the given political framework. The trainees will have the competencies to develop a Strategic plan for water management in all levels of administration as well in the companies in the water sector.

SWARM INITIATIVE – THREE SUCCESSFUL YEARS OF COLLABORATION IN WATER RESOURCES MANAGEMENT BETWEEN EU AND WESTERN BALKANS

The importance of cooperation between the countries of the Western Balkans with EU countries, especially when it comes to sustainable water resources management, is very illustratively represented through the Erasmus + SWARM project. The realization of the idea, the implementation of which will contribute to better sustainable and integrated water resources management in the Western Balkans, was realized through a series of activities planned and implemented during the implementation of the Erasmus + SWARM project.

Recognizing the important difference between traditional and integrated water resources management, it should be noted that the new approach to water resources management, implemented through this project, involves the introduction of the concept of variability, both water needs and variability within natural system, environment, changes in the purpose and manner of land use, climate change, as well as their impact on water resources, which should be a key challenge when considering the education of students and future professionals.Given that not all factors affecting water resources can be predicted, as well as the fact that water management goals change over time, it is necessary to revise them periodically, and any amendments and modernizations, primarily teaching syllabi at HEI of WB will contribute to sustainable water management. resources. In this regard, the strengthening of the higher education sector through the SWARM project has given great contribution.

In order to implement this component through the project, first of all a very detailed analysis of water resources management in the Western Balkan region was done. The analysis provided a very good cross-section of the knowledge of experts, with the aim of finding shortcomings in the existing teaching syllabi, which deal with this issue.This activity showed the necessary and much-needed cooperation, exchange of ideas and good practices between partners from EU countries and the WB. Through a series of trainings and education of the teaching staff of the WB, and intensive cooperation with EU partners in a project in which EU partners through the analysis of the water management sector in their countries contributed to the development of competence-based curricula aligned with EU trends in partner countries.

The concept of sustainable development and integrated water resources management, which is an important backbone of this project, is one of the basic principles in the planning of all human activities with special emphasis on the education of new professionals and additional education of existing professionals. Recognizing that strengthening the water sector alone through curriculum development is not enough, the dual approach to education applied in the project is considered an approach that can yield very good results. Namely, this approach focuses on the project in the education of experts in this field, in order to fill the existing gaps in knowledge and to implement all international obligations and conventions.

A very detailed analysis of the water sector in terms of needs, existing and missing knowledge, the needs of the economy, was performed. Therefore, the development of trainings'content and corresponding educational material had a special impact on the water sector. Through the project, round tables were held with experts in the water sector, through which the importance of such projects was discussed, the shortcomings and omissions made in the water sector so far, but also the needs that the labor market requires from new experts. In connection with that, the Workshop on innovative practices in the EU water sector: barriers and opportunities were realized through the project.

The concept of sustainable and integrated water resources management has been given a central place in considering the long-term perspective and progress of the WB countries. In this regard, the importance of such projects is reflected in a) educational training for both teachers and students since it, encourages harmonization with the knowledge and skills of students in the EU countries and assists the mobility of students and teachers, b) cooperation for the preparation of teaching materials with the development and implementation of innovative practices, exchange of good practices, ideas, joint initiatives to promote cooperation, and c) raising knowledge and awareness of the need for integrated WRM by contributing to sustainable WRM in accordance with EU and domestic legislation and international agreements and conventions. It is certainly important to emphasize the procurement of equipment for the partner countries of the Western Balkans, equipment that greatly raises the quality of teaching.

BUILDING SUSTAINABILITY IN WATER RESOURCES MANAGEMENT HIGHER EDUCATION

Dissemination and exploitation of results are crucial activities of the Erasmus+ project lifecycle improving their sustainability and justifying the European added value of Erasmus+ (EC, 2020). It is important to make project results freely available and sustainable after the end of the project realization. The consortium members wanted other people to benefit from the project using the project results. Therefore, three aspects of sustainability were considered (organizational, financial and institutional sustainability).

Three new and five modernized WRMcompetence-based study programmes have been developed in collaboration with partners from programme countries'HEIs and companies in the water sector implementing 32 courses developed under the SWARM project. These curricula will be based on innovative and interdisciplinary approacheswith the aim of encouraging professionals who can formulate effective responses to complex practices and policy alignment. The WB HEIs will enable these curricula to be sustainable after the project ends by providing financial and human resources. Accreditation of the developed curricula confirms achieved quality standards of the developed curricula. Also, trained WB teaching staff through the theme-based training for acquiring new teaching and learning methods and improving their professional, pedagogical and methodological knowledge will guarantee the implementation of the developed and modernized study programmes. The participation of WB teaching staff at the organized trainings was balanced (Figure 1).

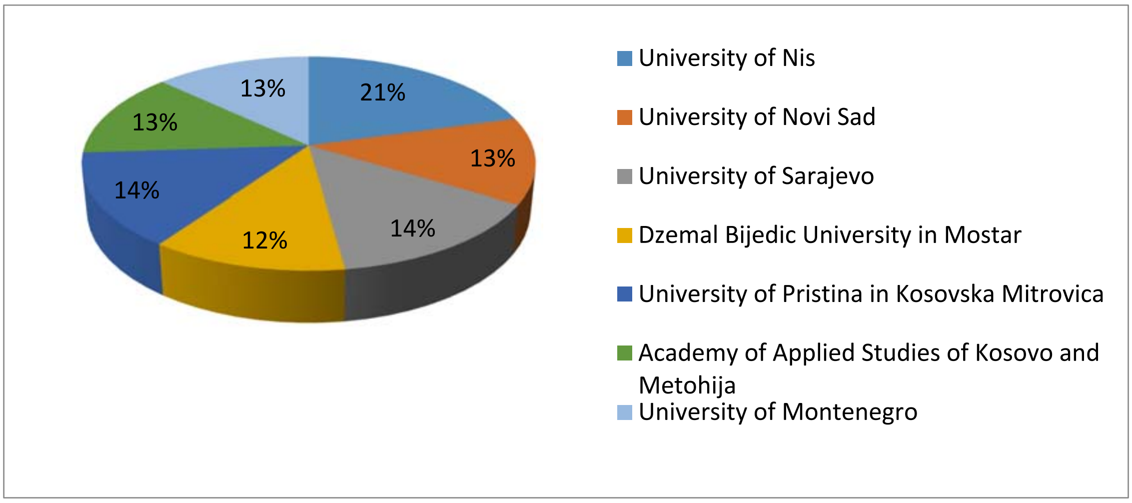

Figure 1. Percentage of WB trained teaching staff per WB HEIs

The developed study programmes will be regularly evaluated and updated and be competitive in the market area. WB partner HEIs will maintain the formed up-to-date laboratories where the students will gain practical knowledge that can be immediately applied.

Implemented trainings for professionals in the water sector are free of charge during the project lifetime and after the project they will be organized and realized in line with the needs of companies in the water sector. Seven developed courses,the handbook for the training and video materials, the Moodle platformcontaining these materials and the register of WRM companies in the WB countrieswill be used after the project end.

The capacity of WB HEIs should be further strengthened so that they can respond to the needs of industry throughdeveloping innovative training programmes, including the methodology of practical training and implementing the latest techniques in the teaching process.

COMMUNICATING WATER RESOURCES MANAGEMENT IN WESTERN BALKANS: BEST PRACTICES AND LESSONS LEARNED

The importance of communicating management of water resources

Effective dissemination of the contemporary achievements in the field of WRM is one of the key actions in implementing the SWARM Erasmus+ project. The project results, new achievements, experiences of good foreign practice have to be openly presented to serve the purpose of knowledge transfer, contributing to the development of WRM in WB countries and beyond. Therefore, the SWARM project underlined the necessity of creating the promotional and educational media contents (all kinds of them) as an agent for presenting contemporary advancements and innovations in the field.

Defining strategy and agenda of activities within the SWARMproject regarding WRM

The strategy developed within the project activities defined our dual focus, on target groups of WRM professionals (local authorities, SME and agencies in the water sector), buton the general public as well, bearing in mind the importance of water topics for the communities and society, in general. From this concept came the approach in the project development which implies direct (personal, institutional) contact with WRM professionals but also promotion through diverse media channels targeting wider community and public.

The necessity of adjustments of activities due to COVID-19 pandemic crisis

By the outbreak of the COVID-19 pandemic crisis, the project activities have had to be adjusted. Since then, numerous online and virtual events had to be added to the project agenda. Although it limited to some extent the possibility for the live (field) activities, it provoked to switch the focus on the production of media content and online events. At this point, many previously locally conceived events and activities became viral and open to the online community worldwide.

Implemented activities

The activities (live and online) performed within the SWARM project in the period of three years could be divided into three major categories:

- The first category targeted the WRM professionals and the performed activities included personal and direct contact with WRM professionals (visits and meetings with WRM representatives and enterprises, round tables and etc.). With an approach that involved an open agenda (or semi-structured), this was an opportunity to share experiences and to understand the needs of professionals working in practice. Besides collaborating with water and communal companies within the WB countries (a database of WB WRM enterprises was compiled), the SWARM project activities also included 5 study visits and contacts with some of significant wastewater treatment plants in the EU countries.
- The second category involved the interactive (and virtual) events. This category has widened the list of collaborators and participants including, besides WRM professionals and sectorial companies, also academia (scientists but students as well) and NGOs from WRM and related fields. These events included: 6 three-day trainings within EU partner institutions (in total 92 teaching staff trained); a day long webinar “Webinar - Frontiers in Water Resources Management” on 5 May 2020 with 6 panellists and 75 participants from 28 countries; 3-day long online training on WRM, from 8 to 10 of June 2021 with 174 participants and 45 water-related companies from 6 WB countries; and Inter-project coaching

meeting with 18 panellists and 57 participants for 16 countries. Unlike the first category, these activities had astructured agenda but still maintained interactivity among participants.

- The third category may be called as “promotional activities”. This part was dedicated to the general public and local communities. It included: self (project)-managed media contents (official project website, official FB page, YT channel, newsletters...), printed material (posters, roll-ups, leaflets, brochures, booklets, etc.); and third-party managed media contents (participated, as guests, in local and national media programs and services). We have made the project website as important vehicle to present and share the outcomes of the project activities, reports and forthcoming events, making it the official source of the project results, while social media was used to communicate with the community in direct, relaxed and unofficial manner, befriending the entire community of people gathered around a joint project and the joint idea of sustainable water resource management.

CONCLUSIONS

The WB HEIs and the water sector in the WB region can be enhanced through the development and implementation of curricula based on competencies and transfer of best practices from EU to WB HEIs, trainingof teaching staff in order to acquire new teaching and learning methods, the education of professionals in the water sector through the organized LLL courses in line with the current approaches applied in this domain, equipping laboratories with up-to-date laboratory equipment and software where the students will gain practical and applicable knowledge.

Having the experience of three years of SWARM project realization, the following could be concluded:

- Therewill be always many professionals in the water sector willing to expand their knowledge and learn from best practices; still a language barrier and lesser motivation is indicated for older and more experienced participants.
- Young professionals should be encouraged to take advantage of contemporary services (social media, computer programs, etc.) to make progress within the field (knowledge transfer, networking, etc.).
- There is an interest of WRM professionals in new educational activities and innovative solutions in WRM, but lack of funding; still, ready-made products and services are more appreciated.
- Networking of professionals and academics from the same and related fields within both, WB and EU countries, are of the most importance for future advancements in local practices and education.
- The exchanged experiences between the professionals coming from different backgrounds (educational and locational) are valuable resources of new ideas and knowledge.
- Local communities and the public are nowadays highly alerted about water and resource management, so it is very important to communicate information and ideas in a clear and simple way, to avoid misleading and deceptions.

ACKNOWLEDGMENT

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IAHR YOUNG PROFESSIONALS NETWORKS

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Abstract:Young Professional Networks or Student Chapters are becoming an increasingly important element of professional associations. They support early career scientists and professionals to grow into the increasingly international community in their field. Young professionals or studentsreceive mentoring from senior members and can develop their network.At the same time, knowledge transfer to scientific offspring and continuity is ensured for the head organization. Students as well as early career researchers and professionals in the sector of hydro-environmental engineering and research have the opportunity to join one of 49 local IAHR Young Professionals Networks (YPN). Besides the individual membership of IAHR at a discounted fee YPNs provide their members a wide range of opportunities to develop skills and network.

Keywords:career development, networking, professional association;

INTRODUCTION

The International Association for Hydro-Environment Engineering and Research (IAHR), founded in 1935, is a professional association of water specialists in science and engineering. The main aim of IAHR is promoting research and its application in a wide range of areas linked to water resources management and development (IAHR, 2021a).

Early career professionals face the challenge of growing into the community and network in their field, especially on an international level (Tritthart, 2017). IAHR Young Professionals Networks (YPNs) provide an opportunity for early career water resources researchers and engineers to connect with peers and learn from experienced IAHR members. Special trainings and mentoring are provided for YPN members in addition to the opportunity to actively participate in technical committees and working groups. Field trips, discussions and workshops are organized by the local IAHR YPNs.

For IAHR the Young Professional Networks are a possibility to connect with future members at an early stage of their career. This way continuity of the different programs and activities of IAHR can be ensured. At the last IAHR World Congress in Panama in 2019 a major part of the contributions was co-authored by members of one of the YPNs.

IAHR YOUNG PROFESSIONAL NETWORKS ON AN INTERNATIONAL LEVEL

History and structure of IAHR YPNs

IAHR YPNs have developed from the IAHR Student Chapter system which started in 2000 with Student Chapters in Iowa and Stuttgart. The first YPN was the Cardiff IAHR YPN formed in 2013 (IAHR, 2020). In 202149 YPNs, covering25 countries have nearly 2500 members (IAHR, 2021b, Figure 1).

Each of the local YPNs is typically hosted by a single university, company or administration. A senior member of the hosting institution is appointed as advisor to the network. An executive committee including a president, vice-president, secretary and treasurer is responsible for administration and organization of events of the local network. Additional officers can be appointed by decision of the network. The formation of new local YPNs is relatively easy, with the names of an advisor and the executive committee being the main requirements (IAHR, 2020a).

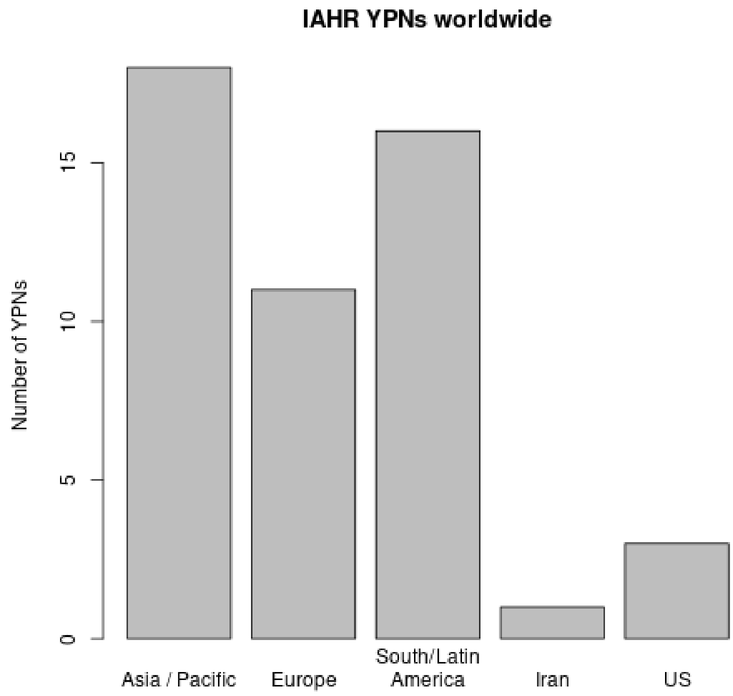

Figure 1. IAHR Young Professionals Networks in different regions

Common activities of IAHR YPNs

Several workshops and events of IAHR are organized with special focus on YPNs. Senior members of IAHR are providing webinars for young professionals, such as insights into how to write a good paper by the editor of the Journal of Hydraulic Research. Also, the current president of IAHR offered a lecture on “How to write a good paper for a Top International Journal”.

In addition to the webinars offered to YPNs as standalone events, IAHR congresses and forums often include keynotes, workshops and seminars particularly tailored for early career professionals and scientists. Examples are the session on “How Best to Approach Paper Writing” at the 85th Anniversary Summit of IAHR, or the invited session at the 6th IAHR Europe Congress “Science communication and Social media: friends or foes?”.

In 2020 the 1st IAHR Young Professionals Congress has been organized by the IAHR technical committee on Education and Professional Development. A total of 140 authors submitted abstracts for presentation at this online event. They received mentoring and feedback from 50 members of the international scientific committee. In total around 1000 participants joined the two-day online event.Extended abstracts of the contributions were published in the Proceedings of the 1st IAHR Young Professionals Congress (Carillo et al., 2020). The 2nd IAHR Young Professionals Congress is planned for 30th November and 1st December 2021.

Another opportunity recently organized by IAHR for all young professionals was the IAHR Young Professionals Hydro-Environment challenge. Participants of the challenge were working on projects in international, interdisciplinary teams over a period of eight weeks. The collaboration was completely online using web-based tools. In addition to universities also companies from industry were involved in the projects. This enhanced not only academic, but also professional experience for the participants. On top of the technical projects, participants of the challenge were also encouraged to reflect on the inter-personal processes in their teams (IAHR, 2020b).

Activities of local IAHR YPNs
There are no central requirements for YPN activities stated by the IAHR YPN Guidelines. Possible activities mentioned in the IAHR Guideline for YPNs (IAHR, 2020c) include:

- Seminars, discussions or workshops
- Field trips
- Group research projects
- Social networking events
- collaborative activities with other YPNs (informal)
- fundraising events for member participation on congresses and forums
- cultural exchange with groups from other regions

Membership benefits for IAHR YPN members
In addition to the wide range of mentoring programs, seminars and workshops describe above, IAHR offers all benefits to its YPN members which also normal IAHR members have. Particularly membership benefits for YPN members include (IAHR, 2020c):

- access to the IAHR membership platform
- access to a range of scientific journals including IAHR's flagship Journal of Hydraulic Research
- discounts on books and monographs published by IAHR and Taylor & Francis
- reduced rates for IAHR Conferences and Symposiums

IAHR YOUNG PROFESSIONAL NETWORK VIENNA

The IAHR YPN Vienna was founded in 2014 by students of the program Civil Engineering and Water Management at the University of Natural Resources and Life Sciences, Vienna. In the course of the last years the network has grown to 20 – 30 members, including also students from other Austrian universities as well as young professionals working in research or industry.

Activities organized by the IAHR YPN Vienna include site visits, discussions as well as presentations by experts and practitioners. The executive committee is running a Facebook page where followers are kept up to date, not only related to IAHR activities but also other relevant developments in water resources management.

In 2021the IAHR YPN Vienna started an exchange with other young members of different professional associations in the water sector in the German speaking countries Germany, Austria and Switzerland (D-A-CH). The collaboration was initiated by JungeDWA in Germany. A first meeting has been held on 30th June 2021. The collaboration so far resulted in great benefit for the participating networks with respect to several aspects: (i) The potential to grow networks on a national basis has already been pretty much exhausted. Particularly in a smaller country like Austria many members of the YPNs have been studying at the same university, thus contacts are already there. Through the extension over the neighboring nations many new links could be fostered between participants from the different countries. (ii) Despite ongoing internationalization many initiatives and processes are running in parallel in the three countries.Discussions with networks working on similar projects in the participating countries resulted in a highly beneficial exchange of know-how and experience. (iii) Finally, multiple networks of young members of different professional associations are running in each of the countries. Preparation of the multi-national meeting in each of the countries also fostered links between the different professional organizations within the countries.

CONCLUSION

YPNs are an important element of IAHR. While on the one hand providing a widerange of opportunities and support for early career researchers and engineers, YPNs ensure early contact to young professionals for the head organization. This way continuity of the programs of IAHR can be ensured on the long run.

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PERSPECTIVES OF A CLIMATE CRISIS: HIGHER RISKS FROM GLOBAL TO A SMALL ISLAND ENVIRONMENT

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Abstract: The progressive mounting costs of climate-induced changes in natural and man-made systems are an emergent and undeniable reality. These changes have been aggravating the already experienced climate crisis — describing global warming and climate change, and their consequences. By witnessing and learning about such an emergent crisis, an increasingly compelling story has been constructed: to limit future risks associated to climate change, governments must act more urgently and firmly measures are required to reduce greenhouse emissions. This should be accompanied with continuous evidence of the pace or magnitude of climate change from the scientific community. Scientists have been making projections of future global warming using climate models of increasing complexity for the past four decades and linking climate extremes to global warming intensity. At smaller scales, for instance, small island environments (e.g. Madeira Island) have long been recognised as being particularly vulnerable to climate change worsening the frequency, intensity, and impacts of some hydrological extremes.

Keywords: climate crisis; climate change; global warming; small island; Madeira Island; hydrological extremes.

INTRODUCTION

Hydrological extremes have been the primary drivers of many natural disasters, leading to large economic losses and damage to infrastructures, and might further bring unprecedented threats to human societies due to the expected increase in their magnitude and frequency (Rahmstorf and Coumou, 2011; De Luca *et al*., 2020) under a changing climate. In fact, the climate-induced changes have increased over many regions of the world during the past decades, and this trend seems likely to continue in the future (García-Cueto *et al*., 2019; Tabari, 2020). Therefore, there is a growing need to improve the understanding about changes in hydrological extremes and their related impacts for current and future risks management and strategic adaptation related to water resources. To achieve these goals, for instance, hydrologists have been improving physically-based models for comprehensive assessment of the impacts of hydrological extremes. The assessment should be done from global to regional and local setups, also ascertaining different time scales. However, identifying, modelling and understanding the changes in hydrological extremes under the current climate conditions still constitute a scientific and technological challenge since they vary spatially and temporally in nature.

In recent years, the rapid development of technology has made available more conventional ground-based data (e.g., hydroclimatic observations) and non-conventional data (e.g., paleo-data proxies or new satellite-based data) — related to large-scale physical factors and to fresh surface water occurrence (Braconnot *et al*., 2012; Giorgi *et al*., 2014; Hersbach *et al*., 2020). This has facilitated the modelling of hydrological extremes and related changes which, however, is still insufficient in some regions (Prudhomme, 2011). Thus, the recognition of changes in climate-induced hydrological extremes could be addressed by synthesising emerging global and local datasets and by improved hydrological models.

AN INTENSIFIED CLIMATE CRISIS

The numerous extreme rainfall events and their most common outputs, such as droughts and floods, only add to experts' awareness of the current intensified climate crisis (Sanson and Goodall, 2017) These types of extreme hydrological events have been intensifying globally but not at the same pace as they could be perceived. Increases in magnitude and frequency in hydrological extremes have been predicted by successive scientific assessments from the Intergovernmental Panel on Climate Change (IPCC) (e.g. Barros *et al*., 2014). Recent hydrological extremes give a clear picture of the impacts, associated costs and risks that come with a warming climate. For instance, climate change increases the odds of worsening drought duration and drought magnitude in many parts of the world in the decades ahead making periods with low rainfall amounts drier than they would be in a no-change scenario. On the other hand, heavy rainfall events have become more common since the 1950s. However, increases (decreases) in rainfall may not always lead to an increase (decrease) in total rainfall over a season or over the year.

Nowadays, the progressive mounting costs of climate-induced changes in both natural and man-made systems are an emergent and undeniable reality — e.g., negative impacts on crop yields, alteration in the distribution of some water-borne illnesses, and progressive expansion of oxygen minimum zones and anoxic "dead zones". By witnessing and learning about it, an increasingly compelling story has been constructed: to limit future risks associated to climate change, governments must act more urgently and firmly measures are required to reduce greenhouse emissions. This should be accompanied with continuous evidence of the pace or magnitude of climate change from the scientific community. Scientists have been making projections of future global warming using climate models of increasing complexity for the past four decades and linking climate extremes to global warming intensity (Wang *et al*., 2020). For instance, looking back at the first IPCC report (Houghton *et al*., 1990), the observed rate of global warming was accurately predicted. Since the publication of that IPCC report, experts have learned more about the global climate interactions from thoughtful, data and analyses, theoretical approaches, developments and improvements in complex characterisations identifying and quantifying Earth systems processes via in climate models. There are examples where this continuously improved learning has led to an upward risk revision, most notably for future global warming scenarios towards a worsening climate. Furthermore, increased number of observations have led to better analyses on impacts of climate change on the hydrological cycle — e.g., as air temperatures increase, more water evaporates into the air which can lead to changes in precipitation and rainfall, and to an increase in extreme events such as droughts and floods (Sheffield and Wood, 2008). To adjust to and prepare for the current and future impacts on the hydrological cycle, measures can be based on existing IPCC global projections supplemented by high-resolution observations and by comprehensive regional analyses on past and projected trends in vulnerability and exposure to hydrological extremes.

What can be said with enough confidence based on scientific evidence is that global warming is unfolding as projected. According to the IPCC Fifth Assessment Report (AR5) in 2014 (Barros *et al*., 2014), the global temperature has been projected to rise. For instance, the decade from 2000 through 2009 was about 0.2 °C warmer than in the previous decade as foreseen. Such upward temperature trend has sustained until now. The 2014 IPCC assessment report also stated that climate models projected short term increases in the duration, magnitude, intensity and spatial extent of heatwaves and warm spells, which is exactly what has been now documented (e.g., Ye, 2018). Examples are the multiple heatwaves that were reported during the 2018 summer in Europe and East Asia which happened earlier than ever before. According to Albergel *et al*. (2019) Central Europe, and some other areas, experienced in 2018 one of the most severe and long-lasting summer drought and heat wave ever recorded which is somewhat in accordance to the drought increases as projected in the AR5 by IPCC in 2014. In addition to the predicted drought conditions, the AR5 and some more recent reports also summarise the following:

1. Flooding is expected to intensify and be more widespread throughout the whole year — both coastal and inland. Through most of Europe, the increasing frequency of relevant heavy precipitation events in summer and especially in winter were detectable, and there is a strong theoretical basis for these hydrological extremes strengthening by different rates per degree of global warming. In general, the number of daily and multi-day extreme rainfall events has increased at a lower rate than the number of sub-daily events over many European regions. This upward trend is predicted to continue particularly for sub-daily events.
2. Hydrological events described by distributions with a heavy tail of low probability — i.e., events that by definition are unlikely to occur — received less attention than the most likely estimates of future climate change, although with high-impact outcomes. Previous IPCC reports largely focused on discussing plausible estimates of future state of nature. Nevertheless, it is necessary to consider the low probability futures, and those ones where climate change has low risk and unnecessary actions might be discarded. Risks are considered when examining future climate projections from the latest set of climate simulations. Several of

these new models show considerably more warming over the twenty-first Century compared with the previous versions of these models, with one model suggesting less warming (Forster *et al*., 2020). Other variety of evidence from observations and theoretical approaches, including how well these models represent current global warming trends, suggest that predictions of high warming futures are unlikely, but these scenarios cannot be excluded. Thus, they constitute a risk that needs to be also considered in future planning.

Evidence of climate change impacts is growing from larger areas to smaller ones such as island environments. As impacts become more easily discernible, so does the sense of an intensified climate crisis and urgency. Many impacts are yet to emerge from the day-to-day and month-to-month natural variations in the weather, with the most difficult and potentially devastating likely to be those affecting human health and biodiversity worldwide (e.g., Waheed *et al*., 2021).

SMALL ISLANDS CHALLENGES

Recent climate model projections have pointed up increased frequency, magnitude, and intensity of some of the extreme hydrological events, such as droughts and floods, for many regions of the world. However, the studies addressing climate-induced changes are developed for large continental areas, leaving aside island environments that are more susceptible since all the adaptation strategies must come from a limited area with no land connections. Then comes the specificity of "Island Hydrology" that is a combination from the surrounding ocean's climatology; the orographic obstruction of the island; its sometimes steep slopes; the specific soil types that have a strong volcanic component, with groundwater recharge implications (Falkland, 1991) — in short, great variability within small areas. This challenge coupled with the chance of a better insight into the teleconnection pattern's detection were the main driving forces for the following case study.

The case of the Portuguese island of Madeira

Small island environments have long been recognised as being particularly vulnerable to the impacts of climate change as in the case of the Portuguese North Atlantic island of Madeira. In recently published articles — Espinosa *et al*., 2019; Espinosa *et al*., 2020; Espinosa *et al*., 2021a; Espinosa *et al*., 2021b — further scientific evidence has been added stressing the fact that the island is particularly at risk, and face unique challenges in addressing climate-induced impacts. Located in European Macaronesia, Madeira is the largest island of the Madeira Archipelago with an area of ~740 km^2, a maximum width of 22.5 km and a length of 57.3 km. Based on its size and topography, Madeira can be categorised as a small island (Falkland, 1991). Centred at N 32°44’30” and W 16°57’58”, and about 610 km northwest of the Western African coast, the island has a very complex orography (Figure 1) and is completely formed by volcanic materials, consisting of a central mountainous system EW oriented (Pico Ruivo with 1862.0 m.a.s.l., Pico do Areeiro with 1818.0 m.a.s.l.; and the Paúl da Serra plateau which lies above1400.0 m.a.s.l.). The differences between the winter and summer temperatures are generally small.

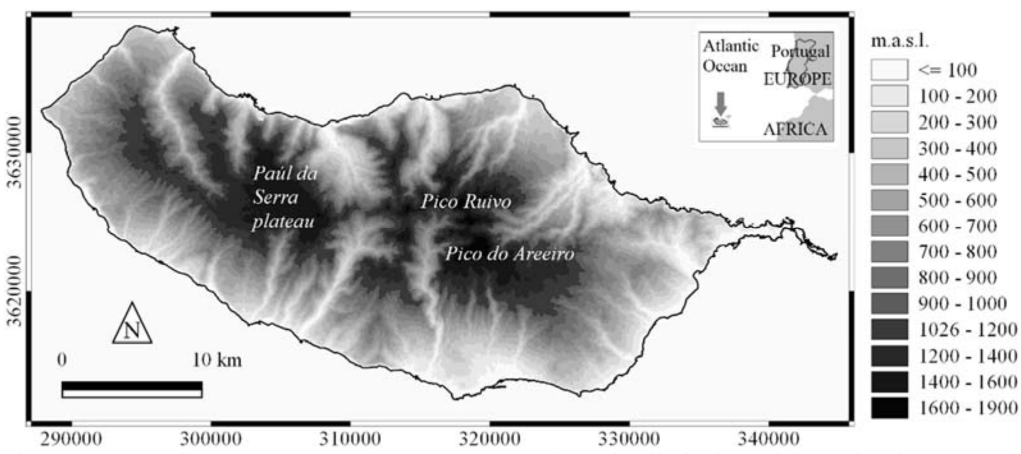

Figure 1. Coordinates WGS84 (UTM zone 28N) and relief of Madeira Island, Portugal.

According to the Koppen's classification, the island's climate is predominantly temperate with dry and warm to hot summers as approaching the coastal lowland zones of Madeira (Chazarra *et al*., 2011). The distribution of rainfall presents an evident seasonal pattern, thoroughly different between the rainy season, that extends from November to March (or sometimes to mid-April), and the dry season, with insignificant rainfall amounts during July and August. The rainfall in the island has a wide variation determined by the elevation with higher amounts in the north (~1500 mm year^{-1}) and central highlands (~2300 mm year^{-1}) than in the south (~600 mm year^{-1}), as previously characterised in Espinosa *et al*., 2021a.

The works in Espinosa *et al*. (2019, 2020, 2021a, 2021b) focus on climate-induced changes in hydrological extremes for Madeira in the last century and earlier years of present century. The changes in hydrological extremes are examined and associated to atmospheric processes through teleconnection patterns (indices) — particularly the North Atlantic Oscillation (NAO) index — that drives research towards a better understanding of the hydrological extremes' variability. The effects of climate on the changes in hydrological extremes are separated from the impact of human activities by using climate indices time series and not global emissions nor temperature data. Overall, the aforementioned publications aim at addressing these issues by identifying the potential for changes in water availability in vulnerable regions to hydrological extremes, increases in the magnitude and occurrence of droughts and heavy rainfall, and teleconnection patterns in a changing climate. These works follow up on climatic and hydrological processes with a theoretical and conceptual approach evidencing higher climate-related risks in small islands as in the case of Madeira.

The criteria for selecting Madeira Island as case study was its fragility to extreme hydrological events, the lack of knowledge regarding the behaviour of those events and their drivers, aggravated by the scarcity of hydrological data to support the studies on the previous issues. These constraints — commonly present in small island environments — made the researches even more challenging from the beginning, reinforcing their relevance. The data used in the studies referred to teleconnection indices and, resulting from the implemented innovative gap-filling procedure, to 80 years of daily rainfall, from 1937/1938 to 2016/2017, at a considerably high number of rain gauges in the island. Based on a regionalisation analysis (Espinosa *et al*., 2019) three homogeneous regions with different temporal climatic variability were identified: the northern slope, the southern slope, and the central region. Special attention was given to the latter region due to its relevance for the island's water security, since it is the main region for the replenishment of the groundwater reservoirs.

Furthermore, to achieve the objectives set in Espinosa et al. (2019, 2020, 2021a, 2021b) and to evidence some of the climate risks in Madeira Island, commonly used techniques such as the Mann-Kendall test and Sen's slope estimator for trend detection, the Standardized Precipitation Index for drought characterisation, and the principal component analysis coupled with principal factor analysis for climatic regionalisation, adjusted for the characteristics of the island. Additionally, novel approaches were proposed, for instance, the Multiple Imputation by Chained Equations applied for the first time for gap-filling of daily rainfall series, and the multivariate modelling with copulas for characterisation of hydrological extremes and for teleconnection. Results show that in the northern slope and central region there is an increase in the magnitude and frequency of drought and heavy rainfall as the likely consequence of changes in large-scale atmospheric patterns. Overall, this research provides mounting evidence that in Madeira Island: (i) seasonal rainfall (e.g. winter and annual rainfall) has shown a gradual, yet marked, decrease since the end of 1960's with the uncertainty regarding to whether rainfall will continue to decrease or it will counterbalance the already experienced rainfall deficits; (ii) the variability of seasonal and annual rainfall is highly correlated with the large-scale atmospheric circulation pattern of NAO; thus, changes in NAO seem to be inextricably linked to those observed in rainfall of the small island; (iii) droughts in the island have become worse and more frequent than in the past especially its central part which is currently in the midst of the worst drought ever registered which started around the year 2010–2011; and that (iv) heavy rainfall is clearly intensified by the persistent changes in the NAO, mainly during its negative phases. These findings highlight the importance of the detection, and characterisation of changes in hydrological extremes, as well as the multivariate modelling for teleconnections to extreme rainfall in North Atlantic regions, especially in small islands which are highly vulnerable to the effects of climate change and abrupt climate variability.

FINAL REMARKS

Complex impacts related to extreme hydrological events in small areas, such as in small islands environments, are sometimes underestimated or not well reproduced by climate models (e.g., general circulation models) since the spatial and temporal resolutions of impacts across the models are often large. This emphasises the urgency of action to build climate change resilience through water management. To achieve that purpose, the understanding of recent changes in hydrological extremes at different spatial and temporal scales of interest, based on as much data as possible, is still a growing relevant issue.

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WATER RESOURCES MANAGEMENT IN URBAN AREAS

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Abstract: Numerous problems that arise in urban areas can be directly or indirectly related to the wise management of water resources. Thus, the problems resulting from the physical degradation of the urban environment, social problems, problems of spatial organization of life in the city, can either be reduced or multiplied by inadequate management of water resources in urban areas. Population growth, urbanization and climate change represent significant pressures on urban water resources, requiring water managers to consider a wider array of management options that account for economic, social and environmental factors. Introducing integrated urban water management (IUWM) as a concept for planning to improve water management by linking different elements such as spatial planning, stormwater management and urban environment provides a more holistic input to planning. In this paper, we examine definitions of IUWM and global experiences. Finally, we describe how solutions based on innovative and integrated approaches are efficient and contribute to improved water management even though not every single element of urban water management can be a part of integrated solutions.

Keywords: climate change, integrated approaches, IUWM, sustainable management, urban areas, water resources

INTRODUCTION

Today, major cities face many challenges, but water management is one of the most serious. Potable water is scarce, many sources of water must be treated at high cost and volumes of waste water are growing. In many parts of the world, city dwellers lack safe drinking water and fall ill with waterborne diseases. As cities seek new sources of water upstream and discharge their effluent downstream, surrounding communities suffer and the hydrological cycle and aquatic systems, including vital ecosystem services, are disrupted. This situation is set to worsen as cities grow.

The way water is currently managed, in many cities, is wasteful and polluting, even though these cities have the inherent potential for more sustainable management. Achieving effective water governance involves a wide range of issues that have been studied by many investigators. One proposed way of achieving improved water management is the implementation of integrated water resources management (IWRM). This has been defined as ‘‘a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems’’ [Global Water Partnership (GWP), 2000, p. 22]. As is the concept of sustainability, IWRM is more of a goal, than of the achievement of a given set of criteria.

Approaches that take into account the full water cycle and the integration of all institutions involved, are the ones that ensure real implementation. Integrated Urban Water Management (IUWM) helps cities meet many water needs - both human and environmental - especially in the context of continuous urbanization and climate variability. It is important to stress that the IUWM requires time and effort to implement and requires many organizations, from utilities and planners to politicians, to work more actively together. It is therefore essential that urban water management (UWM) be an integral part of urban planning. Accordingly, UWM includes the plan, design and operation of infrastructure to provide drinking water and sewage, control infiltration and runoff of rainwater, recreational parks and harmonize the needs of all other water users, as well as the maintenance of urban ecosystems. The introduction of integrated urban water management (IUWM) as a concept for planning to improve water management by linking various elements such as spatial planning, water and environmental protection, stormwater management and the urban environment provides a more comprehensive contribution to planning. It is indisputable that the planning, development and management of urban water requires new ideas, innovations and strategies because water is only one component of an increasingly complex interconnected system that includes urban energy supply, adequate infrastructure, healthy environment and human life, food supply, employment, and the like.

The water needs of modern cities are growing, which will pose a challenge to public health, primarily in developing countries. Water supply, sewerage, wastewater treatment, stormwater drainage and flood mitigation and prevention, then solid waste management are mainly planned and performed as isolated services. Typically, a number of bodies, each governed by different policies and laws, continue to monitor these water sub-sectors at the city level. In practice, water management usually occurs spontaneously, if necessary, and solving current problems over and over again, but each within its own sector. It is quite common opinion among hydrotechnicians that even basin-level management often neglects the need for interdependence in management among drinking water, wastewater, flood control and rainwater. Therefore, it is evident that there is a need to identify the problem and then solve it and implement it. This will require innovative and acceptable institutional mechanisms and a balance between autonomy and inter-cooperation.

PAST AND CURRENT APPROACHES TO URBAN WATER MANAGEMENT

Current approach as described in international policy documents

The 'Dublin Statement' (International Conference on Water and the Environment, 1992) and the 'Agenda 21' (UN Department for Sustainable Development, 1992) unfold a vision about how water resources are best managed, to serve the people, without damaging the environment. The 'Dublin Statement' formulated a number of principles that since have formed the basis for Integrated Water Resources Management (IWRM). IWRM addresses the issue of water management from a river basin perspective, since this is the scale that includes (all) relevant cause-effect relations and stakeholder interests. The principles of the 'Dublin Statement' are:

1. Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment. Management of water resources requires linking social and economic development with environmental protection, within the river basin or catchment area.
2. Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels. Decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in planning and implementation.
3. Women play a central part in the provision, management and safeguarding of water. Institutional arrangements should reflect the role of women in water provision and protection. Empowerment of women to participate in decision-making and implementation, as defined by them, needs to be addressed.
4. Water has an economic value in all its competing uses and should be recognized as an economic good. Access to clean water and sanitation at an affordable price is a basic right of all human beings. Failure to recognize the economic value of water in the past has led to wasteful use and environmental damage.

These principles were applied to the urban environment as well and a future city was envisaged where appropriate water charges are in place, which will help reduce water scarcity and will reduce the need for developing ever more distant (and costly) sources. Waste discharge controls must be enforced and cannot be seen as reasonable trade-offs for prosperity brought by industrial growth (International Conference on Water and the Environment, 1992). The 'Agenda 21' has worked out the 'Dublin Statement' in some more detail for urban areas. The objective of 'Agenda 21' is to develop 'environmentally sound management of water resources for urban use'. To achieve this the following is believed to be critical:

- The role that is played by local and municipal authorities in water supply, sanitation and environmental protection.
- Scarcity drives the development of new resources with escalating costs as a result
- Unsustainable consumption patterns need to be eliminated, in order to help alleviate poverty and improve the quality of life of urban poor.

A large number (26) of potential activities have been formulated. Some of these are very obvious ('Implementation of urban storm-water run-off and drainage programs', others have become commonly accepted as good practice ('Initiation of public-awareness campaigns to encourage the public's move towards rational water utilization'). Some of the more interesting activities are:

- 'Reconciliation of city development planning with the availability and sustainability of water resources'
- 'Adoption of a city-wide approach to the management of water resources'
- Inclusion of water resources development in land-use plans
- 'Basing of choice of technology and service levels on user preferences and willingness to pay'

It should also be noted that the key principles of water resources management are almost completely harmonized at the global level, which is confirmed by the conclusions of the planetarily relevant conferences held in Rio De Janeiro, Dublin and Mar del Plata. In parallel with these global trends, the European Union has also made great progress in drafting a number of directives and accompanying documents that define a common water management policy and methodology for all its Member States.

European legislation on (urban) water management

Since 1976 the European Commission has issued a number of waters related directives, which are aimed at protection of public health, at protection of nature and at mitigation of negative environmental effects of water use and wastewater production. The following directives have come into force: Bathing Water Quality Directive (76/160/EC); Birds Directive (79/409/EC); Drinking Water Directive (80/778/EC), as modified by 98/83/EC; Directive on the control of major-accident hazards involving dangerous substances (Seveso-directive) (96/82/EC); Directive on Environmental Impact Assessment (85/337/EC); Sewage Sludge Directive (86/278/EEC); Urban Wastewater Treatment Directive (91/271/EEC); Plant Protection Products Directive (91/414/EEC); Directive on nitrate from agricultural sources (91/676/EEC); Habitats Directive (92/43/EEC); Integrated Pollution Prevention and Control Directive (96/61/EC).

Urban (waste) water management is mostly addressed in the Urban Wastewater Treatment Directive (91/271/EEC, 1991). This directive regulates the collection and treatment of urban wastewater and the disposal of sludge produced in the process of wastewater treatment. Urban wastewater is defined as the mixture of domestic wastewater, industrial wastewater and/or run-off rainwater. The directive stipulates:

- A time schedule for the construction of collection systems to collect urban wastewater from agglomerations of more than 2000 inhabitants (PE's) (31st of December 2005 as deadline for implementation).
- That individual treatment systems that achieve the same level of environmental protection can be used (decentralized systems), where the establishment of collection systems is not justified because it would generate no environmental benefits or because it would involve excessive costs,
- That receiving waters are classified as either 'sensitive' or 'less sensitive'. Sensitive areas are waterbodies with poor water exchange and that are prone to eutrophication.
- Effluent standards for both 'sensitive' and 'less sensitive' areas for BOD, COD, TSS, total nitrogen and total phosphorous.
- That the disposal of sludge to surface waters should be phased out.
- That treated wastewater shall be reused whenever appropriate. Disposal routes shall minimize the adverse effects on the environment.
- That sludge produced while treating wastewater shall be reused whenever appropriate.
  Disposal routes shall minimize the adverse effects on the environment.

The measures of the Urban Wastewater Treatment Directive are now part of common practice in most European countries. The measures are quite straightforward: setting standards by government bodies, implementing end-of-pipe treatment for domestic and industrial wastewaters, sampling, monitoring and publication of water quality results and enforcement. The prevention of pollution in industry and/or the domestic sector is not addressed at all. The directive is limited to an end-of-pipe approach.

The EC directives shown above have all been integrated in 2000 into one new piece of legislation, the Water Framework Directive. This framework aims to integrate all previous directives into a more holistic approach.

New in this document is that the River Basin becomes the unit of analysis. The reason for this is that at this scale all interests come together (upstream, downstream). The framework requires the formulation of River Basin Plans for each river basin, also if this requires cross border cooperation. Here one sees clearly the application of IWRM principles as previously formulated in the 'Dublin Statement'. The River Basin Plans will contain:

- Analysis of the river basin's characteristics
- Review of the impact that human activity has on water
- Economic analysis of the water use

The major objective of the framework is to achieve 'good status' for all European waters by 2015. What 'good' means is to some extent defined by the framework, for both natural and human influenced waters, but also depends on how the stakeholders in the basin will define this. Active participation of all stakeholders, including NGOs and local communities is prescribed. The Framework Directive clearly is different from the Urban Wastewater Treatment directive, in that it aims to prevent pollution at source and sets out control mechanisms for management of pollution sources. There has been a shift from 'treatment' to 'environmental management'. Some other areas of attention in the WFD are:

- Water pricing policies and polluter pays principle
- Balancing interest of environment with those who depend on it.
- Integration of policies: agriculture, industry, consumers
- Best possible reduction of emissions and a minimum quality threshold for water quality in receiving environment
- Phase out of discharge of priority contaminants in 20 years.
- Water pricing is an incentive for the long-term sustainable use of water resources
- Prices should be set in a transparent way, appropriately integrating economic, environmental and social principles

INNOVATIVE APPROACHES IN URBAN WATER MANAGEMENT

Several projects, programs and approaches go a step further than the WFD. One of these is the 'Bellagio Statement', formulated by the Environmental Sanitation Working Group of the WSSCC in 2000. Its principles are believed to be essential for achieving the objective of worldwide access to safe environmental sanitation and a healthy urban water system (reference):

1. Human dignity, quality of life and environmental security should be at the centre of the new approach, which should be responsive and accountable to needs and demands in the local setting.
    - solutions should be tailored to the full spectrum of social, economic, health and environmental concerns
    - the household and community environment should be protected
    - the economic opportunities of waste recovery and use should be harnessed
2. In line with good governance principles, decision-making should involve participation of all stakeholders, especially the consumers and providers of services.
    - decision-making at all levels should be based on informed choices
    - incentives for provision and consumption of services and facilities should be consistent with the overall goal and objective
    - rights of consumers and providers should be balanced by responsibilities to the wider human community and environment
3. Waste should be considered a resource, and its management should be holistic and form part of integrated water resources, nutrient flows and waste management processes.
    - o inputs should be reduced so as to promote efficiency and water and environmental security
    - exports of waste should be minimized to promote efficiency and reduce the spread of pollution
    - o wastewater should be recycled and added to the water budget

4. The domain in which environmental sanitation problems are resolved should be kept to the minimum practicable size (household, community, town, district, catchment, city) and wastes diluted as little as possible.
    - waste should be managed as close as possible to its source
    - water should be minimally used to transport waste
    - additional technologies for waste sanitization and reuse should be developed

Implementation of these principles would create an urban water system that is based on recycling (waste=resource) and therefore reduce the need for external inputs (water, energy, chemicals). The pollution being generated in the system would also be reduced. However, principle number 4 is questionable. It seems to be based on the assumption that decentralized systems for sanitation (and water supply) are by definition more sustainable (environment, health, socio-economy). True, some literature reports have shown that under certain conditions this is the case, for instance for urine separation systems (Jeppsson and Hellström, 2002). However, in many other cases it is the economies of-scale of centralized systems that is more advantageous. Principle number 4 could better be replaced by a more general statement that the sustainability of systems needs to be optimized, based on some kind of 'sustainability assessment'. This would also make the discussion between 'centralizers' and 'de-centralizers' more rational. This sustainability concept for the urban water system is worked out by Lundin and Morisson (2002), who developed a LCA type of method to evaluate the environmental sustainability of urban water systems.

INTEGRATED URBAN WATER MANAGEMENT (IUWM)

Integrated Water Resources Management (IWRM) is a water management approach that looks holistically at the planning and management of all waters in the area under consideration, from water supply, wastewater, to rainwater and others. IWRM focuses on the water cycle as a single interconnected system and promotes coordinated development and management of water, land and related resources to maximize economic and social benefits while minimizing environmental impact. Urban water management consists of several processes. Traditionally, wastewater, rainwater and water supply are managed separately and this approach does not take into account the natural urban water cycle, thus resulting in excessive water abstraction, water pollution and failure to use rainwater and recycled wastewater as a source of water supply. Integrated Urban Water Management (IUWM) is a holistic way of strategic planning. The concept encompasses various aspects of water management, including environmental, technical, economic, social as well as political impacts and implications.

The transition to integrated urban water management is a necessity given the rapidly growing urban water needs, as well as the need to make urban water systems more resilient to climate change. Conflicting interests in the context of water use within urban systems, mutual competition, droughts, floods, and degradation of water resources make it imperative to reconsider conventional concepts. Therefore, the transition from an approach that tries to manage various aspects of the urban water cycle in isolation to an integrated approach that will meet the needs of all users to be supported by all stakeholders is almost inevitable or a prerequisite for urban development. The IUWM principles are listed below:

- Encompass alternative water sources;
- Match water quality with water use;
- Integrate water storage, distribution, treatment, recycling, and disposal;
- Protect, conserve and exploit water resources at their source;
- Account for non-urban users;
- Recognize and seek to align formal and informal institutions and practices;
- Recognize relationships among water, land use, and energy;
- Pursue efficiency, equity and sustainability;
- Encourage participation by all stakeholders.

The IUWM approach begins with clear national policies on integrated water resources management, backed by effective legislation to guide local authorities. A successful approach requires engaging local communities to

solve the problems of water management, (GWP, 2000). Collaborative approaches should involve all stakeholders in setting priorities, taking action, and assuming responsibility. The IUWM assesses both the quantity and quality of water, assesses future demand, predicts the impact of climate change, and recognizes the importance of efficiency without which water management cannot be sustainable. It also recognizes that different water sources can be used for different purposes - fresh water and desalinated water for domestic use; and treated wastewater for agriculture, industry and the environment. IUWM requires the development of planning and management for all components of urban water services. Figure 1 shows the coordination structure that will ensure communication between departments, levels of government, local communities and stakeholders. (GWP, 2013)
Urban planners can help governments overcome fragmented public policy and decision-making by linking planning to other policy sectors, such as infrastructure, and adopt collaborative approaches involving all stakeholders in setting priorities, actions and responsibilities - see Figure 2.

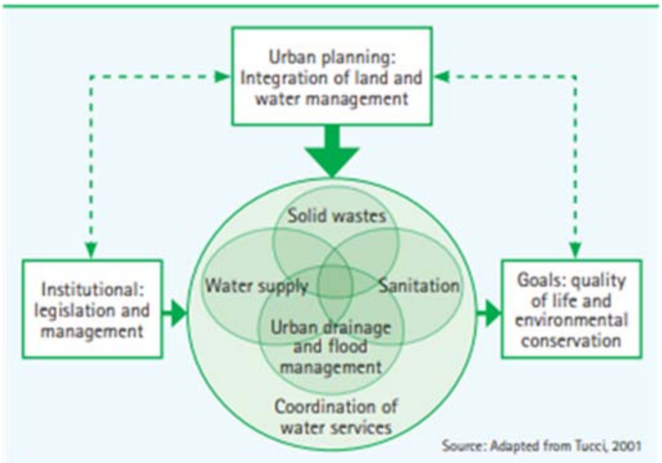

Figure 1. The coordinating structure, (GWP, 2000)

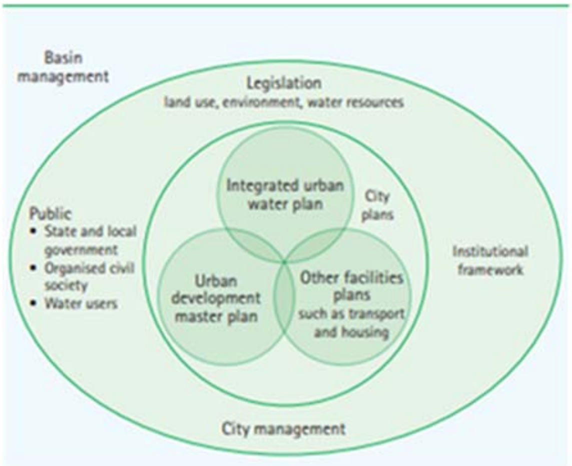

Figure 2. The linking planning (GWP, 2000)

This may involve new ways of coordinating different agencies and controlling water use, such as new regulators to enforce standards and procedures. Integrated urban water policies based on participatory governance can secure sustainable development, but changes will be necessary to stimulate innovation, efficiency, and sustainability. (GWP, 2013)

As presented above, existing water management systems are not sufficient in many cases, and the need to solve the problem of quantity and quality of water exists in order to implement the concept of an urban circular economy. The synergy of constantly growing urban areas with impervious surfaces and pollution associated with human activities, and climate change with an increasing number of meteorological extremes, requires a new approach for cities to become more resilient to socioenvironmental pressures (Figure 3) (Hasan et al. 2020).

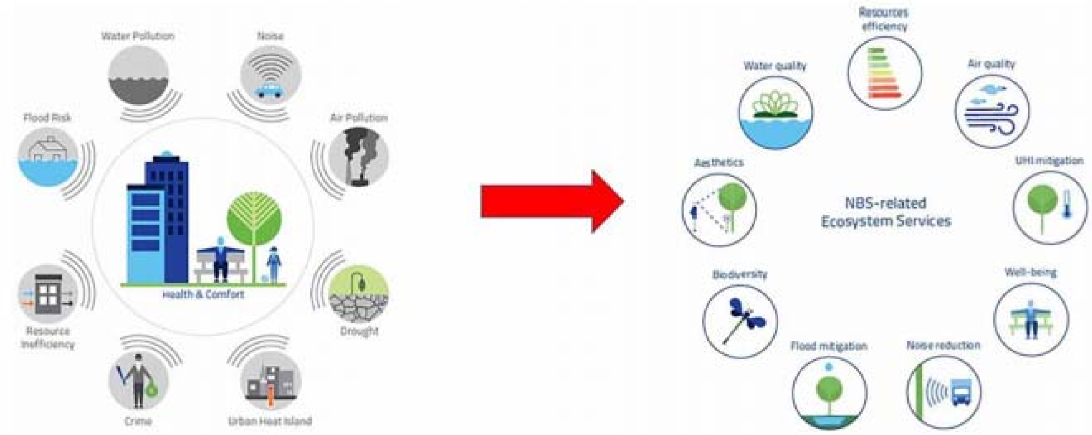

Figure 3. Identified water problems and urban pressures and mitigation options by the application of NBS (Hasan, et al.2020)

CONCLUSION

With the dramatic changes in the water cycle expected in the coming years, traditional and fragmented approaches to water resource planning are simply not good enough. It is clear that only by integrating spring, rain, waste and drinking water management can city leaders, urban planners and water companies address the challenges of urban water. From water scarcity and climate extremes, followed by floods, torrents, etc., to resource fragmentation, more water issues need to be addressed than ever before. For those who manage urban water systems, such as urban planners and utility managers, it is difficult to decide which challenges they will first have to tackle in order to deliver the most benefits. In addition, the world's water needs are constantly evolving, and hydrological systems are not static. This means adapting water management styles and adopting new methods. The great potential when we talk about IUWR lies in smart technologies, which can help us make the right decisions faster. Advanced water management technologies can efficiently collect, combine and analyze complex data from a variety of sources in real time, which is one of the key factors for emergency decision making. Adopting the IUWM concept and its iterative processes can help cities significantly increase the number of people having access to water of appropriate quantity and quality, as well as sewage, and improving the health and productivity of city residents.

Through mechanisms and tools, it should be ensured that state governments find ways and facilitate the implementation of IUWM in practice, at all levels, from local to national, which includes the adoption of the necessary strategies to finance the entire process to be implemented as planned.

In doing so, it is important to take into account climate change forecasts in the city's water supply and sewerage planning, and to install and maintain infrastructure and services that are "climate adaptable". Continuous education of experts and strengthening of institutional capacity for involvement in IUWM are a prerequisite, to ensure implementation and successful implementation in practice of the whole process.

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WATER QUALITY EVALUATION IN BOVAN RESERVOIR

FOR IRRIGATION PURPOSE

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Abstract: Aleksinac field, with a total area of about 5660 ha, is located in the fertile valley of the Južna Morava River in the municipality of Aleksinac. The area planned for irrigation is within the cadastral municipalities of Aleksinac, Bobovište, Ćićuna, Rutevac, Vukašinovac, Deligrad, Jasenje, Brodarevac, Mozgovo, Bovan, Subotinanac, Kraljevo. The feasibility study from year 1994, envisages irrigation of the Aleksinac field from the multi-purpose reservoir Bovan. More than 30 years have passed since. The Bovan reservoir have been used for water supply, which was not the main purpose of this reservoir. The dead volume has decreased and the water quality has changed. In this paper, the water quality for irrigation in the Bovan reservoir was assessed on three profiles in the reservoir and recommendations are given for the future research.

Keywords: irrigation, reservoir “Bovan”, water quality

INTRODUCTION

Water is the most important natural resource. The importance of this resource is especially highlighted when we consider the increase the world population, the accelerated development of industry, the construction of new settlements and especially climate change. Lack of food emphasizes the importance of irrigation systems developing and finding appropriate sources of surface water and groundwater. Water resources and soil quality across globe decreased due to anthropogenic contamination (Dash & Kalamdhad, 2021). Surface waters are a particularly sensitive resource. Many studies assessed water quality of rivers (Merouche et al., 2019; Safari et al., 2021; Elsayed et al., 2020; Sharma et al., 2020), ground waters (Abbasnia et al., 2018; Samtio et al., 2021), channels (Abdel-Fattah et al., 2020) for irrigation purposes, with special reference to the requirements of individual plant species (Allende & Monaghan, 2015). Artificial lakes are usually multi-purpose sources of water (AbuDalo et al., 2020; Jovanic, 2015) and achieving the water quality of such a water source is to harmonize the requirements of a larger number of users.

MATERIALS AND METHODS

Bovan reservoir

Aleksinac field, with a total area of about 5660 ha, is located in the fertile valley of the Južna Morava River in the municipality of Aleksinac. The area planned for irrigation is within the cadastral municipalities of Aleksinac, Bobovište, Ćićuna, Rutevac, Vukašinovac, Deligrad, Jasenje, Brodarevac, Mozgovo, Bovan, Subotinanac, Kraljevo.

The soil is compacted and the average plot area is 60.91 a. Each plot has an access road. The plots are in the private property.

The feasibility study from year 1994 envisages irrigation of the Aleksinac field from the multi-purpose reservoir Bovan. The total net irrigated area is about 4 500 ha (about 7 000 plots), and the system envisages water supply of each plot. According to this study, two irrigation subsystems are planned on areas of about 2250 ha:

- I subsystem which is gravity-fed water supplied system from Bovan reservoir (below elevation 225 MASL)
- II subsystem which is water distribution system supplied by pumping water from the Bovan reservoir and covering high irrigation zones (above 225 MASL).

The multipurpose reservoir Bovan is located on the river Moravica near the village Bovan, 14 km upstream from the mouth of the river Moravica and Južna Morava River.

The main purpose of the reservoir Bovan is water supply, flood protection, protection against sedimentation within the HPS "Iron Gate", increasing of low water level in the river, hydro power and irrigation.

Table 1. The main characteristics of the reservoir

Watercourse	Moravica
Nearest settlement	Aleksinac
Total reservoir volume	60 000 000 m^3
Minimal water level	243.00 MASL
Normal water level	252.00 MASL
Maximal water level	261.50 MASL

The main project of the dam and reservoir Bovan was done in 1974 and envisages about $15*10^6$ m^3 of water for irrigation. More than 30 years have passed since and in the meantime the Bovan reservoir has been used for water supply, which was not the main purpose of this reservoir. The quantities of water have been reduced, socio-economic changes have taken place (privatization of socially owned enterprises has been carried out, the construction zone of Aleksinac has been expanded, a new Law on Planning and Construction is being implemented), it is necessary to revise the available quantities and quality of water for irrigation from the Bovan reservoir. In this paper USSL classification was used in order to define suitability of water quality in Bovan reservoir for irrigation purpose.

USSL Classification

The US Salinity Laboratory (USSL) classification represents the method for evaluation of irrigation water quality, based on the hazards of salinization and alkalization of irrigated soils (Wilcox, 1955). Using this classification irrigated water can be classified into 16 categories (Figure 1). The concentration of salt in irrigated water can be very harmful for the crops, i.e. it will reduce the growth and fertility of crops. In order to define the water salinity, the electrical conductivity (EC) is used. EC measure the amount of total dissolved solids (TDS) in water at 25˚C. Alkalization of irrigated water can be defined using the SAR (Sodium adsorption ratio) value, which represents the risk of sodium in water. The high value of SAR leads that soil becomes hard and compact, which reduces the infiltration rates of air and water into the soil.

SAR value is based on the comparative concentrations of sodium (Na) and calcium (Ca) and magnesium (Mg) in a water sample (high contents of Ca and Mg reduces the soil permeability), and is expressed as (Wilcox, 1955; Richards, 1954):

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \quad (1)$$

The lack of springs with quality water for irrigation leads to the modification of the basic SAR formula into SARcorr (Ayers & Westcot, 1976):

$$SAR_{corr} = SAR\left[1+\left(8.4-pHc\right)\right] \quad (2)$$

$$pHc = \left(pk_2 - pk_c\right) + p\left(Ca+Mg\right) + p\left(Alk\right) \quad (3)$$

where p represents the negative logarithm, k_2 is the second dissociation equilibrium constant of carbonic and k_c is the solubility equilibrium constant for calcite.

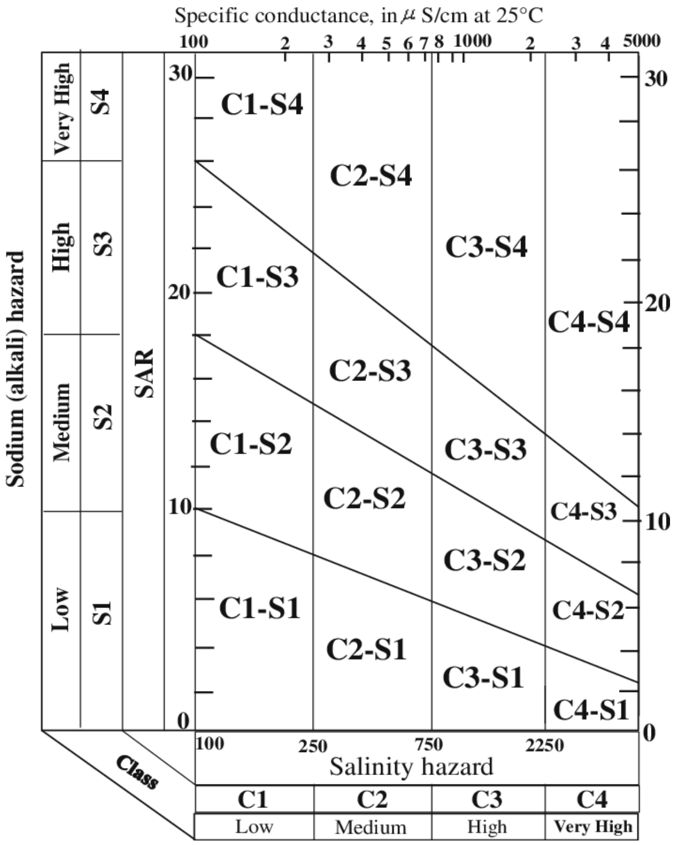

Figure 1. USSL classification of irrigation water (Wilcox, 1955)

RESULTS AND DISCUSSION

In this paper, the water quality for irrigation in the Bovan reservoir was assessed on three profiles in the reservoir and recommendations are given for the future research. The profiles are presented in Figure 2 and results are given in Table 2.

Figure 2. Bovan Reservoir-sampling locations

Table 2: USSL classification of Bovan reservoir water

	A1	A2	A3	B1	B2	B3	V1	V2	V3
Depth (m)	0.5	15	30	0.5	11	22	0.5	4.5	9
EC	382	413	447	387	430	457	418	424	462
S.O. (mg/l)	254	264	291	249	279	288	267	273	301
Na (mg/l)	7.2	7.1	7.2	6.9	7.3	7.4	7.4	7.7	7.9
K (mg/l)	1.8	1.9	3	1.1	2	2.2	1.9	2	1.9
Ca (mg/l)	62	64	71	63	75	75	72	72	83
Mg (mg/l)	17	17	20	15	9	20	11	11	7
CO_3 (mg/l)	7.2	0	0	7.2	0	0	7.2	6	5.4
HCO_3 (mg/l)	196	232	255	200	242	256	218	225	250
SAR corr	0.439	0.436	0.436	0.424	0.456	0.443	0.457	0.474	0.492
Class	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1

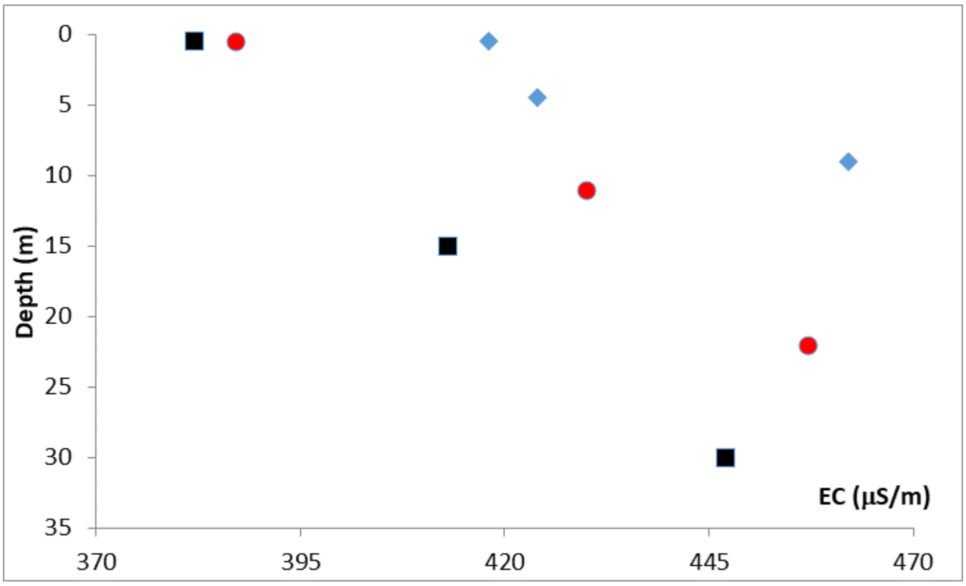

Figure 3. EC versus sampling depth

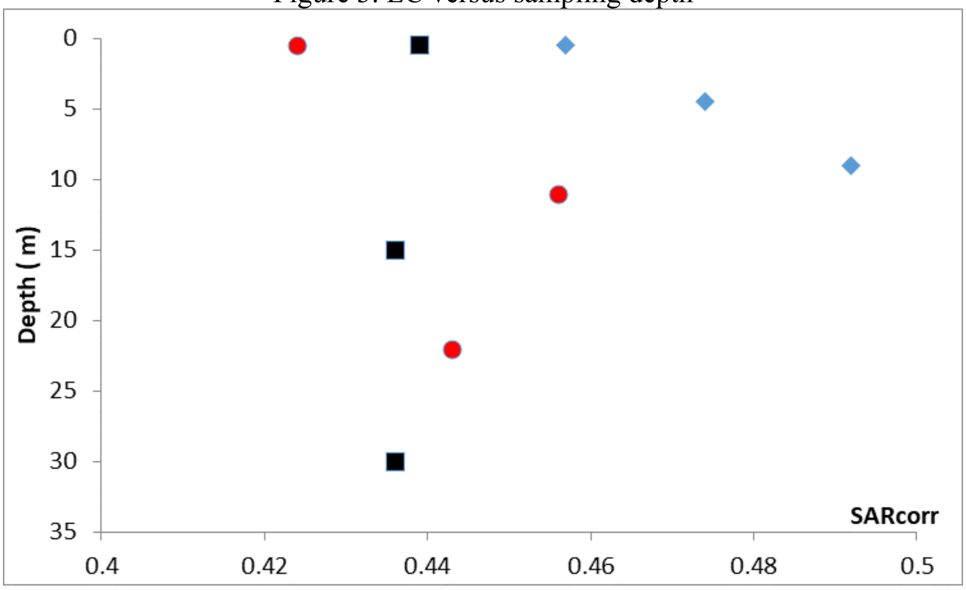

Figure 4. SARcorr versus sampling depth

On the Figure 3, electric conductivity values are given regarding sampling depth. On each profile we can see that electric conductivity increases with depth. On the Figure 4 corrected SAR values are presented regarding sampling depth. These values do not differ significantly so we can conclude that sampling depth has no greater significance.

Results indicate the same water quality class:

- Medium to good quality irrigation water
- Low risk of alkalization
- Medium risk of salting.

CONCLUSIONS

In this paper we tried to evaluate the usability of water from the Bovan reservoir for irrigation purpose, by evaluating the EC (dS/m) of the water and the amount of sodium (mg/l) and consequently the risk of salinity and risk of alkalization respectively. For all three locations where the samples of water were taken, measured values are within the moderate risk of salinization and low risk of alkalization, which indicates that reservoir water can be used for irrigation of crops that are moderately tolerant to the presence of salt in the water. It is recommended that some measures should be taken in terms of reservoir management in order to improve the quality of irrigation water and consequently to increase number of crops to be threated. The main measure would be following the dispatch plan, which would prevent the process of eutrophication of the reservoir. Reservoir silting is a main water quality problem generally, but according to recent studies it does not affect the total dissolved solid and thus to EC of the irrigated water.

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SIMULATION OF UNGAUGED BASINS IN CLIMATE CHANGE CONDITIONS

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Abstract: Simulating ungauged basins is a challenging process both for current and climate change conditions. In the research Geographic Information Systems (GIS) tools and methods are applied to extract necessary topographic and hydrologic parameters for the parametrization of the HEC-HMS hydrological model used for the case study basin simulation. The sensitivity analysis during the model's calibration highlighted the best configuration which was validated during the model's validation process. In both calibration and validation periods, the input rainfall data comes from global gridded datasets, while the simulated discharges are compared with the ones produced by global models. The future runoff of the basin is estimated for the IPSL-CM5A-MR, KNMI-RACMO22E-EC-EARTH and SMHI-RCA4-HadGEM2-ES Regional Climate Models (RCMs) under the Representative Concentration Pathway (RCP) 4.5, with the climate variables to trigger the hydrologic simulations. The results outline future runoff perturbations depending on the RCM used as forcing. Moreover, it is demonstrated that in the future the periods with low discharges are prolonged in comparison to the reference period, and the periods presenting increased runoff are characterized by higher flows with increased duration in comparison to the reference period. These conditions are expected to pose augmented challenges on water resources management and flood protection systems.

Keywords: Climate change, Hydrological modelling, Geographic Information System, Ungauged basin.

INTRODUCTION

Climate change has become an indisputable reality having impacts on urban and natural environments. One of the sectors destined to be affected is water resources. Climate models outputs and indicators demonstrate (with high confidence) that in specific geographic areas, such as the Mediterranean basin, the projected temperature increase will be coupled with perturbations of the hydrological cycle (IPCC, 2014) signifying rainfall decreases, with direct impact on surface water resources availability, and increases in extreme flood events, with direct impact on socioeconomic activities. Hence, knowledge on hydrosystems' behaviour at basin scale is a critical prerequisite for climate change adaptation actions.

The most common approach in estimating future flow regimes under climate change conditions at basin scales is the forcing of validated hydrology models with climate variables derived either by statistical or dynamic downscale of Global Climate Modes (GCMs) outputs (Candela et al., 2012). However, this kind of assessment is very challenging in ungauged basins or basins with scarce space and time datasets because the lack of hydrometeorological data jeopardizes the simulation accuracy of the utilized hydrology model (Athira et al., 2016) and thus depletes the reliability of the future projections. The emerging importance of simulating ungauged basins gained ground with the Prediction in Ungauged Basins (PUB) initiative of the International Association of Hydrological Sciences (Sivapalan, 2003), and since then numerous relevant scientific paths have been proposed, such as the watershed area ratio method for estimating daily flow (Gianfagna et al., 2015), the regional maximum likelihood approach (Castiglioni et al., 2010), the geographical/physical similarity approach where parameter values are transferred from gauged geographically similar catchments to ungauged catchments for prediction (Zhang et al., 2014). On the other hand, there are studies that indicate highly variable hydrological functioning of neighboring and rather similar catchments (Karlsen et al., 2016).

Currently, the advancements of information and communication technologies (ICTs) have fostered the development of scientific research initiatives that produce and offer hydrometeorological datasets for large-scale geographical areas. Gridded rainfall datasets of high spatial resolution, historic river discharges through global hydrological simulations, downscaled climate change variables at regional levels, real time dam outflows, land use coverage maps, digital elevation models and soil maps covering the globe are characteristic examples of the plethora of the available data sources (Skoulikaris and Krestenitis, 2020). At the same time, open source or freeware simulation models, geographic information systems (GIS) platforms, and database management systems are unique tools for the exploitation of the generated data (Skoulikaris et al., 2014).

The present work aims at investigating the impact of climate change on the regime of an ungauged river basin through the use of publicly available large-scale datasets and geographic information systems. GIS tools and methods are applied to extract topographic and hydrological characteristics used for the parametrization of the utilized hydrology model, namely HEC-HMS. The sensitivity analysis on the channel losses during the calibration process resulted in the successful validation of the model performance. Thereafter, the variables of 3 Regional Climate Change Models (RCMs) under the RCP4.5 are used as forcing to the validated hydrology model for assessing the future river discharges for 5 future periods and for 2 different reference periods.

MATERIALS AND METHODS

Case study area

The study basin, namely the Marmara river basin, covers an area of 234.36 km^2 and is located at the northern part of Greece, 42.0 km southwest of the city of Kavala, Figure 1. It belongs to the Water District of Eastern Macedonia (EL11) and is an important subbasin of the Strymonas River Basin. The river basin is bounded by the Paggaio (max altitude at 1,956 m) and Symvolo (max altitude 694.0 m) mountains to the north and south respectively and is drained by the perennial homonymous river that outlets on the North Aegean Sea. Geologically, the crystalline rocks of the Rodopi mass are dominant in the basin. They consist of granites, gneisses and marble inserts; thus, the basin is largely structured by impervious rocky background, apart from marble appearances. However, the newer geological soil deposits of the riverbed area are permeable with coarse gravel with cobbles to overlay the downstream parts of the river (Kromberg and Schenck, 1974). The presence of coarse channel deposits is expected to cause significant flow losses in the channel. Although many historical floods have been recorded in the basin, with significant economic impact on infrastructure and agricultural production, very few time-scattered flow measurements are available.

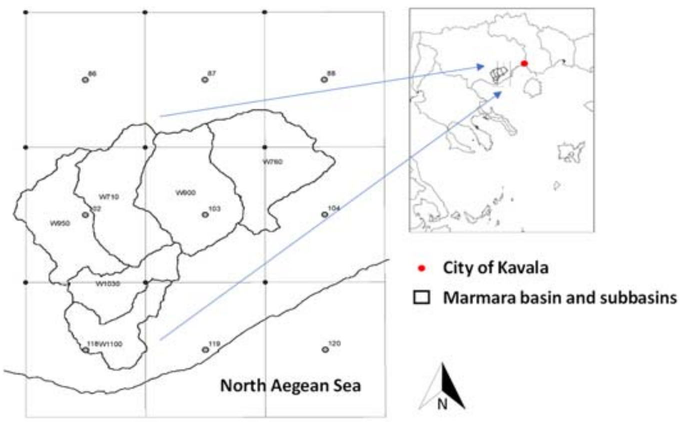

Figure 1. Marmara's river basin subdivided to its subbasins and overlayed by the ERA5 precipitation grid.

Modes and tools for data analysis and simulation

The hydrological model HEC-HMS (Hydrologic Engineering Center – Hydrologic Modeling System) model developed by the US Army Corps of Engineers (U.S. Army Corps of Engineers, 2008) was used to simulate the basin runoff. The applicability of the model for simulating river discharges under current and climate change conditions is peer reviewed in the literature (Ouédraogo et al., 2018; Meenu et al., 2013). For the case study basin, the utilized loss, transform and baseflow methods for each subbasin is presented in Table 1. The routing method and the channel losses were assessed by the Muskingum-Cunge and Constant losses methods respectively (U.S. Army Corps of Engineers, 2008).

The estimation of the subbasins' geometric and hydrological characteristics, which are used as input parameters to the model processes depicted in Table 1, was conducted with the use of standard GIS operational routines as well as with the HEC-GeoHMS toolbox (USACE-HEC, 2013). The toolbox was fed with an ASTER-GDEM v2 digital elevation model (DEM) of horizontal and vertical resolution of 20 m and of 3.0 m respectively for the basin's terrain processing, i.e. computation of flow direction and accumulation, stream definition and segmentation as well as extraction of the hydrographic network per delineated subbasin. Standard GIS tools facilitated the union of the area's geological map with the soil types and the land use, with this new unified product to be used by HEC-GeoHMS for creating the Curve Number (CN) grid map. The latter was developed by using lookup table functions with CN number assignments to land use input, according to the TR-55 catalogs (USDA-NRCS, 1986). Moreover, GIS zonal statistics tool was applied to address the mean CN number and impervious percentages to the sub-basins. The distribution of the rainfall to the subbasins and the calculation of the rainfall impact weights to each subbasin was also performed with geographic information systems.

Table 1. Applied methods in the HEC-HMS model for the simulation of the Marmara river basin.

HEC-HMS component	Process	Applied method	Description and equations
Subbasin	Loss	Soil Conservation Service (SCS) Curve Number (CN)	$P_e = \frac{(P-I_a)^2}{(P-I_a)+S}$ (1) $I_s = 0.2S$ (2) $S = \frac{25400CN}{CN} - 254$ (3)
Subbasin	Transform	SCS Unit Hydrograph	$U_p = C\frac{A}{T_p}$ (4) $T_p = \frac{\Delta t}{2} + t_{lag}$ (5) $t_{lag} = 0.6t_c$ (6)
Subbasin	Baseflow	No method	-

where P_e the accumulated excess rainfall (mm), P the rainfall depth (mm), I_a the initial abstraction (initial loss) (mm), S the possible maximum retention after runoff begins, CN the curve number, U_p the unit hydrograph (UH) peak discharge, T_p the time to UH peak, A the watershed area, C a conversion constant equal to 2.08, Δt the excess precipitation duration, t_{lag} the basin lag time which is defined as the time difference between the center of mass of rainfall excess and the peak of the UH (for ungauged basins the SCS methods suggests t_{lag} to be proportional of the time of concentration t_c).

Historic river discharges and rainfalls, and climate change variables

The lack of meteorological and runoff observations at the basin, necessary for the hydrologic model calibration and validation, has overcome with the use of pan European products. In particular, ERA5 reanalysis rainfall data (Hersbach et al., 2020) and river discharges produced by the European version of the Hydrological Predictions for the Environment (E-HYPE) semi-distributed physically based catchment model (Donnelly et al., 2016) were retrieved for an historic period of 11 years, i.e. from 1984 to 1994. For the assessment of climate change on the Marmaras River discharges, precipitation derivatives of three Regional Climate Models (RCMs), namely the IPSL-CM5A-MR (hereinafter denoted as CM5A), KNMI-RACMO22E-EC-EARTH (hereinafter denoted as EC-EARTH) and SMHI-RCA4-HadGEM2-ES (hereinafter referred as HadGEM2) models, under the RCP4.5 representative concentration pathway were exploited. All the RCMs have been developed and implemented in the framework of the COordinated Regional climate Downscaling EXperiment for the European domain (Euro-CORDEX) (Jacob et al. 2014).

RESULTS AND DISCUSSION

Hydrologic model calibration and validation

Eight initial configurations of the HEC-HMS model were created with the corresponding basin simulations to be triggered by the ERA5 reanalysis precipitation data. The sensitivity analysis of the model performance demonstrated the decisive effect of the channels' flow loss parameterization. The correlation between the eight configuration outputs and the E-HYPE river discharges (which are considered as the observation discharges) for the period from 1984 to 1990 (calibration period) demonstrated the best configuration which was adopted for the validation of the hydrologic model for the period from 1991 to 1994. The output of the calibration procedure, Figure 3a, demonstrated an overall good correlation between the HEC-HMS simulated discharges and observed ones (*Pearson correlation coefficient (PCC) = 0.773, Nash–Sutcliffe efficiency coefficient (NSE) = 0.602, and Root Mean Square Error (RMSE) = 1.672*). Similar performance results, Figure 3b, were also produced during the validation period (*PCC = 0.537, NSE = 0.568 and RMSE = 1.472).* The specific model configuration was used for the runoff simulation under climate change conditions.

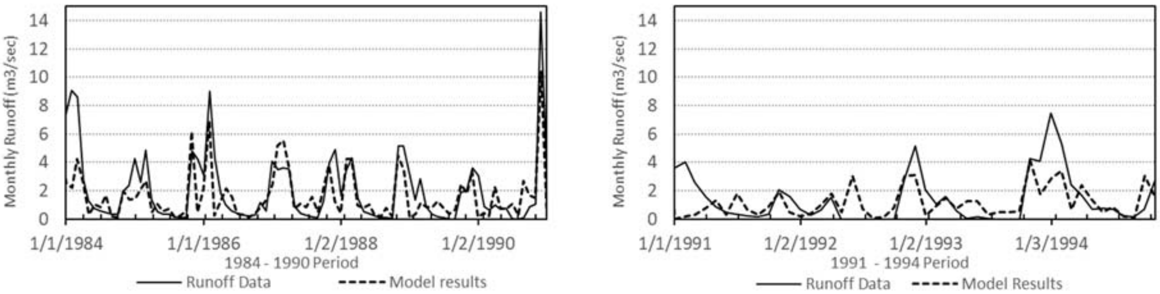

Figure 3. Hydrological model a) calibration for the period 1984-1990 (left hand figure) and b) validation for the period 1990-1994 (right hand figure).

Results under climate change conditions

The average monthly future river discharges for 5 different 20-year periods together with those of the reference period (Ref.P) 1981-2000, which was also produced by the simulation of the RCMs hindcast data, are demonstrated in Figure 4. According to the results produced with forcing by the CM5A model, an increase of the average runoff varying from 23.4% to 39.8% is projected for all the future subperiods in comparison to the relevant reference period. In the case of the EC-EARTH model, a negligible decrease of 3.2% of the river's runoff is foreseen only for the period 2021-2040. Finally, the triggering of the hydrologic model with the HadGEM2 data showed a decrease of 7.4% of the average runoff during the period 2021-2040, while small discharge decreases varying from 1.1% to 2.3% are foreseen for the periods 2041-2060 and 2061-2080 when compared to the reference period.

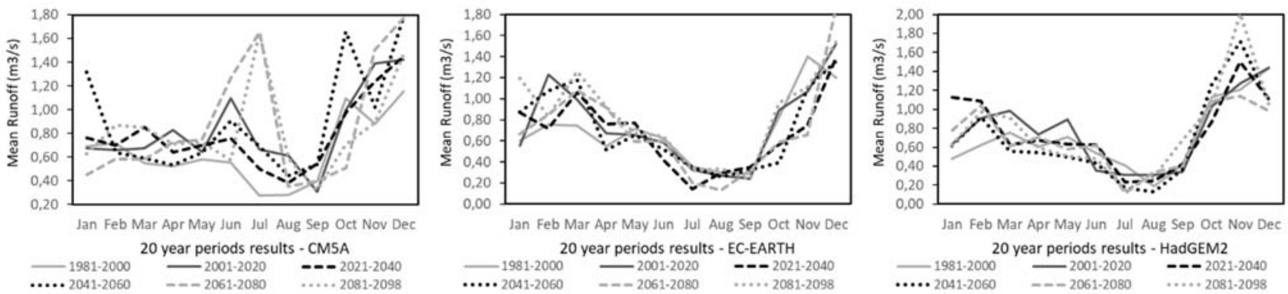

Figure 5. Hydrological model outputs over 20-year periods under climate change at intermonthly level.

To correlate the long-term future discharges with the ones simulated for the beginning of the century, the period 2001-2020 was set as an alternative reference period (Ref.P'). Figure 6 summarizes the hydrologic model simulations concerning the mean runoff (MR) (left hand figure), the mean discharges during the maximum dry periods (MDP), i.e. periods with no discharges, (middle figure), and the mean runoff during the periods of elevated discharges (MER) (right hand figure) as simulated for each of the 20 year periods in comparison to the period 2001-2020 (Ref.P'). According to MR, reduced runoff (compared to the relevant RefP') varying from 4.5% to 9.8% is foreseen for the EC-EARTH and HadGEM2 models throughout the period 2021-2080, while increased runoff from + 5.9% to + 7.9% is forecasted for the CM5A model for the same time period. According to the MDP analysis, the maximum duration of dryness increases up to 229% in the CM5A and EC-EARTH models, while the HadGEM2 model demonstrates decreases from 13.4% to 16.2%. in the period 2021-2060. Based on the MER analysis, it is predicted an increase of the maximum average runoff from +11.5% to +18.0% in the period 2021-2040 and an increase up to +50.9% during the period 2041-2080 for the models EC-EARTH and HadGEM2. The CM5A model shows a reduction of the maximum runoff up to 30.7% during the period 2021-2040 and an increase up to +35.7% from 2041 till the end of the century.

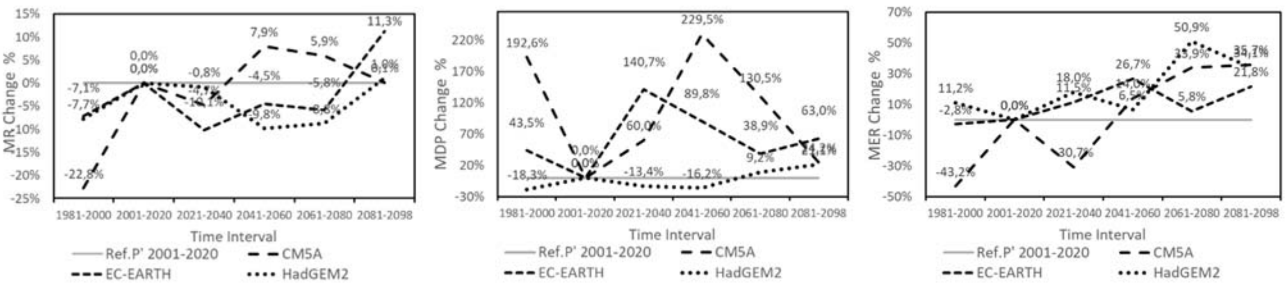

Figure 6. Hydrologic model outputs regarding the mean runoff (MR) (left hand figure), dry periods, i.e. no discharge, (MDP) (middle figure) and maximum runoff events (MER) in comparison to the period 2001-2020.

The overall assessment of the simulation outputs, when the hydrologic model is triggered by the RCMs for the future periods 2021-2040 and 2041-2060 periods is presented in Table 2. In particular, the table clearly depicts the predicted changes of average runoff, seasonal runoff (DJF, MAM, JJA, SON), dryness events (60 consecutive days threshold), maximum dryness period, continuous flow (7 consecutive days threshold), continuous flow periods, and finally the average runoff of the 20 higher flow events, in comparison to the reference periods 1981-2000 (Ref.P) and 2001-2020 (Ref.P').

Table 2. Forecasted changes of quantitative and qualitative runoff parameters relative to reference periods.

% to Ref. Period	2021-2040 Ref.P			2021-2040 Ref.P'			2041-2060 Ref.P			2041-2060 Ref.P'		
Climate Model	CM5A	EC-EARTH	HadGEM2	CM5A	EC-EARTH	HadGEM2	CM5A	EC-EARTH	HadGEM2	CM5A	EC-EARTH	HadGEM2
Average runoff	23,4	-3,2	7,4	-4,7	-10,1	-0,8	39,8	2,9	-2,3	7,9	-4,5	-9,8
DJF	13,8	17,0	30,7	5,6	-9,3	11,5	46,1	29,1	3,4	35,6	0,1	-11,7
MAM	32,5	28,7	-6,7	2,2	11,5	-26,2	6,8	17,0	-22,7	-17,7	1,4	-38,8
JJA	44,6	-23,1	-1,9	-18,4	-15,3	15,7	70,7	-7,3	-29,0	-3,7	2,0	-16,3
SON	12,0	-41,3	1,0	-7,5	-33,3	2,5	35,7	-32,9	27,3	12,0	-23,7	29,2
Dryness events	14,3	0,0	-33,3	-11,1	0,0	-11,1	-28,6	22,2	25,0	-44,4	22,2	66,7
Dryness period	-45,3	67,7	6,0	60,0	140,7	-13,4	12,6	32,3	2,6	229,5	89,8	-16,2
Continuous flow	44,4	-21,4	41,7	0,0	-8,3	-29,2	66,7	14,3	-50,0	15,4	33,3	-75,0
Con. Flow period	0,0	27,3	-9,1	44,4	16,7	-41,2	-15,4	27,3	18,2	22,2	16,7	-23,5
High-flow runoff	22,0	14,7	6,1	-30,7	11,5	18,0	100,8	30,4	-4,2	14,0	26,7	6,5

CONCLUSIONS

The sensitivity analysis during the calibration process of the hydrology model at the case study ungauged basin, demonstrated the importance of optimum estimation of channel losses, a parameter that cannot be accurately assessed by the SCS Curve Number method that is applied for estimating the losses in the subbasins. In terms of climate change and future runoff, the outputs showed that there is not a clear discharges' trend and the outputs depend on the RCM that is used for triggering the hydrologic simulation. On the other hand, at seasonal scale, all simulation outputs agree on decreased runoffs during late summer and early autumn, while varying runoff increases are presented during the winter. For most of the future 20-year periods, it can be concluded an increased number of anhydrous days (lack of discharge) together with an increased duration of these incidents. Additionally, for almost all periods and climate models, the maximum runoff is quite bigger than the one observed in the past. The findings of the research foster the need for sustainable water resources management also at ungauged basins in the framework of climate change adaptation plans and policies.

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MULTI CRITERIA ANALYSIS FOR PRIORITIZATION OF INVESTMENTS FOR RECONSTRUCTION AND MODERNIZATION OF IRRIGATION INFRASTRUCTURE

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Abstract: The reconstruction and modernization (R&M) of irrigation schemes (ISs) in Bulgaria was included as a sub-measure of Rural Development Programme 2014-2020. The funds for R&M were not sufficient for needs of all 223 ISs in the country and the problem of most efficient allocation of the funds appear. Multi-criteria analysis (MCA) is an appropriate tool for prioritization of investments for R&M of irrigation infrastructure, considering different aspects of these investments. Four main criteria for MCA are proposed in this study – Technical, Economic, Environmental and Social, each one of them comprising of multiple sub-criteria. The study is focused on the technical criterion and its sub-criteria. It is used Simple Additive Weighting (SAW) MCA approach. Forty scenarios of different combinations of weighting factors for the main criteria and their sub-criteria are investigated. Estimates are performed for all 223 ISs in Bulgaria and the most suitable ten schemes for R&M are determined. A Geographic Information System (GIS) overlay analysis was performed in parallel and the results of the study are presented in a map.

Keywords: GIS, Irrigation Infrastructure, Irrigation Schemes, Multi-Criteria Analysis, Modernization, Reconstruction

INTRODUCTION

Bulgaria is a country endowed with soils of high fertility, which are suitable for many types of irrigated crops. The country has a significant irrigation infrastructure (IrIs), but after social and economic changes in 1989, this infrastructure has been deteriorating significantly. According official data (Decision of the Council of Ministers, 2000) there are 252 ISs with a total constructed area of 747 113 ha and a total equipped area of 541 780 ha. The term constructed area refers to the area which was supplied with water after completion of the IS, while equipped area refers to the area which can be supplied at present. In the GIS database (JICA, 2008) the number of the ISs is much larger (288 ISs) than the one determined by (Decision of the Council of Ministers, 2000). The detailed analysis shows that the discrepancy in the number of ISs is due to the following groups of reasons: artificial fragmentation of ISs (in this case the total areas are preserved, but the number of systems increases), consolidation of irrigation schemes (In this unification the total areas are preserved, but the number of irrigation systems decreases); redistribution of areas between irrigation systems; technical errors (Bogdanova & Filkov, 2020). The number of the irrigation schemes, included the analysis is 237, based on the available data. Currently in Bulgaria there are 223 ISs, considering the fact that some ISs formally have equipped area equal to zero, and the equipped area has been further decreased to approx. 400 000 ha, mainly in the period 2011-2013.

At same time, climate change is expected to increasingly affect Bulgaria's agriculture in the medium- and long-term with expect a steady rise in annual average temperature that can vary between 0.5˚ C and 1.5˚ C by 2029 and between 2.0˚ C and 5.0˚ C by the end of the century (The World Bank, 2015). The process of reconstruction and modernization (R&M) of the irrigation infrastructure it is not only an instrument for balanced water resources use, but is also the only tool to mitigate the impact of the climate change.

It is recommended (The World Bank, 2015) to use a multi-criteria analysis (MCA) for ranking the projects related to investments in the rehabilitation, R&M of the irrigation infrastructure in Bulgaria.

MATERIALS AND METHODS

A preliminary analysis is done for the needs of prioritization of investments in irrigation infrastructure (Filkov et al., 2018). Indicators for classification of ISs are proposed, as well as rules for structuring the GIS database for the purpose of R&M are suggested. For the study, the ISs are classified by the water intake and delivery network as follows:

- Type G – Gravity fed irrigation schemes. Sub-divided in: Gravity fed IS with a canal network (index Gc) and Gravity fed IS with a pressurized network (index Gp);
- Type P – Pump fed IS, Sub-divided in: Pump fed IS with a canal network (Pc) and Pump fed IS with a pressurized network (Pp). A numerical index shows the levels of pumping in the system – e.g. P1p.;
- Type S – Sprinkler irrigation schemes/systems;
- Type C – Complex ISs. These are a combination of the previous three types. The indices used to mark such ISs show the ways of water delivery – e.g. C-Gc-P1p, C-Gc-Pc-Pp, etc. Most of the Large and Medium IS in Bulgaria belong to this type.

The type of the IS should not be considered as an unambiguous condition for prioritization of the investments. The prioritization of investments for irrigation infrastructure (IrIs) is a complex process, which consists of comparing data for different ISs and classifying them by a certain number of criteria. Some of the criteria have a quantitative range, while others have qualitative features. The Multi-Criteria Analysis (MCA) is suitable for solving complex problems, including both quantitative and qualitative features.

There are variety of methods for MCA: AHP, FSM (fuzzy set method), gray relational method, a method for estimating the enrichment of preferences (PROMETHEE), Elimination and Selection of Translated Reality (ELECTRE), NAIADE, MACBETH, Estimation of Preferences by Inaccurate Ratio Statements (PAIRS), CBIM Interactive Method, etc. (Karleuša et al., 2019), (Tscheikner-Gratl et al., 2017), (Wang et al., 2009), (Aldababseh et al., 2018), (Stemn et al., 2016), (Antunes, 2011). In water management, one of the most commonly used MCA methods is the Simple Additive Weighting – SAW (Hwang and Yoon, 1981). It is a simplified version of the Multi-Attribute Value Theory (MAVT), (Watróbski, J. et al., 2019). SAW is a simple multi-attribute decision technique, based on the weighted average (Afshari, A. et al., 2010) and for that reason SAW is used for the present study.

The cardinal score of a given IS is a weighted sum of evaluation scores S_i of different criteria i:

$$S = \sum_{i=1}^{n} w_i S_i \quad (1)$$

where w_i is the weight of the score S_i.

The score of a criterion S_i can be obtained analogically:

$$S_i = \sum_{j=1}^{m} w_j . x_{ij} \ , \quad (2)$$

where w_j is the weight of the normalized value x_{ij} of the sub-criterion j of the criterion i.

Criteria selection

A summary of criteria which can be used for MCA for prioritization of investments for R&M of irrigation infrastructure is presented in Table 1. The table is an adaptation from (Wang et al., 2009), which considers MCA in energetics. The criteria included in the present analysis are in boldface in Table 1.

This study is focused on the technical criterion. A short description of each criterion and sub-criterion (attribute) used in the study is presented below.

Technical criterion

Equipped/Constructed Area ratio (E/C area ratio)

This quantitative sub-criterion takes into account the extent to which the system is preserved. The values range between 0 and 1, so there is no need of normalizing. The value of 1 is the best and it means that the infrastructure is well preserved. The lowest priority is given to irrigation schemes with an equipped area of zero.

IS Size

It is decided to give advantage to larger ISs because the larger number of users will benefit from R&M. According to IS size and category (Bogdanova and Filkov, 2020) points are assigned to each IS, using the rules below:

- ISs with a constructed area ≥ 25 000 ha are assigned with 15 points;
- ISs with a constructed area from 7 500 to 25 000 ha – 13 points;

- ISs with a constructed area of 2 500 to 7 500 ha – 8 points;
- ISs with a constructed area from 1 000 to 2 500 ha – 3 points;
- ISs with a constructed area ≤ 1 000 ha – 1 point.

The values of the sub-criterion are normalized, with the highest score of 1 being assigned to largest ISs.

Table. 1 Criteria for MCA for prioritization of investments for R&M of irrigation infrastructure

Result	Method Criterion	Criterion	Method Sub-criteria	Sub-criteria
Ranking of the Irrigation Schemes ←	Multi-criteria analysis (MCA)	**Technical** ←	MCA	**Equipped/Constructed Area ratio**
				Irrigation system size
				Water intake type
				IS efficiency
				Automation opportunity
				Reliability
				Safety
				Others
		Economic ←	B/C Ratio	Specific investment cost for R&M
				Depreciation, operation and maintenance cost
				Electricity expenses
				Net present value
				Payback period
				Potential additional farm income
				Benefit/Cost ratio
				Others
		Environ-mental ←	MCA	**Water savings potential**
				Water body status
				Land use
				Others*
		Social		Priority within the NRDP 2014-20
				Social acceptability
				Job creation
				Social benefits
				Others

* New criteria must be added due to present European politics (Regulation (EU) 2020/741).

Water Intake Type (WI Type)

This qualitative sub-criterion takes into account the water supply security at source. In order to quantify the sub-criterion points are assigned to each type of IS according to the type of water intake. Priority is given to ISs with a “regulated runoff” type of supply for which 10 points are assigned. To “multiple sourced” ISs as well as for ISs supplied by the Danube River 8 points are assigned. The lowest score is given to “run-of-the-river” and “groundwater intake” ISs – 5 points. Normalization is applied, where 1 is for the “regulated runoff” ISs.

Present IS efficiency

The present conveyance and distribution network efficiency is taken into account. Average values by types of ISs have been estimated. It is assumed to restore with priority ISs with low efficiency, since they need R&M more urgently. The sub-criterion ranges between 0 and 1, with 1 corresponding to the lowest current efficiency. The value for each IS is obtained via normalization between the lowest and highest current efficiency of the ISs in Bulgaria.

Automation opportunity
For the different types of ISs a rating is given from 1 to 5, where 1 - bad, 2 - satisfactory, 3 - good, 4 - very good, 5 - excellent. Type S (Sprinkler) schemes/systems are rated the highest (5 points), as the water flow in the network is always automatically coordinated with the actual consumption.
Reliability
The criterion is scored from 1 to 5, where 1 - bad, 2 - satisfactory, 3 - good, 4 - very good, 5 - excellent. A different number of points are given for each type of irrigation scheme/subsystem. ISs with multiple stages of water lifting (Type P2p, P3p, P2c, etc.) are rated with the lowest number of points. The maximum of 5 points is awarded to Type Gc irrigation schemes/subsystems.
Safety
The safety of the facilities of the irrigation infrastructure has both a technical and a social aspect. In the present work this sub-criterion is assumed as part of the technical criterion, but due to need of additional information and analysis, it is not taken into account.

Economic criterion
For the purpose of the study this criterion has only one sub-criterion – Benefit/Cost ratio.
Benefit/Cost ratio (B/C ratio)
This ratio is an integral parameter which incorporates variety of other sub-criteria. In this research the B/C ratio for each IS is estimated by including Potential additional farm income in the part of the benefits and Annual operation and maintenance costs, and Annual depreciation costs in the part of the costs.
Potential additional farm income for different ISs is adopted from (The World Bank-2, 2015).
Annual operation and maintenance costs are estimated including electricity expenses, calculated for pumping water volumes in an average year and data for the pumps in the specific system. Maintenance and other operation costs are estimated only for the structures for which rehabilitation, R&M are provided. These structures are dams, intake structures (headworks), parts of main and secondary canals/pipelines, pumping stations, regulating reservoirs, canal regulating structures, water measuring structures and devices, turnouts, etc. *Annual depreciation costs* are estimated only for the structures for which rehabilitation, R&M are provided.
The B/C ratio results for the 237 ISs in Bulgaria vary considerably from 0.3 to 133. For the purpose of MCA analysis B/C ration values are normalized. To avoid overestimation, the maximum one-point score is given for a value of 19, which corresponds to the 90% quintile of all calculated values.

Environmental criterion
Water savings potential (Relative potential water savings - RPWS)
Water savings are defined as difference between the anticipated future water use and the current one. The anticipated future water use is estimated for all ISs using the efficiency of their conveyance and distribution networks according to Standards (Standards for Design of Irrigation and Drainage Systems, 1994). Relative potential water savings (RPWS) are estimated as ratio between the potential water savings and the current water use. Priority is given to ISs that offer the greatest potential for water savings.
Water body status (WB status)
The indicator used is the current ecological status of the surface water body from which irrigation water is abstracted for the need of a given IS. Unfortunately, to present day in Bulgaria there it is not defined the status of the water body based on water quantity. The information available for ecological status of the surface water bodies has been scored as follows: very good (1.0), good (0.8), moderate/possibly at risk (0.6), at risk (0.4), bad (0.2), very bad/no data (0.0). No normalization is needed.
Land use
In the current MCA, it is assumed that R&M affects only constructed areas, therefore this criterion is excluded from the analysis.
Others
Requirements for water reuse should be included as a sub-criterion, following up the new EU directive (European Union, 2020). The study was made before the issuing of this EU regulation, so water reuse is not included in the present MCA.

Social criterion
This criterion as well as all sub-criteria are excluded from the current study, due to its complexity and need of completely different data than available.

Planning the research experiment
Determining the weights for MCA

The weights of the main criteria are considered in five variants A, B, C, D and E (Table 2). Variant A gives advantage to Technical criterion, Variant C – to Economic criterion, and Varian E – to Environmental. Variant B favorize Technical and Economic criteria, as Varian D provides equal weights to all main criteria. For the technical sub-criteria, four variants are considered - 1, 2, 3 and 4. Variant 1 assumes equal weights for all attributes, while variants 3 and 4 favorize the most sub-criteria IS size and IS Efficiency, but also give advantage to WI Type. The Ecological criterion is developed in two variants - i and j.

Table 2. Variants of criteria and sub-criteria weights

Main Criteria	**Weights in points**					**Relative weight within a group**				
	Variants					**Variants**				
	A	***B***	***C***	***D***	***E***	***A***	***B***	***C***	***D***	***E***
Technical	6	4	3	3	1	0,6	0,4	0,3	0,333	0,25
Economic	3	4	6	3	1	0,3	0,4	0,6	0,333	0,25
Environmental	1	2	1	3	2	0,1	0,2	0,1	0,333	0,5

Technical Sub-criteria	**Variants**				**Variants**			
	1	***2***	***3***	***4***	***1***	***2***	***3***	***4***
E/C Area Ratio	1	2	2	2	0,167	0,182	0,100	0,125
IS size	1	2	5	4	0,167	0,182	0,250	0,250
WI Type	1	2	4	3	0,167	0,182	0,200	0,188
Present IS Efficiency	1	2	5	4	0,167	0,182	0,250	0,250
Automation opportunity	1	2	3	2	0,167	0,182	0,150	0,125
Reliability	1	1	1	1	0,167	0,091	0,050	0,063
Safety	0	0	0	0	0	0	0	0

Economic Sub-criteria	**Variants**	**Variants**
	0	***0***
B/C ratio	1	1

Ecological Sub-criteria	**Variants**		**Variants**	
	i	***j***	***i***	***j***
RPWS	1	3	0,5	0,75
Water body status (WBS)	1	1	0,5	0,25

Forty scenarios are investigated on the basis of the assumed variants of weighting factors for different criteria in Table 4. Each scenario is named after the variants from which it is formed – e.g. A10i, A10j, B20i, etc. The zero in the name is placed to take into account the absence of variants for the economic criterion an MCA.
The overall ranking is done using the following approach. For each of the 40 scenarios the ISs are ranked and the average place in ranking is estimated for each IS. A list of ranked ISs is arranged in descending order and the first 30 ISs are determined. To find which scenario represents in the best way the average ranking of the ISs the list is compared with rankings of all 40 scenarios. Three scenarios are selected, in which the rankings of the ISs coincide the most with the average ranking.

RESULTS AND DISCUSSION

The values of sub-criteria and main criteria are estimated for each of 237 ISs in Bulgaria. It was found that several ISs appear in the forefront in all 40 scenarios (e.g. Ihtiman IS).
There are three scenarios in which the rankings of the ISs coincide the most with the average ranking are B40i, B30j and D40j. Scenarios B40i and B30j give advantage to Technical criterion and to its sub-criteria *IS size*, *IS Efficiency* and *WI Type*. Scenario D40j does not tolerate neither of the main criteria, but again the mentioned three technical sub-criteria are weighted more, as well as the *RPWS* in the Environmental criterion.
After comparison scenarios B30j, B40i and D40j, the scenario B40i was chosen to be representative as it matches the best with the average ranking. The results from Scenario B40i are shown in Table 3.

Table 3. Sample on MCA results of Scenario B40i

№	Irrigation Scheme	IS Type	Technical Criteria						Econ. criteria	Environmental criteria		Final Score
			E/C Area	IS size	WI Type	Present effi-ciency	Autom . opp.	Reli-abilty	Norm. B/C Ratio	RPWS normal .	WBS	S
1	Ihtiman IS	Gp	1.00	0.50	1.00	0.61	0.50	0.75	1.00	1.00	0.60	0.84
2	Dobromirtsi IF	Pp	1.00	0.14	1.00	0.81	0.75	0.25	1.00	1.00	0.41	0.80
3	Karaysen IS	C-P2c-S	0.16	0.50	1.00	0.99	0.45	0.07	0.86	1.00	1.00	0.80
4	Petelovo IF	Pp	0.95	0.00	1.00	0.81	1.00	0.25	1.00	1.00	0.41	0.80
5	Bolyarovo IS	C-Pc-P2c	1.00	0.50	1.00	0.56	0.25	0.41	1.00	0.78	0.54	0.79
6	Peshtera IS	C-Gc-Pc	0.53	0.50	0.50	0.64	0.25	0.93	1.00	1.00	0.71	0.78
7	Yastreb IF	Pp	0.71	0.00	1.00	0.81	0.75	0.25	1.00	1.00	0.41	0.78
8	Gorsko slivovo IS	Gc	0.45	0.14	1.00	0.79	0.25	1.00	1.00	1.00	0.47	0.77
9	Vitska IS	C-Gc-Pg-Pp	0.72	1.00	1.00	0.79	0.25	0.58	0.77	1.00	0.47	0.77
10	Polyanovo IF	P1p	1.00	0.14	0.50	0.81	0.75	0.25	1.00	1.00	0.41	0.77

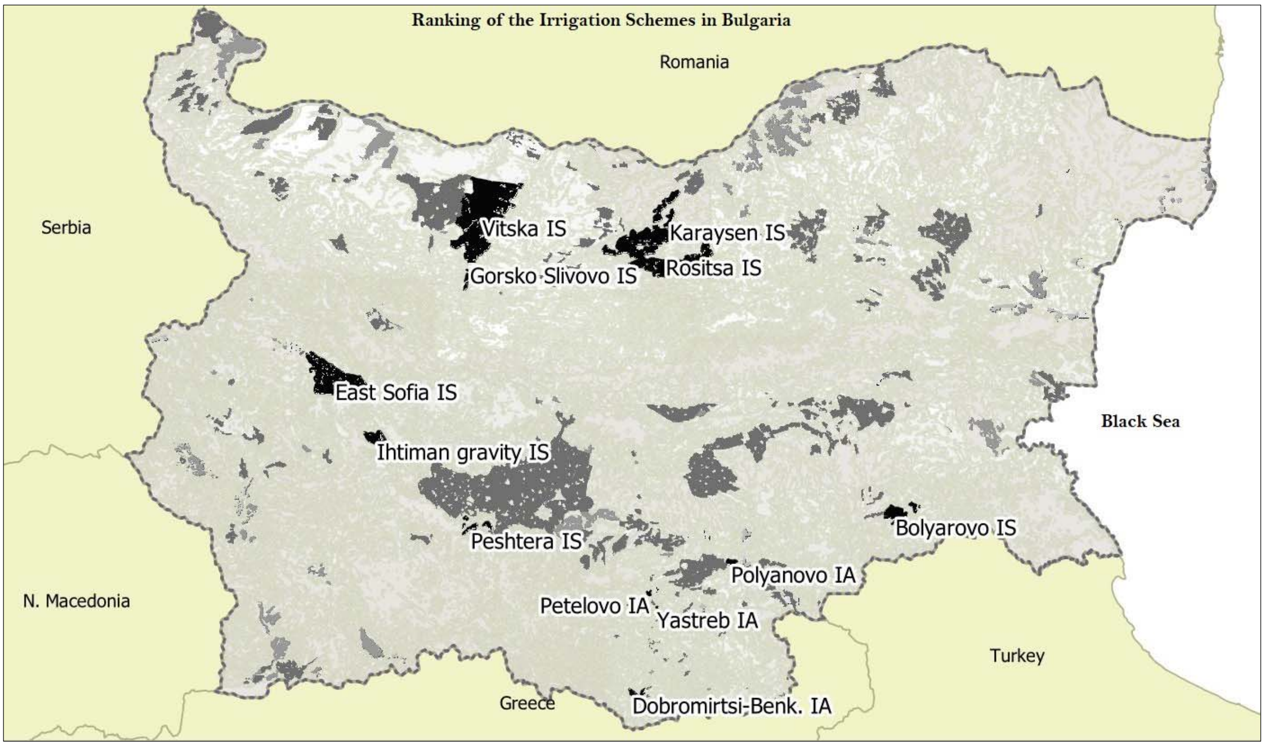

Figure 1. Map of first twelve ranked as “excellent” Irrigation Schemes in Bulgaria

GIS overlay analyses result

GIS overlay analysis was performed in parallel for all scenarios. Five groups of ISs are formed according to their average MCA ranking, as follows: Bad (<0.17), Satisfactory (0.17÷0.34), Good (0.34÷0.51), Very good (0.51÷0.76) and Excellent (>0.76). The ISs in “Excellent” group are shown in dark grey in Fig. 1.

Analysis of MCA results

The data is analyzed using statistical methods by ISs and sub-systems. The best ranked ISs, which can be fund by one of the sub-measures in Rural Development Programme 2014-2020 are shown in Table 4. The results of the MCA and GIS overlay analysis can be compared. The last column shows the average ranking result *R* in relative terms of the ISs which fell in top 30 of each scenario. The result *R* is calculated by the formula:

$$R_i = 1 - \frac{\sum_{j=1}^{m} Y_{ij}}{m.n} \quad (3)$$

where Y_{ij} is the place in ranking of IS *i*, in scenario *j*; *m* is the total number of scenarios (*m* = 40); *n* are the top places in each ranking (*n* = 30).

Table 4. Analysis of Investments for the first ten ISs

№	IS name	Constructed Area, ha	Total Investments, €	IS Type	Score MCA	Score GIS	Number of times in Top 30	R
1	Ihtiman IS	3 901.3	7 553 522	Gp	0.84	0.84	40	0.96
2	Dobromirtsi IF	1 538.3	1 347 101	Pp	0.80	0.80	40	0.89
3	Karaysen IS	3 119.0	4 253 557	C-P2c-S	0.80	0.80	35	0.61
4	Petelovo IF	350.8	159 194	Pp	0.80	0.80	40	0.89
5	Bolyarovo IS	4 975.4	5 479 360	C-Pc-P2c	0.79	0.79	40	0.68
6	Peshtera IS	3 596.8	4 376 725	C-Gc-Pc	0.78	0.78	40	0.75
7	Yastreb IF	545.9	190 774	Pp	0.78	0.80	40	0.77
8	Gorsko slivovo IS.	1 180.8	544 567	Gc	0.77	0.76	40	0.76
9	Vitska IS	29 200.4	34 679 990	C-Gc-Pg-Pp	0.77	0.80	32	0.54
10	Polyanovo IF	1 097.0	534 348	Pp	0.77	0.79	40	0.69
	Total Investments:		59 119 138	€				

The funds allocated for R&M of IrIs under Rural Development Programme 2014-2020 amount to 54 699 274 €. As evident by data in Table 4, these funds can be used for R&M of only 10 ISs out of 237, if R&M of the entire ISs are assumed.

CONCLUSIONS

The presented MCA approach might be used both in government and private sector assessments. It allows different analyses and calculations, especially implemented in GIS environment. The following conclusions can be drawn, considering the application of MCA in this study:

- The inclusion of three criteria in the MCA - technical, economic and environmental, with sub-criteria, makes it possible to objectively assess all indicators of the irrigation systems in Bulgaria. MCA with only major criterion is sensible to the judgement of the decision-maker and are not recommended.
- Although different weights are given in the forty scenarios, Ihtiman IS always ranks first, which shows that the MCA method completely excludes the factor of subjectivity in evaluation. This system is gravity fed with pressurized network, there are no electricity expenses, and the pressurized network allows automation of the system and significant RPWS.

- The GIS overlay analysis shows similar results to SAW MCA method and it can be used for prioritization of the investments for R&M of the IrIs. There are differences in the score results, but the sorted ranking by score matches the result of the SAW MCA average ranking of the ISs.
- The result shows that small ISs with a constructed area less than 2 500 ha are ranked with high scores, despite the low points, given in *IS Size* sub-criteria. Such ISs most commonly consist of a Pumping Station, a regulated reservoir and a pipeline network. The reason to be scored best is that the benefits (both environmental and economic) of the R&M can be achieved with less investments in comparison to large systems.
- The approach used in the current MCA allows future analyses and rankings to be made on the basis of sub-systems. Thus, the investments can be allocated to parts of the ISs.

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MASTER'S THESES IN THE FIELD OF HYDROTECHNICAL ENGINEERING AT THE FACULTY OF CIVIL ENGINEERING (UNIVERSITY OF RIJEKA) - GOOD PRACTICE EXAMPLES

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Abstract: The aim of this paper is to give an overview of the student master's theses on the University Master level at the Faculty of Civil Engineering, University of Rijeka in the area of hydrotechnical engineering since 2015 in order to point out good practices with students that could be useful to other Higher Education (HE) institutions. After presenting the short history of the Chair for Hydrotechnics development, based on analyses of 104 master's theses in the area of hydrotechnical engineering, different types of the master's theses are defined and examples from each type of the master's thesis (practical, scientific, and theoretical) are presented.

Keywords: hydrotechnical engineering, hydrotechnical laboratory, master's thesis, practical, scientific, theoretical.

INTRODUCTION

The Faculty of Civil Engineering of the University of Rijeka was established and started with civil engineering studies as an independent institution in 1976. Since then, the Faculty has undergone many reorganizations. Although the Chair for Hydrotechnics in various forms within the departments or chairs has existed since 1982, the biggest organizational change can be considered the establishment of the Department of Hydrotechnics and Geotechnics in 2005 within which the Chair for Hydrotechnics operates today. Organizational changes were accompanied by an increase in the number of teaching staff, study programs development, an increase in the number of students, and moving to a new larger building with laboratories (Dragičević (edc), 2018). Today the Chair for Hydrotechnics employs 12 people (10 scientific teaching staff and 2 professional/research staff). Since 2008 the Faculty offers study programs in civil engineering that are in line with the principles of the Bologna Declaration, namely in accordance with the propositions of the European Credit Transfer System (ECTS). Moving to the new building within the University of Rijeka campus in 2011, in addition to increasing working space and improving working conditions, enabled the establishment of the Hydrotechnical laboratory in 2014 (http://iuri.uniri.hr/const_edu/faculty-of-civil-engineering/). The Laboratory equipment purchase and installment were mostly founded by the European Union under the European Regional Development Fund (RC.2.2.06-0001) through the project "Development of Research Infrastructure at the University of Rijeka Campus" (Croatian abbreviation: RISK).

All the mentioned above led to the development of the academic, scientific, and professional work at the Chair for Hydrotechnics, and it has improved the cooperation with students. In the beginning, master's theses were mainly focused on professional civil engineering problem solutions, and through the years, the focus has widened toward scientific problems and on the cooperation with other domestic and foreign Universities as well as cooperation with the industry. Because of that, the quality of the master's theses also increased, preparing students better for the working market.

Therefore, the aim of this paper is to give an overview of the students' master's theses on the University Master level that were done since 2015 in order to point out our good practices with students that could be useful to other Higher Education (HE) institutions.

TYPES OF MASTER'S THESES IN HYDROTECHNICAL ENGINEERING

In this paper, the focus is placed on the University Master Study in Civil Engineering. The study offers the possibility to enroll in 6 branches (the Chair for Hydrotechnics is mostly involved in courses offered in the hydrotechnical engineering and urban engineering branch), it consists of four semesters and with a minimum of 120 ECTS. The master's thesis is prepared in the fourth semester. There are different types of master's theses that students can choose from. The student writes the master thesis during the planned 120 hours of active teaching at the Faculty and a total effort of a maximum of 30 ECTS credits (Academic graduate programme in Civil Engineering, 2018). The thesis can be on, practical, theoretical, and scientific topics (Figure 1.) related by its contents to civil engineering and the offered courses within the study programme. Students define the list of mentors under whose supervision they would like to prepare their master's thesis and the committee for the master's thesis approves a mentor, based on student's interest but also its grades and ECTS gathered during the study. This is done during the third semester or at the latest by the beginning of the fourth semester of the academic year in question. A part of the master's thesis can be carried out as fieldwork - practical teaching (a total of up to 15 ECTS), and in this case, the student has to prepare the diary of activities carried out at the other institution / firm and that must be related to the master's thesis topic. The mentor at the Faculty collaborates with the mentor provided by the other institution / firm in order to define in detail the thesis topic and follow student's work. Students may also choose to complete a whole or part of their master's thesis at another domestic or foreign University as part of student ERASMUS or CEEPUS mobility.

Scientific topics

- creating a civil engineering construction computer model
- numerical modeling of materials and processes in materials
- creating studies related to water management
- topics related to design, analysis and construction of more complex civil engineering structures and systems
- and similar.

Practical topics

- design of a civil engineering structures
- static and dynamic analysis (calculation) of structures
- analysis of hydraulic structures solutions
- project and project analysis related to urban areas (transportation projects, spatial and spatial planning studies, water management structures in urban areas)
- and similar.

Theoretical topics

- analysis of a more complex problem which requires additional theoretical processing and presentation of an analytical or a numerical solution procedure.

Figure 1. The master's theses basic topics for all branches

When writing the master's thesis, the student actively cooperates with his teacher-mentor who, as a rule, teaches the course whose contents are related to the selected topic. A teacher co-mentor can also participate in advising the student in writing the thesis if required (https://gradri.uniri.hr/files/Pravilnik_o_studijima_2018.pdf). At the moment, students can choose between ten different mentors and fourteen offered courses in the field of hydrotechnical engineering.

OVERVIEW OF MASTER'S THESES IN HYDROTECHNICAL ENGINEERING

In this section, a statistical overview of the master's theses in the area of hydrotechnical engineering since 2015 is going to be presented. In this period, there were 104 master's theses done in the area of hydrotechnical engineering, and the yearly statistic is shown in Figure 2.

Master's theses analysis according to scientific, professional, or theoretical type was done. Under the theoretical type of master's thesis, also a combination of the scientific- professional topics is counted. The analysis is shown in Figure 3.a) where is visible that 24,04% (25 theses) of all master's theses are done as scientific research, while 43,27% (45 theses) are done as a professional type where studies and design of different hydrotechnical constructions and systems are conducted. The rest of the theses 32,36% (34 theses) are done either as theoretical or as a scientific-practical type of the theses, which means that some part of the work fits different types.

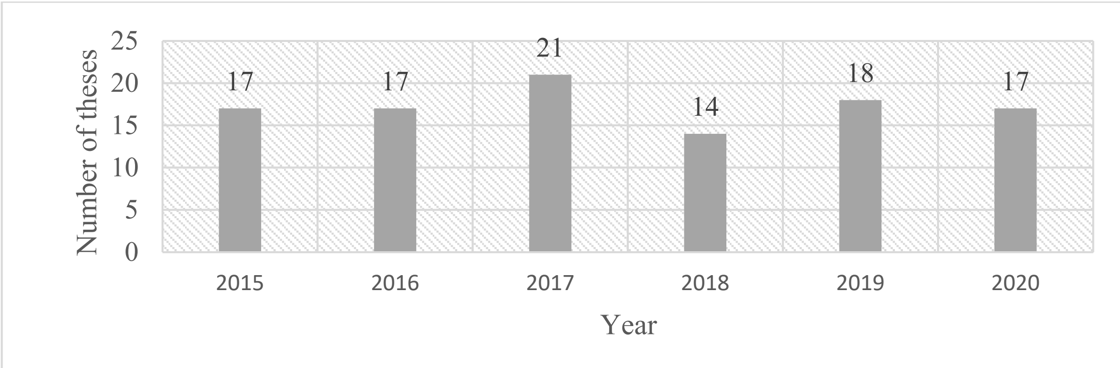

Figure 2. Yearly statistics of the master's theses number in hydrotechnical engineering

Since the Hydrotechnical laboratory and other 4 laboratories started with work in 2014, the competitiveness of our whole Institution increased which resulted in leadership and participation in many domestic and foreign scientific-professional projects as well as professional projects. Mentioned projects in the area of hydrotechnical engineering are mostly based on hydrotechnical field measurements, laboratory research, and numerical modeling providing the opportunity to involve students in the research and project work. As a result of the students' work within various projects, in the last 6 years, 25,96% of master's theses were done with scientific or professional projects affiliations.

An appropriate data source can be considered a base for a good master thesis, and that is why the laboratory and field measurement equipment is used wherever it is possible in order to expand cooperation with students and give them different choices in selecting the master's thesis topic. As a result, around 30% of the master theses are based on the laboratory or field measurements in the last six years as is shown in Figure 3.b), and the rest of these data are provided by cooperation with either other institutions or industry.

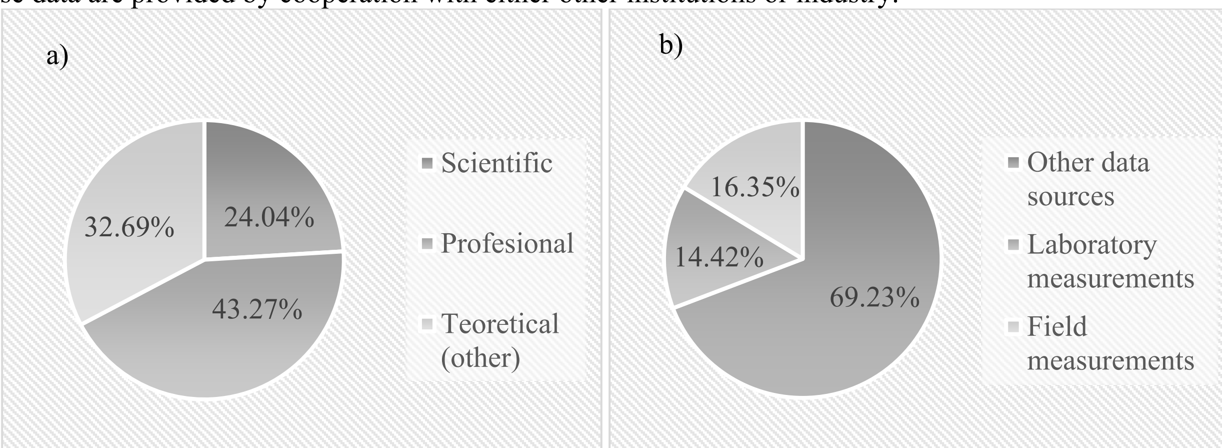

Figure 3. Distribution according to: a) master's theses type and b) master's theses data source

It is very important to point out, that the interest of students in laboratory work and scientific research has increased significantly in the last six years. Just three students did their master theses in cooperation with other foreign Universities and the reason for that may be laying on the fact that students now have a lot of opportunities at the Faculty, and also because of the COVID-19 situation in 2020 and 2021.

Students are encouraged to learn how to use different computer languages for example MATLAB (MathWorks) and PYTHON, as well as to be up to date with the development of new computer programs for example CloudCompare (EDF R&D,Telecom ParisTech), ArcGIS (Esri), Urbano Hydra (StudioArs), Urbano Canalis (StudioArs) and Bentley WaterCAD (Bentley Systems, Inc.). As a result, 26% of all master's theses in hydrotechnical engineering in the last six years were done using mentioned computer languages and programs. The success of the cooperation with students on their master theses is also visible in 17 scientific and professional articles that were published in co-authorship of students and teachers in the last six years.

EXAMPLES OF MASTER'S THESES IN HYDROTECHNICAL ENGINEERING

In this section, examples of different master's theses types are going to be presented. Three typical master theses as follows: scientific, professional, and thesis that is representing synergy between the scientific and professional area, are going to be described.

Conceptual Solution of the Surface Water Drainage from the Slani Potok Catchment

This scientific type of master's thesis was done by student Marko Lettich, and he was rewarded with Croatian Waters Award for the best master's thesis for the hydrotechnical engineering and water management area in 2016. This thesis proposes the conceptual solution for the surface water drainage from the Slani potok catchment by the usage of the experimental material with specific capillary drainage properties (Figure 5). Due to its unique hydrogeological, lithological, and tectonic proprieties, the Slani potok catchment is one of the largest areas affected by excessive erosion. In order to mitigate possible damaging effects to the nearby objects and population, it was necessary to diminish the erosion processes and stabilize the area. The solution that was examined through this thesis was a mitigation of the erosion processes by drainage of the surface water from the center of the area affected by erosion. The conceptual solution consists of a description of the area in geological and hydrological terms, a review of the current situation, explanations of the conceptual solution that was tested by the physical model in the laboratory (Figure 5), and hydrological-hydraulic calculations. The channel discharge is defined and calculated by means of the Soil Conservation Service method (SCS). This kind of solution has the objective to drain away from the surface water from the center of the affected area in a quick and simple manner using an experimental material with improved drainage properties which will drain the surface and subsurface water from the surrounding soil (Lettich, 2016).

a) b)

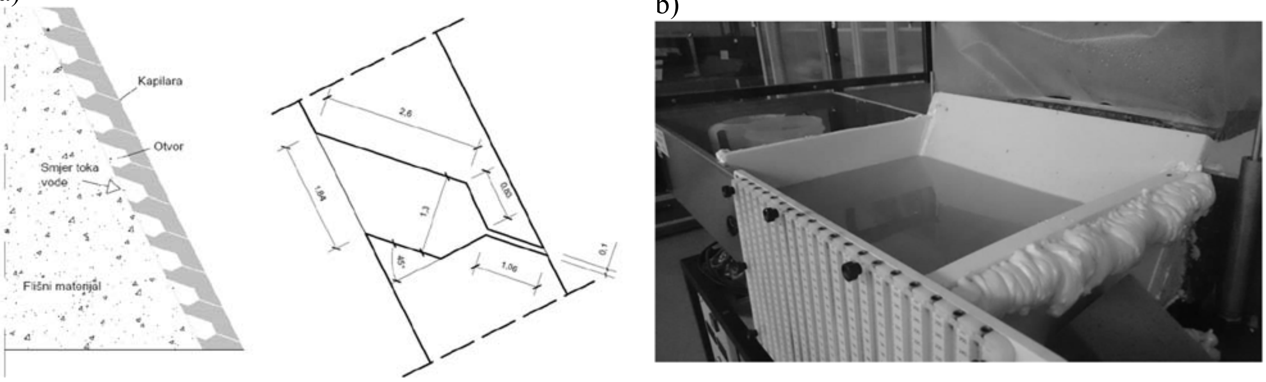

Figure 5. Experimental material with specific capillary drainage properties (Lettich, 2016): a) Cross section plan and b) Laboratory research on HM 145 - Advanced hydrological investigations

Conceptual Design of Sanitary Wastewater Drainage of the Municipality of Hreljin

This professional master's thesis was done by student Doris Kalc and its objective was to make a conceptual design for the sanitary wastewater drainage system for the Municipality of Hreljin. The basis for the project is taken from the Spatial Plans of the City of Bakar. Two solutions for wastewater collection and for wastewater treatment are considered: first stage solution (wastewater collection and treatment on a temporary waste water treatment plant (WWTP) Hreljin) and long-term solution (wastewater collection and treatment on WWTP with submarine discharge in Kostrena). In the thesis, detailed descriptions of all drainage system elements, calculation of wastewater quantities, sizes of all collectors, calculation of the pipes' statics, and design of pumps is presented. In the graphic part are given collector network plans of for the whole systems as well as longitudinal and cross-sections of drainage collectors (Figure 6). The design of the drainage system in this thesis is done using software Urbano Canalis (StudioArs) (Kalc, 2015).

a) b)

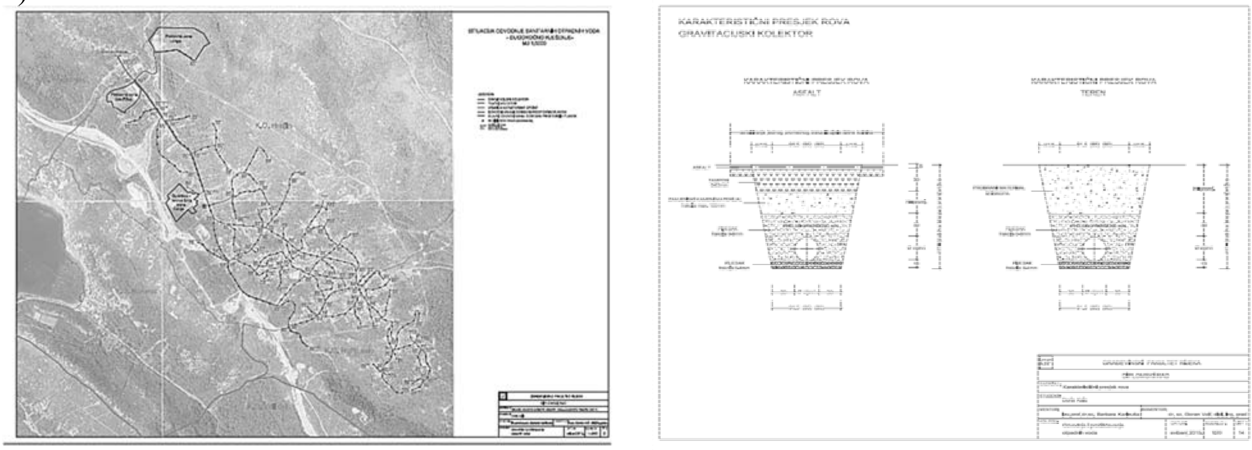

Figure 6. Conceptual design for the drainage of sanitary waste water for the Municipality of Hreljin (Kalc, 2015): a) collector network plan and b) characteristic cross section of the collector

Spatial interpolation of the measured precipitation data using multiple linear regression in GIS environment

This master thesis is done by student Davor Šepić and it represents the synergy between the scientific and professional approach in the analyses of the precipitation distribution by comparison of different distribution methods within the QGIS software, considering digitalized information about the natural characteristics of the area. This thesis shows and explains the procedure of how a map of the spatial interpolation of precipitation in the catchment area of the river Mirna and the entire Istrian peninsula is made. The method used is multiple linear regression with input data of annual precipitation at meteorological stations of the Istrian peninsula. The information used on the precipitation are from the period from 1961 to 1990 collected from the Croatian Meteorological and Hydrological Service. Analysis results showed that the area with the lowest predicted precipitation in the western part of Istria, and the largest predicted precipitation we found on the slopes of mounts Učka and Ćićarija (Figure 7). In the river Mirna basin, the area with the most precipitation is the area around the town of Hum and with the least precipitation is the area near the town of Novigrad at the mouth of the river (Šepić, 2015).

a) b)

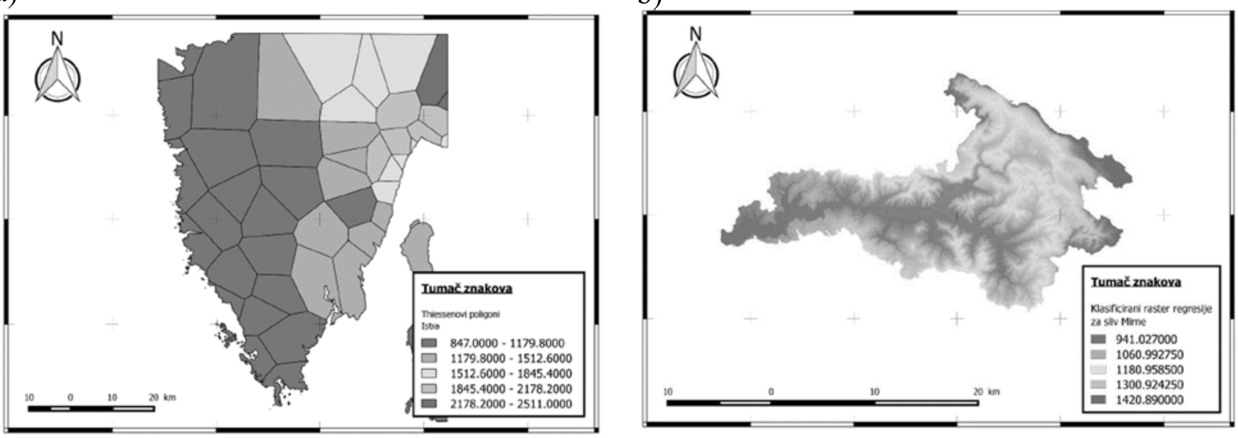

Figure 7. QGIS software precipitation analyses results (Šepić, 2015): a) Thiessen polygon method and b) classified raster of the river Mirna

DISCUSION AND CONCLUSION

The Faculty of Civil Engineering moving to the new building at the University campus with equipped laboratories, led to the enhancement of teaching, scientific, and professional activities. Also, the number of employees has grown and today the Chair for Hydrotechnics counts 12 people (10 scientific teaching staff and 2 professional/research staff).

Development of the work with students is visible especially in the quality of the master's theses in the last six years as well as in practical and scientific articles that are published in cooperation with students.

Students are offered to work on practical, scientific and theoretical types of the master's theses. In the last six years, at the Chair for Hydrotechnics 104 master's theses were mentored, of which 24,04% (25 theses) of all are done as scientific research, while 43,27% (45 theses) are done as a professional type and the rest of the theses 32,36% (34 theses) are done as theoretical and scientific-practical type.

Today, the civil engineering industry demands all kinds of a different profiles of civil engineers. That means that it is necessary to adapt study programmes and learning outcomes according to the market development and needs and as well to satisfy student's interests and affinities. Some students see their future job in the industry and because of that, there is an opportunity to do the practical master's thesis topic in cooperation with the industry and in combination with the learning of new software. Also, some of the students have affinities toward science, and they would like to continue their research after graduation. The use of the hydrotechnical laboratory is also given as an option. If the students have an interest in the analysis of the hydrotechnical data there is also an opportunity to do field measurement work and to do master's theses that are going to be partly theoretical with a mixture of practical and scientific knowledge. Overall, students have a lot of different topics to choose from and if they want to, they can also do their theses through the student ERASMUS or CEEPUS mobility programs in other HE institutions.

The Faculty of Civil Engineering, University of Rijeka continuously develops in line with the market and science needs. By elaborating and solving different hydrotechnical problems through students' master's theses contributes to the regional and local communities and to continuous knowledge improvement in the field of hydrotechnical engineering.

ACKNOWLEDGMENT

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THE FUNDAMENTALS OF RISK ASSESSMENTS ON THE GEOHAZARD CONSEQUENCES

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Abstract: This paper provides the basis for possible geohazards assessments and geohazard risks, as well as a description of measures that need to be implemented in the event of the formation of debris flow and mudflow in a particular area. The most common causes of the formation of debris flow and mudflow in a certain area can be the consequence of slipping or landslides in certain valleys. Therefore, the paper will describe the possible consequences of geohazard, as well as the process of hazard analysis and organizational resilience of the community to the consequences of landslides. The paper describes the general procedure of risk management from possible formation of debris flow and mudflows. The methodology on which the assessment of geohazards in a particular area is based includes Quantitative and Qualitative Risk Analysis from the consequences of rock mass slippage. Qualitative risk analysis uses a descriptive pattern, descriptive or numerical scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur. The quantitative risk analysis is based on numerical values of probability, vulnerability, consequences and the resulting numerical values of risk.

Keywords:landslide risk, risk assessment, hazard assessment, landslide zoning, vulnerability, risk management.

INTRODUCTION

The key to understanding the analysis of vulnerability and risk from the consequences of natural disasters is the overall consideration of hazard analysis, ie a multidisciplinary approach to the consideration of risk management issues. The main purpose of managing the risk of possible consequences of natural disasters is to: (i) provide a framework for understanding the nature and consequences of natural and man-made hazards on people, built property, infrastructure and the environment, and (ii) examine strategies that can protect individuals, organizations, communities, ie a wider area in order to reduce the negative consequences of natural hazards and encourage sustainability. Hazard identification provides specific information about the nature and properties of hazardous events within the community (Žic, 2015).

Vulnerability analysis is the analysis of combinations of consequences and related uncertainties with respect to the initial (hazard) event. It can be focus on physical, political, economic and social vulnerability. Vulnerability is the degree of sensitivity and resilience of a community and the environment to the consequences of danger (Pine, 2008). Vulnerability analysis identifies geographic areas that may be affected by hazards, individuals that may be subject to injury or death, as well as buildings and the environment that may be vulnerable to natural disasters. Vulnerability assessment is an assessment of the exposure or sensitivity or resilience of a community to the consequences of hazards (Roberds, 2005; Crozier and Glade, 2005). Risk analysis is the systematic use of information to determine the initial event, the causes and consequences of the initial event and to express risk. Risk analysis provides the basis for risk evaluation, treatment and acceptance. It represents the determination of the likelihood of possible consequences that may be based on previous historical events, local experiences and the best currently available technological information (Pine, 2008). Quantitative definition of risk (R) can be represented as the product of the probability of occurrence of hazard (H), sensitivity (V) and social elements of hazard (E): $R = E * H * V$.

METHODS OF HAZARD ASSESSMENT SINCE LANDSLIDE

The paper presents the key components of Quantitative Risk Analysis (QRA) for landslide and landslide hazards, which allows scientists and engineers to quantify risk in an objective and reproducible way. The QRA approach is not necessarily accurate in relation to a qualitative assessment, the probability of which can be calculated based on personal judgment. The large and numerous human losses and material damage that have occurred throughout history have led to the current national and international needs to reduce hazards from natural disasters.

Landslide susceptibility is the probability of landslides occurring in a particular area due to characteristic local terrain conditions, while landslide hazard is the probability of landslides occurring that can create potential damage to a particular area over a period of time. Hazard as such directly involves: (i) the strength of the slip (magnitude and intensity), (ii) the geographical location of the slip, and (iii) the frequency of events (Guzzetti et al., 2005). Different approaches in considering landslide hazard assessment have led to a number of classification methods for landslide hazard assessment. One of the first such classifications was developed by Hansen (1984) who divided landslide hazard estimation methods into direct and indirect. The direct method of geomorphological mapping identifies past and present landslides, creating subjective assumptions about where new landslides could occur in the future. Indirect methods consist of assigning weight factors to the causes of landslides. These methods include heuristic methods, experiential methods, statistical and deterministic methods(Crozier and Glade, 2005). Landslide hazard analysis and zoning involves spatial analyzes of landslide probability and a graphical representation of the results in the form of zoning a specific area with respect to the relative hazard of a landslide. Landslide susceptibility analyzes phenomena that have occurred in the past, while landslide hazard assessment consists of predicting what will happen in the future. Risk represents the consequences of the effect of hazard on risk elements taking into account temporal and spatial probability and their vulnerability (Roberds, 2005). Figure 1 shows landslide hazard assessment methods that can be broadly divided into qualitative, semi-qualitative and quantitative methods. They can be distinguished on the basis of defining the cartographic units on which the assessment is carried out: terrain units, mapping units, homogeneous domains or on the basis of distinguishing hazard categories.

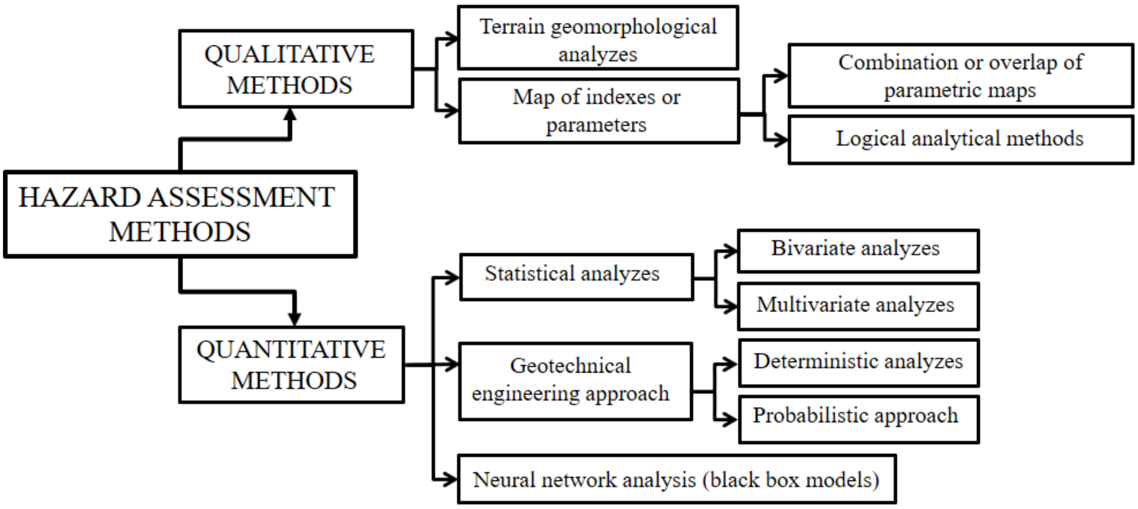

Figure 1. Methods for estimating landslide hazards

A basic feature of a qualitative hazard assessment methodology is the assessment that one or more landslides will occur in an area (Fall et al., 2006). The main disadvantage of this approach is manifested in the subjectivity of researchers in the selection of input data and the creation of results.
Qualitative hazard assessment methodology takes into account the following landslide factors: geological structure, slope inclination, land use (cover layer), vegetation and hydrogeological conditions (Figure 2). All these factors affect the identification of areas that are prone to landslides of similar geological and geomorphological features (index methods). Field implementation of geomorphological analysis is the first form of qualitative approach that allows a rapid assessment of the stability of a particular area, taking into account a large number of influencing factors.Quantitative methodology is based on mathematical expressions and establishes a correlation between causal factors and landslides. The two most commonly used types of quantitative methodology are the statistical and deterministic approaches (Caniani et al., 2008). Statistical (probabilistic) methods are based on the relationship of each factor and the distribution of landslides in the past, which includes mapping existing landslides and combinations of factors that are directly or indirectly related to slope stability. These methods include bivariate methods (Brabb, 1984), multivariate methods (van Westen et al., 1997), discriminant methods (Carrara et al., 1995), so-called Boolean approach that uses logistic

regression (Ayalew and Yamagishi, 2005) and the so-called Bayesian method that uses neural networks to determine the probability of landslides (Lee et al., 2006). The application of GIS can facilitate a deterministic and statistical approach as part of a landslide hazard assessment methodology.

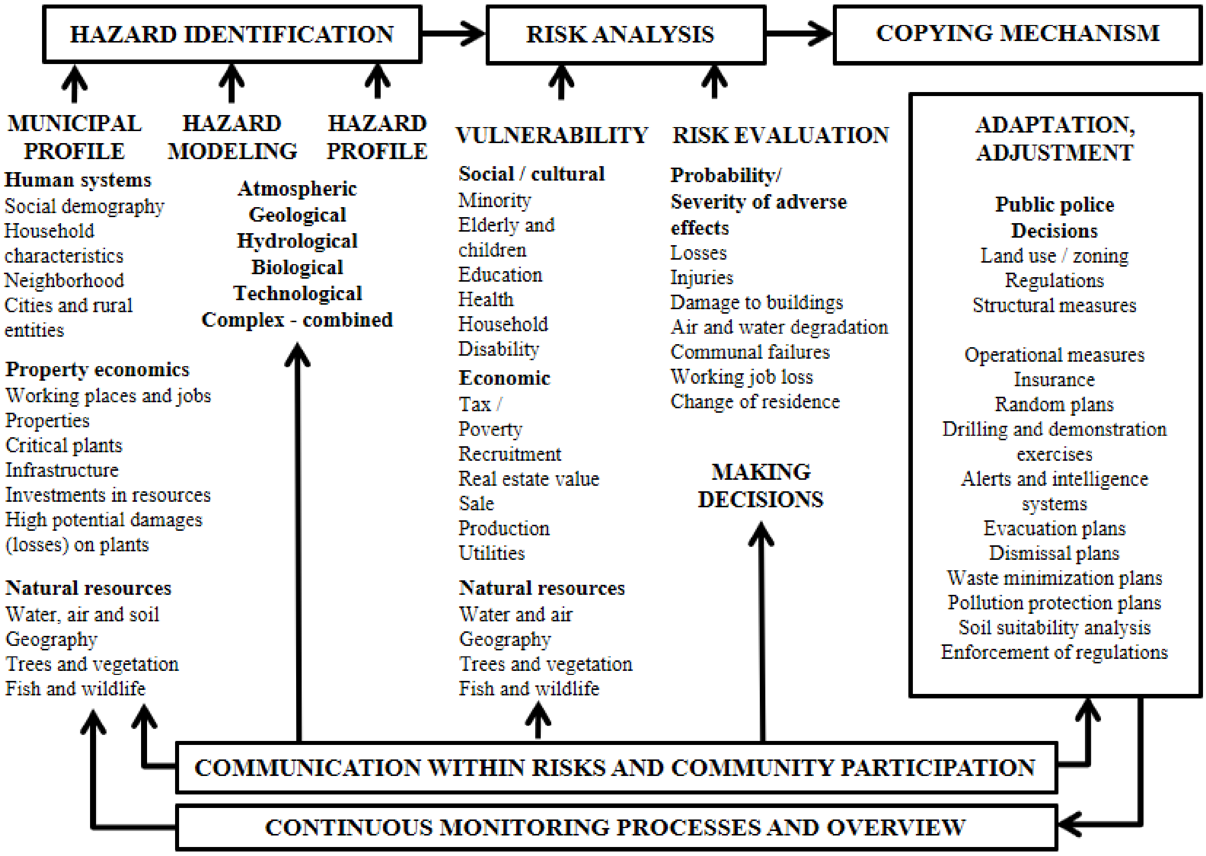

Figure 2. Hazard analysis process and community organizational resilience (modified according to Pine, 2008)

DISCUSSION

The risk of landslide consequences for an individual building or area must be calculated with regard to a certain period of time within which a hazardous event of a certain intensity is expected to occur in relation to the estimated minimum established values (Figure 3). In this regard, there is a growing need to conduct a Quantitative Risk Analysis (QRA). Compared to qualitative risk analysis, which gives results in terms of weighted indicators in certain classes or numerical classification, QRA quantifies the probability of a certain degree of loss and associated uncertainty. The QRA requires accurate input of geological and geomechanical data and a quality digital terrain model for a good assessment of possible scenarios, event calculations and return periods. The risk for a landslide scenario$R$of strength M_i on the risk element located at a distance X from the landslide sourcecan be expressed analytically:

$$R=P(M_i)P(X_j|M_i)P(T|X_j)V_{ij}C \qquad (1)$$

where $P(M_i)$is the probability of landslides of a certain strength M_i, $P(X_j|M_i)$ is the probability of landslides to a point located on the distance X from the landslide starting source with intensity j, $P(T|X_j)$is the probability of the element at the place X at the time of landslide, V_{ij} is the vulnerability of the landslide element of intensity i and j, while C is the value of the hazard element. The three basic components that appear in Eq. (1) must be specifically considered when making a hazard assessment, the exposure of hazard elements and theirvulnerability. Elements of risk are the population, buildings, economic activities, including public services, orany other persons who are directly exposed to hazard in a particular area.

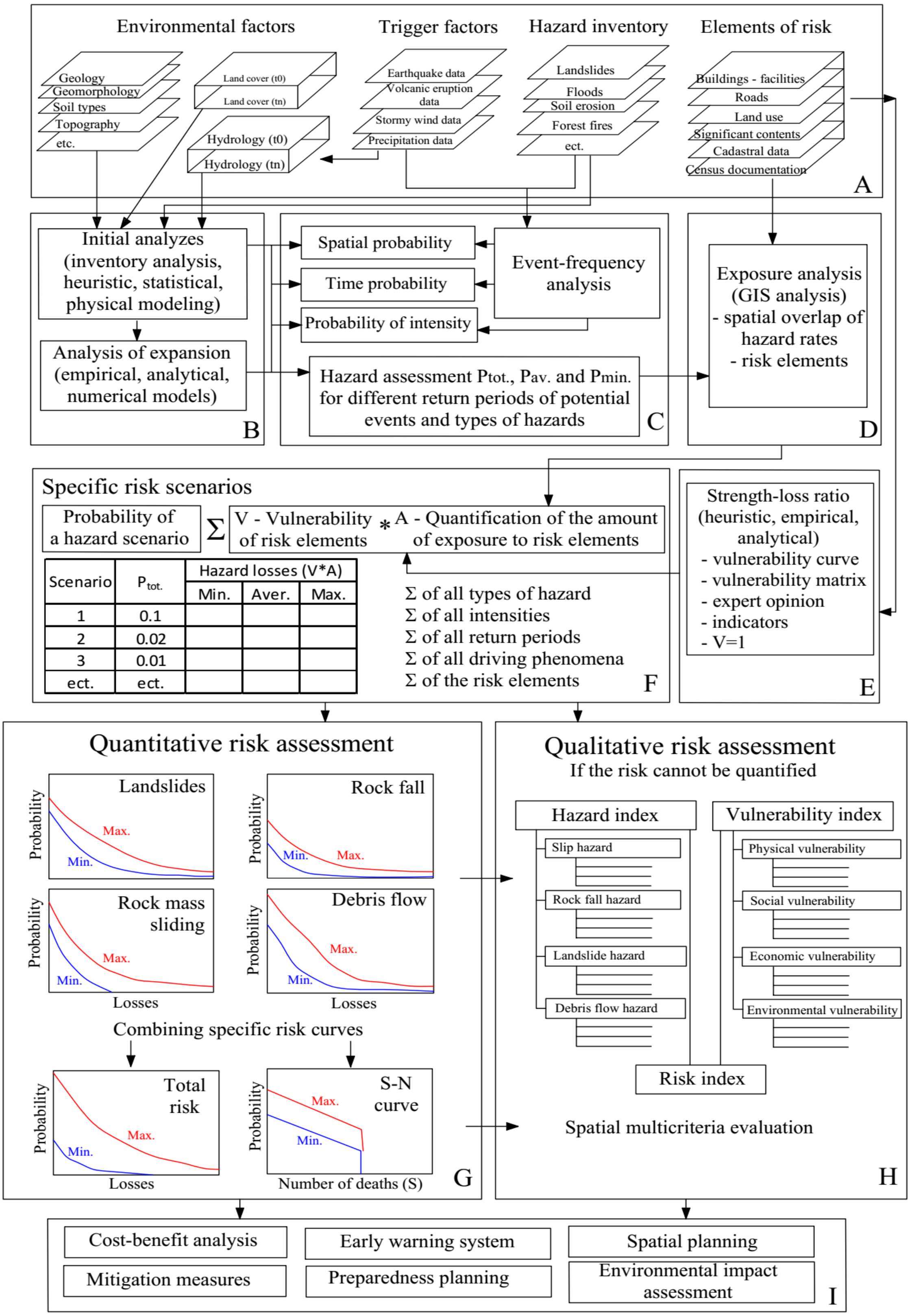

Figure 3. Indicative overview of multi-hazard assessment of landslide risk analysis; A - input data for landslide assessment, B - sensitivity assessment, C - landslide hazard assessment, D - risk element exposure analysis, E - vulnerability assessment, F - integration of hazards, vulnerabilities, nature and quantity of risk elements, G - quantitative risk assessment approach , H - qualitative approach to risk assessment, I - use of risk information in risk management (modified according to Van Westen et al., 2005)

The interaction of hazards and risk elements includes their exposure and vulnerability. The general QRA framework includes a complete risk assessment process and risk management. Risk analysis uses available data to assess a particular risk, population, assets or environment from hazard. It typically contains the following steps: hazard identification assessment, list of risk and risk exposure elements, vulnerability assessment and risk assessment. Because all of these steps have an important spatial component, risk analysis often requires spatial data set management. Risk assessment is the state in which values and judgments enter the decision-making process (explicitly or implicitly), including considerations of the importance of the assessed risks and the associated social, environmental and economic consequences in order to identify a range of risk management alternatives.
Figure 3. based on the work of Van Westen et al. (2005) provides a framework for estimating multiple landslide risk hazards simultaneously, indicating different steps (from A – H). The first step (A) includes the input data needed to assess the risk of multiple hazards simultaneously, with an emphasis on the data needed to generate sensitivity and range of slip mass, trigger factors, multi-time inventories and hazard elements. The second step (B) focuses on sensitivity assessment and is divided into two components. The first, which is most commonly used, deals with the modeling of potential drivers of a particular area (sensitivity initiation), which can use different methods (based on landslide inventory, heuristic, statistical, deterministic methods). The maps that are created show the areas for further modeling of the range of the sliding mass (range probability). The third step (C) includes a landslide risk assessment, which largely depends on the availability of the so-called landslide inventory, based on the same or similar landslide events that have occurred predominantly in the past. By linking landslide distributions to the time probability of activated events, it is possible to perform frequency range analysis. Landslide inventory based on past events, among other factors, is also used to determine the spatial probability of a landslide, ie its start-up and the extent of the landslide mass. The fourth step (D) is the analysis of the exposure of risk elements, which includes the production of hazard maps and risk elements using the GIS environment. Step (E) focuses on vulnerability assessment and indicates various types of vulnerabilities and provides solutions that can be used. The focus is on the use of expert opinion, empirical data and physically based analytical and numerical models in defining vulnerabilities, and the application of available vulnerability curves or vulnerability matrices. Other types of vulnerabilities (eg social, environmental and economic) are mainly analyzed using spatial multi-criteria assessment as part of a qualitative risk assessment (step H). Step (F) integrates hazards, vulnerabilities and the nature and number of elements at risk (whether as the number of persons, the number of buildings or the economic value). The risk for each individual element (specific risk) is determined based on many different situations and refers to the type of landslide, volume, return period of event initiation, type of hazard element and the like. The integration in step (G) shows a quantitative risk assessment approach in which the results are presented in the form of hazard curves that plan the expected losses according to the probability of occurrence for each type of landslide, and are expressed through uncertainty of input data in risk analysis. This can be illustrated by generating two loss curves that express the minimum and maximum values for each trigger event for different return periods or the associated annual probability. Individual risk curves can be integrated into total risk curves for a particular area and population loss can be expressed via the S-N curve (Figure 3). Risk curves can be created for different basic units such as individual slopes, roads, settlements, municipalities, regions or counties. Step (H) provides an overview of methods for qualitative risk assessment, which are based on the integration of hazard index and vulnerability index using spatial multicriteria assessment. The last step (I) concerns the use of risk information at different stages of natural disaster risk management.

CONCLUSIONS

For adequate analysis of landslide hazard it is necessary to conduct a good geotechnical and engineering geological assessment, geomorphological and geographical analysis, political and economic perspective of the area development, as well as economic and social circumstances in the analyzed area and know the factors influencing spatial and temporal variation of the threatening process. The accuracy of landslide hazard estimates depends on the quality and quantity of available data, the time spent collecting and processing data, conducting the necessary analyzes, as well as the financial resources needed to investigate the elements needed to obtain input parameters. When estimating landslide hazard predictions, various methods are available today, developed over the last 40 years or so that are clearly presented in this paper. As a result of the landslide hazard assessment, a landslide hazard map is made. It shows the spatial distribution of different degrees of landslide hazard, including information on the probability or return period of possible landslides.

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HORIZONTAL LEGISLATION IN ENVIRONMENTAL PROTECTION, CASE STUDY: STUDENT PARTICIPATION IN MAKING A DECISION FOR WATER RESOURCE MANAGEMENT

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Abstract: The paper presents a project of student participation in the decision making process in the field of water protection. The project is directly related to the field of Chapter 27, i.e. Environment and Climate Change, Horizontal legislation that defines the access to environmental information and public participation in the environmental decision making process. It represents support to the social participation of young people, i.e. student population. It is a program whose purpose is to inform, train and to connect students, as future leaders of social development, with the local government and civil sector, in order to become one of the key actors in forming an environmentally sustainable future. The project is implemented in cooperation with the Faculty of Civil Engineering and Architecture and the Faculty of Occupational Safety (University of Nis), as well as with the City municipality of Mediana, the City of Nis (Serbia).

Keywords: environmentally sustainable future, Serbia, students, water protection

INTRODUCTION

The EU (European union) horizontal environmental legislation covers various issues and regulations that have cross sector implications, and thus differs from other regulations, aimed at protecting certain environmental aspects (Handbook on the Implementation of EC Environmental Legislation, 2014).

Although most of the strategic documents of the city of Nis imply the active participation of young people in the decision making processes, in practice, the system does not work in that way, and the young mostly do not have influence on the processes, such as decision making and policy development. What is more, as a special category of young people, students are not recognized in these documents.

The participation of students, as a category of young people, entails their participation in: identifying needs, creating and implementing public policies, and therefore, in processes such as decision making in all areas of social life that affect their personal and professional development (Drenovak-Ivanovic, 2018). For this reason, it is necessary to emphasize the possibilities and importance of student participation. In addition, it is necessary to set a good framework in their education for future active and responsible citizens, educated when it comes to the participation mechanism, and prepared for life in a responsible and democratic society.

Strengthening the capacity of students opens the possibility of creating new generations that will solve current and future development needs with the use of multidisciplinary approaches. Environmental protection, including water protection, will be the area that will bring most new jobs in the processes of accession to the EU. The fact that the adoption of EU documents will be an obligation for Serbia provides the necessary additional support for the current generations of students, which means that, in the future, students will be the key actors in environmental protection.

The overall goal of the project is to increase the public participation in the creation of water management documents by involving students in these processes and creating a permanent platform for cooperation in resolving relevant issues and the decision making concerning the environment in the local community.

The specific goals of the project are:

- Empowering the student population to actively participate in the working authorities for the protection of city environment and city municipalities and to make decisions related to environmental protection and sustainable development, with a special emphasis on water management.
- Improving the dialogue and joint action of the key actors at the local level (public and civil sector, educational institutions, students, media, etc.) in order to solve the environmental issues, with a special emphasis on water management.

PROJECT BENEFICIARIES

Direct beneficiaries of the project are: 1) students of the Faculty of Occupational Safety, and the Faculty of Civil Engineering and Architecture – raising students' awareness of the need, importance and possibilities of their activities in the local community in the field of environmental protection, with a special emphasis on water management (Burchi, 2012; Hernando et al, 2011; Rebelo et al, 2020). The student participation in the work of working bodies for environmental protection and in the creation of local planning documents on environmental issues becomes regulated and mandatory. Furthermore, this achieves civil participation in the planning and realization of the project; 2) By participating in this and similar projects, the Faculty of Occupational Safety and the Faculty of Civil Engineering and Architecture, in addition to the basic educational and scientific-research function, respond to requests of the society related to the environment; 3) As a civil society organization, the Municipality of Mediana (Nis), which will present its Office of Youth to students, in cooperation with the Association of Green Building (project leader), will encourage and develop cross sector cooperation. This cooperation is one of the prerequisites for strengthening the capacity of local governments to improve the environment and to strengthen the activism of people in this field (especially young people); 4) Local government: the project contributes to raising awareness of key actors in this field at the local community level, especially among students as a social force, which can encourage the improvement of the environment with new ideas; 5) Student organizations of the University and faculties: the project provides an opportunity for further expansion of the initiative for the participation of students from other faculties in other working groups and the councils of city municipality and the City of Nis; 6) Other CSO (civil society organizations) dealing with environmental protection: the project provides them with the opportunity to solve the problems of the local community in the field of environmental protection, in partnership with other CSOs and students (as new actors).

The final user is the local community: The inclusion of students into working bodies of the city municipalities and the city of Nis would be a significant step towards ensuring the sustainability development of the local community. What is more, this way directly contributes to raising the awareness of the general population of young people concerning the need for mass activism and volunteerism in order to preserve the environment for future generations.

The project includes the student population in solving the problems, as an integral part of the local community (it covers 9.33 % of the total population). Moreover, it contributes to the development of the awareness of students and the wider local community concerning the special role of students in society. As future academic citizens, students should use their positive example to motivate the community to influence the decisions related to the protection of the environment and water resources in the community through a joint process and a constructive dialogue.

EXPECTED RESULTS AND ACTIVITIES
Expected results

Result 1: The analysis of youth activism in social life, their attitude towards environmental protection and activism in water management.

Result 2: Contribution to the improvement of the cross-sector cooperation in the field of environmental protection in the local community.

Result 3: Improved student knowledge regarding the target faculties of ecology and environmental protection, as well as improved student awareness of the importance and possibilities of their inclusion in the decision making processes, related to environmental protection and sustainable development, with a special emphasis on water management.

Result 4: Submitted initiative for the inclusion of students in working bodies for the environmental protection of city municipalities and the city of Nis through the "Green Chair" mechanism.

Result 5: Encouragement to spread the initiative among students of other faculties, for their participation in the working authorities of city municipalities and the city.

Result 6: Achieved visibility of the project.

Description of Project Activities

In order to have the most successful dissemination of results (undertaken activities), the project combines: different formats, educational programs, cooperation with the local government and civil sector, different media products in constant insistence on the engagement of local people, as associates and participants.

1) Empirical research of the opinions and attitudes of students of the faculties (Faculty of Occupational Safety and the Faculty of Civil Engineering and Architecture) about their active participation in society: activism, attitude towards the environment and activism in the field of environmental protection. The research includes: defining the methodological framework, defining questionnaires and a survey, statistical data processing and their interpretation, as well as preparing a report (narrative) with an analysis, result discussion and conclusion. The research team, consisting of two experts – for statistics and for research, will conduct all the above research activities. The research results will be presented in a printed publication and at the panel discussion: "Social Participation of Students".

2) Meetings with representatives of the local government – Before submitting the initiative for involving the students in working bodies of the municipality and the city of Nis for environmental protection, and beside the meetings with the representatives of the Mediana municipality, in its capacity of project associate, the plan is to hold the meetings with other representatives of the local government in order to present the project, and to send an invitation for participating in project activities. The aim of the meetings is to emphasize the fact that readiness for challenges, lively critical thinking, academic engagement, intellectual potential and other characteristics related to students are the key to progress and success.

3) Organizing a program for strengthening the capacities of students from the mentioned faculties. There will be four workshops at each of the faculties, which will cover ten topics:
1st workshop: 1) Civil participation; 2) "Green Chair" mechanism; 3) Youth policy and related concepts: work with young people, activism, youth work
2nd workshop: 4) Aarhus Convention; 5) Horizontal legislation;
3rd workshop: 6) Climate change; 7) Air protection; 8) Nature protection;
4th workshop: 9) Water protection and management; 10) Waste management.

4) The panel discussion "Social Participation of Students" – The panel discussion will be held after the workshops, where research results will be presented, and then students will be introduced to the members of the Youth office of the Mediana municipality, other local government representatives and the representatives of the CSO which deal with environmental protection. The objectives of the panel discussion: 1) Acquaint students with the work of the Mediana municipality Youth Office; 2) Present the youth with the possibilities for inclusion in the local government activities related to environmental protection; 3) Support students in initiating their participation to create planned documents of city municipalities and the city of Nis related to

environmental protection by using the “Green Chair” mechanism; 4) Present the opportunities for youth engagement in the CSO (related to environmental protection).
5) Defining and preparing an initiative for student inclusion in the working bodies of city municipalities and the city of Nis which are involved in environmental protection through the “Green Chair” mechanism. The initiative will be prepared by the students – participants in the project, with their teaching assistants and professors, after the panel discussion, and they will send the proposed initiative to the city and city municipalities, i.e. to the councilor for environmental protection, to the city administration for property and sustainable development and civil engineering, to the coordinator and members of the working group for energetics, environmental protection and climate change, to the commission for environmental protection, to the councils for energy efficiency, environmental protection and the young, as well as to the city municipalities and their councilors.

6) The meeting with the representatives of student organizations – The final activity is the meeting with: 1) Representatives of student organizations from the University of Nis (student alliance, student union and student association); 2) Representatives of student organizations from each of the 14 faculties. The aims of the meeting are: 1) Presentation of the project, its results and submitted initiative; 2) Indicating the possibility of further expansion of the initiative for the participation of students from other faculties in other working bodies of city municipalities and the city.

7) Communication with target groups and project beneficiaries – the member of the project team (PR manager) will be involved. The whole process will be continuous, in accordance with the communication strategy, but it will also monitor activity development and adjust to the mentioned, if necessary.

Monitoring and Evaluation of Achievements in Project Implementation

Monitoring will be done on two different levels: 1st level – through regular project team meetings, 2nd level – through monthly project progress reports and through the final report.

The dynamics and realization (who participated in the realization, the number of participants in the events, resources used and communication activities) of the project activities will be monitored. The project evaluation will be done on the basis of quantitative and qualitative data.

Sustainability after Project Completion

Sustainability is reflected in the following:
A significant step towards ensuring the project sustainability and development of the local community would be accepting the initiative for admission of students in the working bodies of the city of Nis and its municipalities for environmental protection (in the form of a green chair). The sustainability is confirmed by raising the awareness among other students, considering that only a certain number of students from the Faculty of Occupational Safety and the Faculty of Civil Engineering and Architecture participate in project activities, as well as other young people, concerning the needs and possibilities of their activities for environmental protection in the local community.

The sustainability of the project is confirmed by raising the awareness (students as a social force can improve the status of environment using new ideas) among the key actors in this field in the local community. What is more, project sustainability is reflected in the possible further expansion of the initiative for the participation of other students from other faculties in the working authorities of the city of Nis and its municipalities.

Cross-sector cooperation in the creation and implementation of public politics in the field of environmental protection ensures the sustainability of positive changes and contributes to the quality and better implementation of public policies.

Further participation of the Green building association could be: a) in monitoring the work of students and student organizations in the field of environmental protection; b) in supporting the new initiatives; c) in direct cooperation with further project activities (there will be no need for additional resources for all the mentioned activities).

CONCLUSIONS

Student inclusion in the working bodies for the environmental protection of the city and municipalities increases the participation of young people in environmental protection and sustainable development. What is more, this further encourages activism and the active participation of the young in all the sectors and levels of the local government, i.e. encourages strengthening the civil structure of young people for the development of a modern civil society. Furthermore, by involving students in different solutions for the environment, especially in water management, students will have an opportunity to propose the solutions through learning and open conversations for the benefit of the entire local community. Student engagement is crucial for creating a society in which we would all like to live.

The project encourages the citizens to be actively involved in the decision making processes. The aim of the project is to enable the students, who represent a significant part of the population both in terms of quantity and quality, and as future bearer of changes, to participate in the working authorities of the city municipalities and the city of Nis for environmental protection. Finally, the project enables the approach to creating documents from the environmental area.

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WATER QUALITY ASSESSMENT OF RURAL WATER SUPPLIES OTHERWISE AND AFTER THE FLOOD ON THE TERRITORY OF THE CITY OF KRALJEVO AND THE MUNICIPALITY OF VRNJACHKA BANJA

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Abstract: Climate variability significantly affects the availability and quality of water resources, as well as the increase in the number and magnitude of hydrological extremes. Water quality depends on natural factors and human activity, proper management of water resources, as well as the regulation of the catchment area itself. There are thousands of rural water supply systems on the entire territory of the Republic of Serbia, according to which there is a legal obligation to provide a sufficient amount of quality drinking water. The multidisciplinary of water supply is especially expressed in the examples of rural water supply systems. The present problems in this area, the way of solving them and the possible consequences require that this problem must be approached far more professionally and organized than before. The paper analyzes the conditions and ways of solving the water supply with quality sanitary-chemically correct drinking water in rural areas of certain municipalities in Serbia. The segments important for the assessment of the risk of harmful events, which can occur due to torrential floods, were also reviewed and analyzed, and proposals for the introduction of additional measures for flood defense and protection of life, property of citizens and critical communal infrastructure were given, with special reference to rural waterworks.

Keywords: Climate variability, rural water supply, torrential floods

INTRODUCTION

Water quality depends on natural factors and human activity, proper management of water resources, as well as the regulation of the catchment area itself. Accelerated and large population growth leads to increased water demand. Water is a good solvent for many harmful chemicals, but also a suitable medium for the transmission of microorganisms that adversely affect human health (*Zlatanović, 2009*). Considering that water has a large heat capacity and that various inorganic and organic substances are dissolved in it, it is an ideal medium for the development of life (*Veljkovic and Jovicic 2007*). In the water can be found: bacteria such as *Echerichia colli, Streptococcus faecalis, Salmonellae, Shigellae, Vibrio Cholerae*, etc.; viruses such as *Adenovirus, Echovirus, Polyovirus, Hepatovirus, Parvovirus*, etc.; parasitic organisms such as *Entamoeba Hystolitica, Ascaris Lumbricoides, Entrobius Vermicularis, Echinococcus Granulosus, Dracanculus Medinensis, Schistosoma*, etc. (*Poček, 1990*). The causes of infectious diseases such as typhoid fever, paratyphoid fever, bacillary dysentery, cholera, leptospirosis, brucellosis, tularemia, poliomyelitis, hepatitis A and E, but also children's worms, nematodes, histolytic amoeba, etc. can be transmitted through water. The role of water in the transmission and spread of intestinal and other infectious and parasitic diseases is manifested qualitatively and quantitatively. In the first case, water contaminated with disease agents is a way of transmitting and spreading the infection, and in the second case, insufficient amounts of water make it difficult or impossible to maintain general and personal hygiene, which enables conditions for the appearance and transmission of the disease *(Dalmatia et al.,1996*). Around 200 million people worldwide suffer from waterborne diseases (water-borne diseases) each year, while almost 5 million cases end in death. One of the most important tasks of the World Health Organization in the fight against infectious diseases is therefore to provide preconditions for supplying the population with healthy drinking water. In the period from 1900 to 2001 alone, there were 87 epidemics of infectious diseases in Serbia caused by polluted drinking water, with 4,481 infected people (*Knezević and Ile, 2000*). Water can also be contaminated with chemicals that have high toxicity, such as: lead, mercury, fluorine, cadmium, pesticides, nitrites and nitrates, arsenic, etc (*Jovančičević, 2006*). Toxic substances get into the water mostly through the spillage of industrial and communal waters, but also through atmospheric waters that wash away agricultural areas contaminated with insecticides and pesticides (*Soldatović, 1980, Decree on limit values for emissions of* *pollutants into water and deadlines for their achievement, O.g. RS 67/11*). Lack of certain elements in water such as fluorine, calcium, iodine, magnesium, etc. it can also negatively affect the health of the population. In addition, the use of nuclear energy brings with it new risks due to possible accidents and contamination of water with radionucleotides that can cause radiation sickness (*Rulebook on hygienic safety of drinking water, 1999*). With the development of agriculture, animal husbandry and industry, due to inconsistencies in industrial development and appropriate protection measures, the process of disruption and endangerment of all environmental media has intensified. Increasing the population on earth increases the problem of quantity and quality of water, both for the needs of the population and for food production. The solution is a more rational use of water resources and prevention of its pollution (*Jovančičević, 2006*; *www.who.int/07/'21/30*). Significant sources of watercourse pollution include industrial and urban waste, chemicalization of agriculture, fossil fuels, etc. the effect of pollutants on water is multiple, and the changes can be primary, secondary and tertiary (*Rulebook on hazardous substances in water, 1982, Official Gazette of SRS 31/82*). Primary changes occur during the direct action of pollutants and are expressed by physico-chemical and biological changes in water properties. These changes are amplified into complex secondary changes, resulting from the reaction of pollutants and water components, which can lead to the formation of new substances that have a detrimental effect primarily on aquatic organisms, and beyond. Tertiary changes are reflected in the disruption of the relationship between aquatic and non-aquatic organisms, which can lead to disruption of the life cycle. The environmental protection system should ensure the protection of all spheres of the environment. Water protection has a wide and complex issue, which indicates that it cannot be classified into one scientific discipline, but goes into the domain of different border disciplines. Due to the increasingly serious and visible consequences of pollution, a wide front of the fight has been opened for their elimination and prevention of further degradation of the environment, and for a healthy environment (*www.who.int/07/'21/30*).

Water quality of rural water supplies

Water quality depends on natural factors and human activity, as well as the regulation of the catchment area itself. Due to the complexity of the hydrosphere, it is almost impossible to predict the movement and transformation of pollutants that enter it, which indicates that it is necessary to monitor potentially dangerous substances from the moment they enter the environment (*Law on Waters of R. Serbia, O.g.RS 30/10,…. 95/2018.)*. Intensive development of agriculture and increasing use of chemicals in agricultural production lead to the appearance of larger amounts of toxic chemicals in water. Application of certain agro-technical measures in order to achieve the highest possible yields in agriculture, such as pesticides, artificial mineral fertilizers, herbicides, fungicides, etc. are the main causes of water pollution. These substances, with their negative physiological effect, endanger the health of present and future generations (*Soldatović, 1980*). Intensive development of agriculture and increasing use of chemicals leads to the appearance of larger amounts of toxic substances in water. One of the agrotechnical measures is the application of organochlorine insecticides (OHI), which are very often and uncontrolled used (*Rulebook on hazardous substances in water, 1982; Jovančević, 2006*).

Some commonly used OHI in agricultural production, and whose standards are given by the Ordinance on the hygienic safety of drinking water. (*Soldatović, 1980; O.g. No. 42/98 and 44/99*) are:

α-HCH is an organochlorine insecticide, used in forest protection; Lindane is a broad-spectrum insecticide. It is used for agricultural and non-agricultural purposes, which include treatment of seeds and soil, application on trees, trunks and stored materials, treatment of animals against ectoparasites; Heptachlor is an insecticide used mainly to control termites and terrestrial insects; Aldrin is an organochlorine insecticide, which was previously used to kill insects (such as termites and locusts), in order to protect crops such as potatoes and corn. It is a chemical made in the laboratory and does not appear in nature as native; Dieldrin is an organochlorine insecticide used against termites, textile and agricultural pests and insect-borne diseases. It is mainly used to protect corn, cotton and potatoes. It is not found in nature as native; Endrin is an organochlorine insecticide that has been used since 1950 against a large number of agricultural pests, primarily on cotton, rice, sugar cane, corn and other crops; DDT is one of the first chlorinated insecticides used in agriculture, forestry and health (*Rulebook on hazardous substances in water, 1982; Jovančević, 2006).* Halogenated hydrocarbons are characterized by high chemical stability, which leads to retention in water and soil for a longer period of time. Structurally the most stable organochlorine insecticides are DDT derivatives, followed by cyclodienes and the least stable are compounds from the group of hexachlorocyclohexanes.

The paper monitors the physical and chemical parameters of water and the total amount of organochlorine insecticides in drinking water samples taken from local reservoirs of 20 villages around the city of Kraljevo, as well as analysis of quantity and quality of available water and population needs, flow and pressure analysis and monitoring water quality with analysis of the situation and guidelines for further work of 5 large waterworks in the villages of Tavnik, Ladjevci, Milochaj and Toplik in the vicinity of the city of Kraljevo. The inhabitants of these villages (about 8000 inhabitants) are supplied with drinking water from reservoirs that are mostly occasionally cleaned and maintained. Usually, there is no person in charge of maintaining the tank, but the locals do. The main activity of the inhabitants of this area is agriculture.

METHODS AND MATERIALS

Drinking water samples were prepared according to the procedures given in the "*Ordinance on the method of sampling and methods for laboratory analysis of drinking water. O.g. of SFRJ br. 33/87*"; "Standard methods for testing the hygienic correctness of water" or Validated methods of the Institute of Public Health from Kraljevo (VMK). Physico-chemical analysis of drinking water samples was performed:
1) volumetric methods (quantitative determination of organic matter consumption of $KMnO_4$, content of calcium-Ca, magnesium-Mg and chloride), 2)electrochemical method (pH value), 3) spectrophotometric methods (content: nitrate, ammonia, sulfate, iron - Fe and manganese - Mn).

The instruments used for the mentioned tests are: pH-meter (Hanna) and spectrophotometers: Lambda 2 (Perkin Elmer), conductometer (WTW) and turbidimeter (WTW). The microbiological analysis of drinking water of the examined rural waterworks was inspired by the following microbiological parameters: 1) total number of aerobic mesophilic bacteria, 2) coliform bacteria of fecal origin, 3) total coliform bacteria, 4) sulphite-reducing clostridia, 5) pseudomonas aeruqinosa, 6) streptococci of fecal origin and proteus species.

The analysis of organochlorine insecticides (OHI) included those prescribed by the Ordinance on the hygienic quality of drinking water (*Official Gazette of the FRY", No. 42/98 and 44/99*): α-HCH, lindane, heptachlor, aldrin, dieldrin, endrin and DDT. The organochlorine insecticides present were prepared by the appropriate EPA-608 method, by liquid-liquid extraction. The sample of drinking water is extracted with methylene chloride and the extract is dried and concentrated to $1cm^2$. The tested organochlorine insecticides were detected by gas chromatography on a gas chromatograph of Perkin Elmer 8500 with ECD detector (electronic capture detector), using the appropriate capillary column SPB-5, length 30 mm and isothermal temperature program at 250 ^{0}C.

RESULTS AND DISCUSSION

The results of the measured physico-chemical parameters and OHI concentrations in drinking water samples taken from local reservoirs of 20 villages in the vicinity of the city of Kraljevo are shown in Tables 1, 2 and 3 (*Decision on water supply and sewerage, Official gazette of the municipality of Vrnjachka Spa 19/2014; Decision on general conditions for maintenance and use for maintenance and use of public local water supply in rural settlements on the territory of the city of Kraljevo, Official gazette of city Kraljevo br.27/18; Marinović, 2012; Marinović 2014*). The results of the examined microbiological and physico-chemical parameters in the drinking water of the villages around the town of Kraljevo show that they do not meet the requirements of the Rulebook on the hygienic safety of drinking water (*Official Gazette of the FRY No. 42/98 and 44/99*). Out of a total of 20 waters, 6 (30%) are microbiologically defective, and 8 (40%) are chemically defective. One water is defective due to turbidity (8.7 NTU), one due to increased values of ammonia (1.09 mg/l) and iron (0.33 mg/l) which are at the limit of permitted values and one due to increased consumption of $KMnO_4$. Five waters are defective due to the increased value of Mg, and from the aspect of increased Mg content we can state that Mg is a microelement necessary for the human body and requires its daily intake through water and food (daily body need for Mg is 250-300 mg) and the maximum daily level in drinking water according to the recommendations of the World Health Organization is 100 mg/l, so the found concentration of Mg (68-114 mg/l) is not risky for health and is in the natural background, so water from the aspect of Mg value can be used for drinking with regular monthly content control Mg.

Table 1. Results of examined microbiological and physicochemical parameters in drinking water of rural waterworks

R.no.	Parameter / unit measures	Metikoshi	Dragosinjci	Ribnica	Kamenica	Zicha	Bogutovac	Drakchici	Vrdila	Rodicevici	Dedevci	MAC
1.	pH value	8.20	7.40	8.20	7.70	8.50	8.10	7.60	7.40	8.40	7.90	6.8-8.5
2.	NTU turbidity	0.59	0.34	0	0.33	0.32	1.567	1.08	1.52	0.36	1.00	5
3.	KMnO4 mg/l	4.42	3.16	3.16	3.16	5.58	12.64	4.74	3.16	3.16	7.90	8.00
4.	Ammonia mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	1.09	<0.02	<0.02	<0.02	1.00
5.	Nitrates mg/l	1.7	2.0	1.6	12.5	5.1	4.8	0.2	12.5	0.8	4.2	50.0
6.	El.Conduct. µS/cm	390	265	420	460	475	350	560	530	475	420	to 1000
7.	Fe mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.33	<0.02	<0.02	<0.02	0.300
8.	Mn mg/l	<0.01	<0.01	0.013	<0.01	<0.01	<0.01	0.012	<0.01	<0.01	<0.01	0.05
9.	Sulphates mg/l	7.10	12.38	5.25	41.47	6.94	7.71	3.73	20.74	31.03	20.79	250
10.	Ca mg/l	26.61	43.05	22.30	75.33	15.52	17.84	35.49	86.91	75.34	68.76	200.0
11.	Mg mg/l	26.61	43.05	22.30	75.33	15.52	17.84	35.49	86.91	75.34	68.76	200.0
12.	Microbiol.analysis	Faulty	Correct	Correct	Correct	Faulty	Correct	Correct	Correct	Correct	Faulty	
13.	Water correctness	Faulty	Correct	Faulty	Correct	Faulty	Faulty	Faulty	Correct	Faulty	Faulty	

Table 2. Results of examined microbiological and physicochemical parameters in drinking water of rural waterworks

R.no.	Parameter / unit measures	Mrsac	Adrani	Sircha	Oplanici	Popovici	Upper Godachica	Lower Godachica	Stubal	Ratina	Vrba	MAC
1.	pH value	6.90	6.90	7.10	7.60	7.40	7.40	7.60	7.70	7.80	7.30	6.8-8.5
2.	NTU turbidity	8.74	0	0	0	0	0	0.63	0	1.15	0	5
3.	KMnO4 mg/l	2.84	3.79	4.74	4.42	2.52	6.32	3.16	4.42	4.74	5.37	8.00
4.	Ammonia mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	1.00
5.	Nitrates mg/l	4.9	35.9	31.4	0.2	1.3	9.5	1.2	5.2	0.4	43.3	50.0
6.	El.Conduct. µS/cm	505	475	785	670	335	350	420	240	670	615	to 1000
7.	Fe mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.131	<0.02	0.300
8.	Mn mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.039	<0.01	0.05
9.	Sulphates mg/l	19.87	36.62	63.17	25.60	31.76	35.86	37.73	18.10	7.81	67.75	250
10.	Ca mg/l	44.36	70.98	14.25	51.01	55.45	60.27	78.89	40.89	37.70	44.61	200.0
11.	Mg mg/l	73.94	35.59	75.93	49.78	24.84	22.38	18.18	10.41	114.97	89.91	50.0
12.	Microbiol.analysis	Faulty	Correct	Correct	Correct	Faulty	Correct	Correct	Faulty	Correct	Correct	
13.	Water correctness	Faulty	Correct	Faulty	Correct	Faulty	Correct	Correct	Faulty	Faulty	Faulty	

The results of the obtained concentrations of organochlorine insecticides in the tested samples of drinking water in 20 villages in the vicinity of the town of Kraljevo show that they range mainly within the limits given by the Ordinance on the hygienic safety of drinking water. FRY Gazette No. 42/98 and 44/99.

Even if the use of DDT has long been banned in EU countries and the developed world, it can still be found in our country, as shown by the examined samples. Of the tested organochlorine insecticides, heptachlor and DDT have the lowest concentration. The concentration of the organochlorine insecticide lindane, although found in a large number of water samples, is significantly below the MAC. Concentrations of aldrin and dieldrin in water samples in the villages of Dedevci, Godachica, Dragosinjci, Kamenica, Ribnica, Vrba and Bogutovac have an increased value compared to other villages in the study area, but are within the MAC limits. Certain amounts of α-HCH and endrin indicate the presence of these insecticides in most of the tested water samples, however, the concentrations are within the permitted values according to the "Ordinance on the hygienic safety of drinking water. FRY Gazette No. 42/98 and 44/99 ".

Table 3. Results of tested organochlorine insecticides in drinking water, rural waterworks

No.	Villages	OHI (10-2 µgl)							
		α-HCH	Lindane	Hepta-chlorine	Aldrin	Dieldrin	Endrin	DDT	Total
1.	Mrsac	1.81	0.00	0.00	0.73	0.00	0.00	0.00	2.54
2.	Adrani	0.00	0.25	0.00	0.62	1.02	1.04	0.00	2.93
3.	Sircha	1.28	0.00	0.00	0.00	0.77	0.92	0.00	2.97
4.	Oplanici	0.90	1.06	0.00	0.76	0.83	1.51	0.00	5.06
5.	Popovici	1.28	0.00	0.00	0.00	0.77	0.92	0.00	2.97
6.	Upper Godachica	1.58	0.00	0.00	1.86	0.96	1.50	0.00	5.90
7.	Lower Godachica	1.41	1.46	0.00	0.78	0.90	0.68	0.00	5.23

8.	Stubal	1.62	0.00	0.75	0.81	1.89	1.52	1.26	7.85
9.	Ratina	0.00	4.42	0.00	0.00	0.00	1.11	0.00	5.53
10.	Vrba	0.00	2.15	0.00	1.60	1.33	0.78	0.00	5.86
11.	Metikoshi	0.00	0.00	0.00	1.12	0.00	1.17	0.00	2.29
12.	Dragosinjci	1.05	0.00	0.00	1.25	1.61	1.23	1.17	6.31
13.	Ribnica	1.51	1.92	0.00	1.01	1.59	0.88	0.00	6.91
14.	Kamenica	1.68	2.38	0.00	1.35	1.58	1.98	1.53	10.5
15.	Zicha	0.00	4.56	0.00	0.00	0.00	1.68	0.00	6.24
16.	Bogutovac	1.21	2.58	0.00	1.64	1.22	0.84	0.00	7.49
17.	Drakchici	0.00	2.91	0.00	0.00	0.00	2.84	0.00	5.75
18.	Vrdila	0.00	3.49	0.00	0.00	0.00	2.09	0.00	5.58
19.	Rocevici	1.43	0.00	0.00	0.99	0.00	1.24	0.58	4.24
20.	Dedevci	2.19	0.00	0.00	1.20	1.08	0.00	1.01	5.48
MAC (10^{-2} µg/l)			20.00	3.00	3.00	3.00		10.00	50.00

Observing the total values of the tested organochlorine insecticides in the water samples from the aspect of the geographical position of the examined villages, a somewhat higher concentration in the water reservoirs of the villages located southwest, southeast and south in relation to the city of Kraljevo is observed. As the locality under investigation is a characteristic agricultural and fruit-growing area, periodic annual testing is required due to the increasingly intensive use of organochlorine insecticides for product protection, but also their possible uncontrolled application. OHI monitoring would timely examine the harmful effects of their use on the water system of the examined region *(Law on Communal Activities, O.g. RS 88/2011, 104/2016 and 95/2018*).

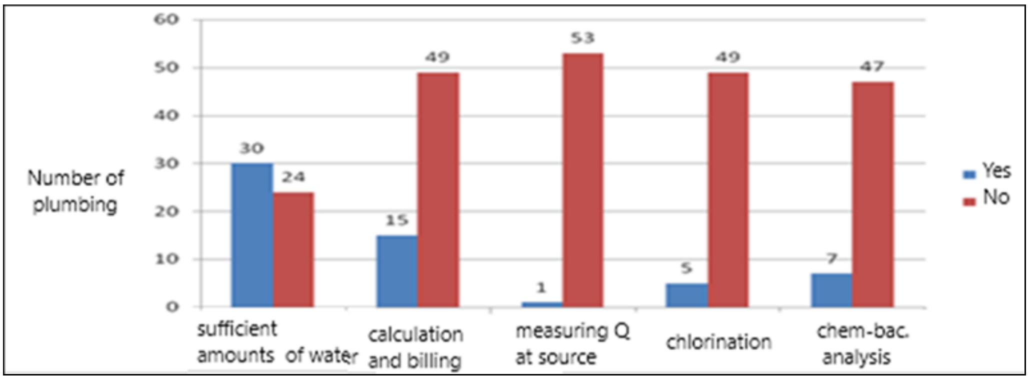

Fig.1. Graphic representation of water supply system maintenance parameters

CONCLUSION

Based on the analysis of microbiological, physico-chemical parameters and OHI concentrations in the drinking water of rural waterworks in the vicinity of the city of Kraljevo, it can be concluded:

1. that out of the tested 20 drinking waters, 6 (30%) and 8 (40%) are microbiologically defective,
2. the following can be neglected: chemical malfunction of water due to increased value of Mg and increased value for ammonia and Fe which are on the border and microbiological malfunction which can be eliminated by chlorination of water,
3. It remains that out of a total of 20 tested waters in terms of microbiological and physico-chemical correctness, only two drinking waters are defective, one due to increased turbidity (8.74 NTU) and one due to increased consumption of KMnO4,
4. that the concentrations of organochlorine insecticides in all tested rural water supply systems are within the limits of the maximum permitted values standardized by the “Rulebook on the hygienic correctness of drinking water Sl. FRY Gazette No. 42/98 and 44/99 ”,
5. springs-catchments are mostly in poor construction, technical and sanitary condition, they are not fenced and locked. Sanitary zones generally do not exist. Water from the catchment to the tank and from the tank to the user is distributed in combination: pressure, pumps and gravity. Cleaning and disinfection of catchments, reservoirs and networks in most villages is done occasionally. Also, there are generally no people in charge of water supply maintenance,

6. The examined localities are characteristic agricultural and fruit rural areas and it is possible to expect changes in the amount of tested compounds in the waters, which imposes the necessity of a periodic year testing.

Based on the assessment of damage to the water supply network and water infrastructure facilities, the company that manages and maintains the rural water supply systems in the municipality of Vrnjachka Spa has prepared project documentation for rehabilitation and reconstruction of damaged utility infrastructure caused by inadequate maintenance and previous floods to avoid and reduced real flood hazards. After the implementation of five projects for the reconstruction and construction of water supply network and water infrastructure facilities (drainage buildings, watercourses under rivers, measurement and regulation of reinforced concrete manholes, collection chambers, chlorine houses, connecting pipelines, pipelines, etc.), moderate danger and risk were assessed from floods in the area.

ACKNOWLEDGMENT

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WASTEWATER TREATMENT USING HALLOYSITE/BIOPOLYMER NANOCOMPOSITE

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Abstract: The use of natural materials and composites for the removal of dyestuffs from wastewater has gained importance in recent years. Especially using clay/polymer composites as adsorbent in adsorption processes is preferred. Halloysite is a natural mineral and its structure is very close to nanotubes. Therefore, it is preferably used in water treatment processes, especially in the removal of dyestuffs from aqueous solutions. In this study halloysite clay is combined with chitosan, a natural polymer, to increase its adsorption capacity and to be used in the removal of dye, cresol red, from wastewater. For this purpose, the change in adsorption amount with time as well as the adsorption capacity were investigated. In order to compare the adsorption capacities, the adsorption study of dye by natural halloysite was also carried out.

Experimental studies indicated a maximum adsorption percentage and maximum adsorption capacity are 96% and 82 mg/g for the halloysite/chitosan composite material, respectively whereas these values remained around 45% and 42 mg/g for the unmodified halloysite. Langmuir and Freundlich isotherm models were used to analyze the adsorption data. The results showed that equilibrium data were fitted well to the Freundlich model as confirmed by the calculated values of lineer regression (R^2) and indicaed to the multilayer adsorption.

Keywords: Adsorption, Halloysite, Cresol red, Biopolymer, kinetic model.

INTRODUCTION

The introducing of toxic substances of synthetic or natural origin (as dyes, heavy metals, pesticides, detergents, etc) into the environment presents a big problem now and in the future. Among these materials dyes are widely used in many industrial processes such as textiles, staining paper, leather, rubber, plastics (Alengebawy et.al. 2021). Today approximated that over 100,000 commercial dyes are industrially used and more than 700,000 tons of dyestuff are produced every year worldwide (Uygun et.al. 2021). These toxic chemicals must be removed from wastewater before they are discharged into ecosystems. In particular, water pollution should be prevented in advance. The development of efficient technologies for the improvement of water resources has become an important subject of the studies in environmental research. Various technologies include advanced oxidation, ion ex-change, precipitation, decantation, adsorption, membrane filtration, ozonation crystallization, are used for the removal of pollutants from aqueous solution (Saufi et.al. 2020; Abu-Nada et.al. 2021). Adsorption is widely used among these technologies for the removal of dyes from waste water (Abu-Nada et.al. 2021; Suleyman et.al. 2021)

Many researchers have focused on inexpensive, more stable, environmentally friendly and natural materials for use in adsorption processes. They used these materials either directly or after processing in the adsorption processes [Rehman et.al.2021). Clays are eco-friendly and natural minerals with these properties (Khan et.al.). Therefore, they are preferred to be used in adsorption processes. Clays are mostly modified before used to increase their effectiveness. Halloysite one of the efficient clay was used in the waste water adsorption process (Ballay et.al. 2014; Liu et.al.2012). Halloysite nanotubes are one-dimensional nanoparticles which are a kind of layered aluminosilicate. It belongs to the kaolin group of minerals mined from natural source (Peng et.al.2015). Cresol red is one of the commercial and toxic dye. It is widely used to color some textile materials as wool, nylon, cotton (Kristanti et.al.2016). Khudhair and co-workers worked on the removal of Cresol red by using recycled waste tire rubber. They showed that waste tire rubber has good ability to remove cresol red from aqueous solution even without activation (Khudhair et.al.2015).

MATERIALS AND METHODS

Cresol red used in this study as model dye was purchased from Merck. Halloysite was obtained from Canakkale region, in Turkey. The cetyltrimethylammonium bromide (CTAB) was 99% in purity and supplied from Sigma Company. Chitosan was purchased from Aldrich Company.

Preparation of Adsorbents

Halloysite mineral was first washed with distilled water in order to remove the impurities. The washed sample was dried in the oven at 120 °C until its weight did not change. The dried clay were grounded and sieved through a sieve (80 mesh). Halloysite was then stored in a desiccator for later use as an adsorbent (unmodified halloysite). The modified halloysite were prepared by dispersing of 2 grams sieved halloysite in 1mmol CTAB solution. The solution was continuously stirred for 3h at room temperature. Then the solution was left overnight to settle dawn. After centrifugating the solid particles were washed with distilled water and were dried in the oven at 120 °C until no changes in weight. To prepare halloysite/chitosan (10/1) (g/g) adsorbent chitosan solution (0,5 wt%) was first prepared by dissolving chitosan in 0,1 M acetic acid. After added halloysite solution, the mixture was sonicated to obtain homogenous mixture. The halloysite/chitosan composites were separated from the solution phase by centrifugation. The resultant solution was washed with distilled water to remove unbound chitosan and was dried for 12 h at 50 ◦C, grounded and sieved through a 80 mesh sieve.

X-ray Diffraction of Halloysite

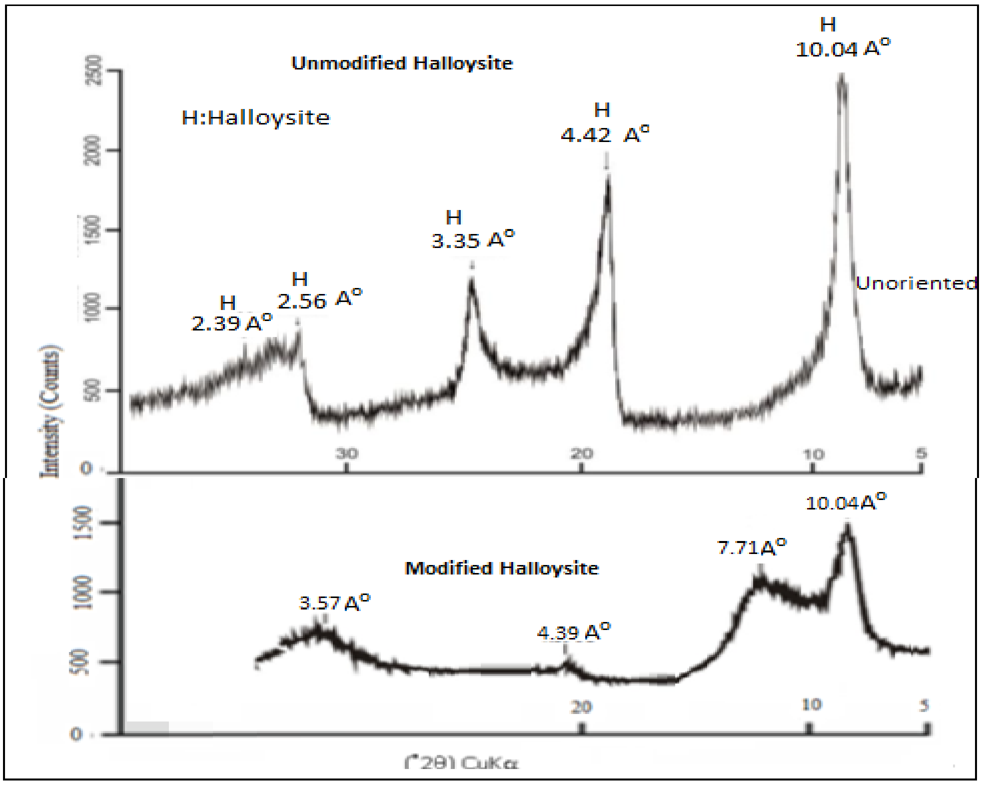

Fig 1: XRD pattern of (**a**) unmodified halloysite (**b**) modified halloysite

X-Ray pattern of clay was determined by using X-ray Diffraction (XRD) instrument (Philips diffractometer with a PW-1730 at 36 kV and 30 mA, using Ni-filtered CuK α-radiation). XRD patterns of the unmodified halloysite and modified halloysite were seen in Fig.1.

FTIR of Halloysite

The FTIR spectra of the clay samples were obtained by the spectrometer (ThermoNicolet 380 FT model). Fig 2 compare the FTIR results of the unmodified and modified halloysite.

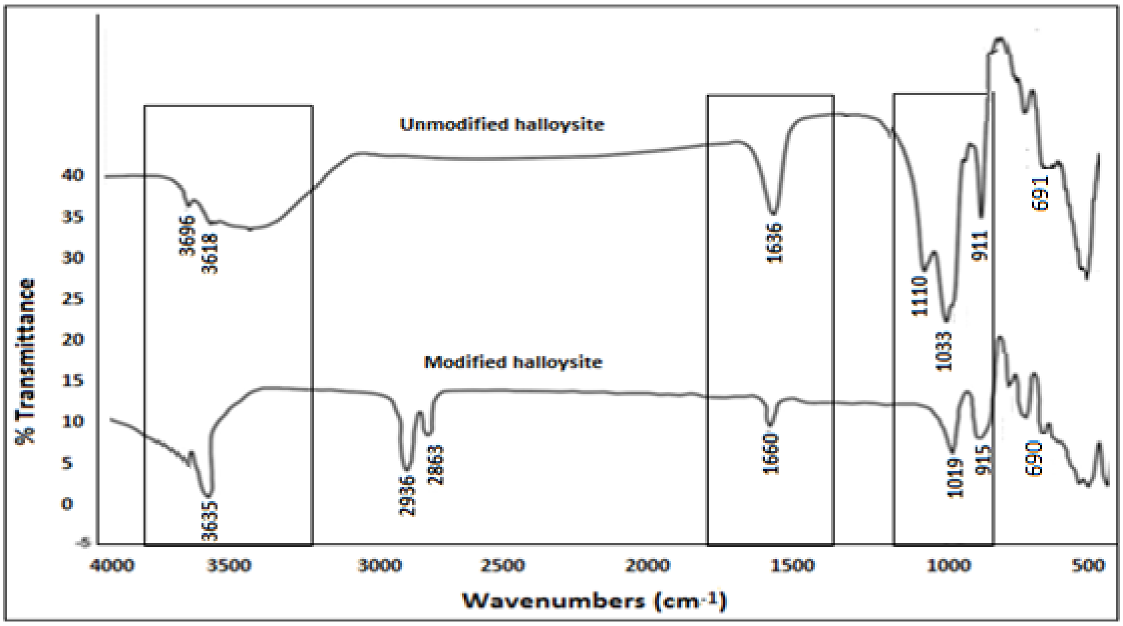

Figure 2: FTIR graph of halloysite before and after modification

Batch Experiments

Adsorption of cresol red from waste water was monitored in batch process. In this work, during the adsorption process, the effect of the dye concentrations and contact time were investigated. The different concentrations of cresol red (0,25 gr/L; 0,50 gr/L; 0,75 gr/L) solutions were prepared by diluting of the stock solution (1,0 g/L). 25 ml volume of the dye solutions and 0,25g halloysite/kitosan adsorbent were used for the adsorption. The absorbance values were measured by UV-spectrophotometer at λ=540 nm. The dye removal (%) was calculated using the equation given below.

$$\% \, Adsorption = \frac{C_0 - C_t}{C_0} \times 100 \quad (1)$$

Here, C_o is initial concentration (mg/L) and C_t is the concentration (mg/L) at an arbitrary time. The adsorbed amount of dye per unit adsorbent q_t (mgg^{-1}) was calculated according to the following equation.

$$q_t = \frac{C_0 - C_t}{m} \times V \quad (2)$$

RESULTS AND DISCUSSION

In this study, the adsorption isotherms of cresol red on the unmodified halloysite and modified halloysite/chitosan were examined, and the suitability of the adsorption isotherms were investigated. In addition, the adsorption percentage and adsorption capacity were calculated.

XRD results of the samples from Fig.1 indicate that the intensities of the peaks decreased and shifted in the modified halloysite compared with the unmodified halloysite. These results showed the successful modification process.

From Fig.2 the absorption peaks due to stretching vibrations of Al–OH bonds in unmodified halloysite was observed at 3696 cm^{-1} and 3618 cm^{-1}. These peaks seen in unmodified halloysite were shifted to 3635 cm^{-1} in modified Halloysite due to lose its outer hydroxyls. Another peaks related to Al–OH bending vibration, can be seen at 1033 cm^{-1} and 911 cm^{-1} in unmodified halloysite and at 1019 cm^{-1} and 915 cm^{-1} in modifid halloysite. Si–O stretching vibration peak is observed at 691 (and 690) cm^{-1} in both clay samples. These results showed successful modification of the halloysite without distortion of the structure and they are in agreement with the study conducted by Frost et. al (Frost and Vassalo 1996).

The effect of contact time of cresol red adsorption unmodified halloysite and halloysite/chitosan adsorbent was investigated due to concentrations. The changes in the adsorption percentage at different times were shown in Fig.3. The maximum adsorption percentage of cresol red was obtained 96% on halloysite/chitosan (Fig. 3a) whereas the max adsorption percentage on unmodified halloysite was 45% (Fig 3b). The adsorbed percentage on halloysite/chitosan increases with concentration. The maximum adsorption capacity was found 82 mg/g for the halloysite/chitosan composite material and 42 mg/g for the unmodified halloysite.
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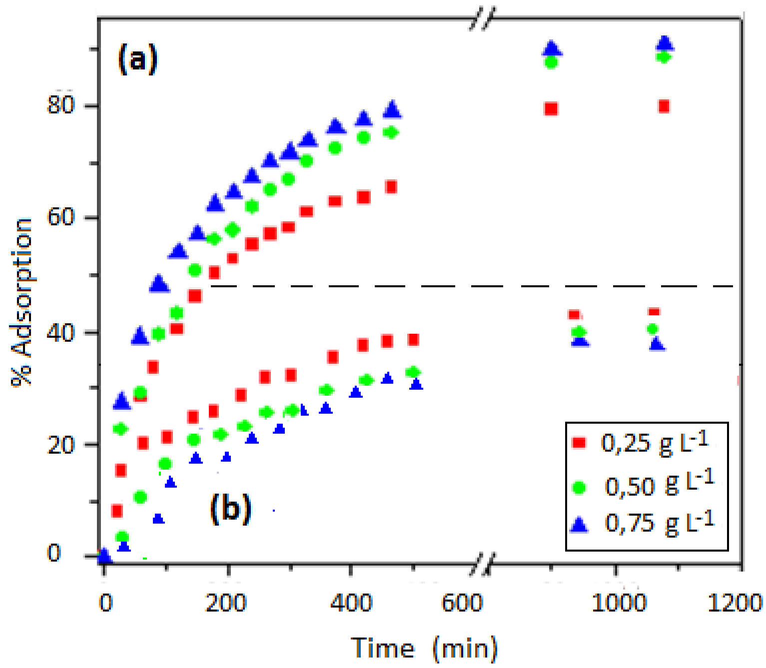

Figure 3: The (%) of adsorption on (a) halloysite/chitosan (b) unmodified halloysite

Langmuir (Langmuir1918) and Freundlich (Freundlich 1906) isotherms were modeled to analyze the results obtained from adsorption process. The correlation coefficient of Freundlich isotherm (R^2= 0,954) is higher than those obtained by Langmuir isotherms (R^2 = 0,921) suggesting that the removal of cresol red onto chitosan-halloysite carry in a multilayer adsorption.

CONCLUSIONS

In this work, the adsorption of cresol red were investigated on unmodified halloysite and halloysite/chitosan adsorbents. It was seen that the adsorption on both adsorbents wss very fast at the beginning, but slowed down over time and reaches saturation. As the concentration increased, the percentage of adsorption on halloysite/chitosan increased. Freundlich isotherm showed the best fit for the data and multilayer adsorption took place.The modification process significantly increased the adsorption capacity of halloysite. The halloysite/chitosan adsorbent prepared in this study was extremely effective in removing cresol red from aqueous solutions.

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OVERVIEW OF INPUT DATA FOR QUANTITATIVE RISK ANALYSIS FROM THE CONSEQUENCES OF GEOHAZARD

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Abstract: The aim of landslide risk assessment is to determine the spatial and temporal probability of landslides in a particular area, together with their mode of spread, size and intensity. Risk analysis must take into account possible breakdown mechanisms. Regardless of the work scale, the hazard assessment must define the time frame for the occurrence of potential types of landslides and their intensities at the considered location. The time occurrence of a landslide is normally expressed in terms of frequency, return period or probability overrun. The return period is the inverse annual probability return and refers to the average time interval in which an event of a certain magnitude is expected to occur. This paper provides an overview of the input data required for the assessment and quantitative risk analysis related to the occurrence of the most common geohazards in practice (landslides, shallow landslides, debris flows and large slow landslides). For a clearer overview, their importance in the assessment of sensitivity and hazards for different landslide mechanisms is given. At the same time, methods for quantitative risk analysis of landslide have been proposed.

Keywords: landslide, hazard, risk analysis, risk assessment, quantitative risk analysis, input parameters.

INTRODUCTION

This paper provides an overview of the input data required for adequate risk analysis of the consequences of geohazards. Risk is a combination of the consequences of activities and the associated uncertainties of the outcome of those activities. At the same time, it represents the expected degree of damage in the occurrence of some form of geohazard in relation to the loss of human lives, property and the harmful impact on the environment. Risk involves quantifying the probability of occurrence of some form of geohazard that may have adverse consequences. In practice, the acceptable level of risk is assessed (Benac, 2013), as well as measures of the probability and severity of adverse effects on human life and health, property or the environment. Landslide risk is often defined as the probability of a landslide event multiplied by the consequences.

The risk assessment involves the process of making recommendations on whether existing acceptable risks and current risk control measures are adequate. If not, the question is whether alternative risk control measures are justified and whether they will be implemented. Risk assessment includes phases of risk analysis and risk assessment. Risk assessment also encompasses the entire process of risk analysis and evaluation. Risk analysis applies the use of available data to calculate the risks to individuals, the population, property and the environment from the consequences of hazards. They typically contain the following steps: scope definition, hazard identification, vulnerability assessment and risk assessment. Risk analysis includes the systematic use of information to determine the initial event, the causes and consequences of the initial event and to express risk (Table 1). The main data needed to define risk analysis can be divided into four groups: landslide inventory data, environmental factors, driving factors and risk elements (Soeters and Van Westen, 1996; Van Westen et al., 2008). The inventory of landslides is the most important because it provides insight into the locations of past landslides, as well as their breakdown mechanisms, causal factors, frequency of occurrences, quantities and damage they caused.

There are relatively few papers that provide an overview of the original input data for quantitative hazard and risk analysis (Van Westen et al., 2008). Corominas and Moya (2008) provide an overview of the data methodsused in slide description studies and Cepeda et al. (2012) provide an overview of methods for using meteorological data in analyzing precipitation thresholds for quantitative hazard assessment. Pitilakis et al. (2011) present in their paper a comprehensive overview of the data to be collected for the characterization and physical assessment of hazard vulnerability elements, such as buildings, roads, pipelines and the like. A good overview of the use of remote sensing for landslide hazard analysis and risk analysis can be found in the papers of Soeters and van Westen (1996), Singhroy (2005), Michoud et al. (2010) and Stumpf et al. (2011). In order to develop a reliable hazard and landslide risk map in a given area, which is crucial for insight into the spatial and temporal frequency of landslides, each hazard and/or risk study should begin with the most complete inventory of landslides in space and time according to Table 1.

Table 1. Overview of input data sources and their relevance for quantitative risk analysis for different landslide mechanisms (F = fall, SL = shallow landslides and debris flows, LSL = large slow landslides), (modified according to Corominas et al., 2013).

Basic source	Data group	Examples	M	Scale				Relevance		
				N	R	L	LS	F	SL	LSL
Laboratory analyzes	Soil properties	Grain size distribution, saturated and unsaturated shear strength of soil, soil water retention curves, hydraulic conductivity of saturated soil, clay minerals, sensitivity, viscosity, density.	Ps	x	x	o	•	L	C	V
	Rock properties	Unlimited compressive strength, shear strength, mineralogy.	Ps	x	x	o	•	C	L	C
	Vegetation properties	Tensile strength of roots, strength of pulling of roots, evapotranspiration.	Ps	x	x	o	•	L	V	M
	Age assessment	Radiocarbon C-14 test, pollen analysis.	Pl	o	o	o	•	L	L	V
Terrain measurements	Landslide age	Dendrochronology, lichen method for estimating landslide age, tephrochronology, archaeolog. artifacts.	Pl	o	o	o	•	M	M	V
	Depth of soil	Wells, trenches, pits, material outcrops, material sampling drills.	Ps	x	x	o	•	L	C	M
	Geophysics	Seismic wave refraction, microseismic observation, electromagnetic method, magnetic method, ground-penetration radar, geophysical drilling methods.	Ps	x	x	o	•	L	M	V
	Soil characteristics	Standard penetration tests, field drilling.	Ps	x	x	o	•	L	C	M
	Rock characteristics	Lithology, discontinuities (types, spacing, orientation, openings, fillings), rock mass ranking.	Ps	x	x	o	•	C	L	V
	Hydrological characteristics	Infiltration capacity, water face fluctuation, soil absorption, pore pressure.	Ps	x	x	o	•	V	C	C
	Characteristic of vegetation	Root depth, root density, vegetation species, crop factor, ratio of rock cover material.	Ps	x	x	o	•	M	V	L
Observation networks	Landslide shifts	Electronic distance measuring devices, GPS systems, theodolite, terrestrial laser scanner, interferometry.	Pl	x	x	o	•	V	V	V
	Groundwater	Piezometers, strain gauges, water flow measuring stations.	Pn	x	x	o	•	V	C	C
	Meteorological data	Precipitation, temperature, humidity, wind speed.	Pn	•	•	•	•	V	V	V
	Seismic data	Stations for measuring seismic activity, stations for strong displacement, microseismic studies.	Pn	•	•	•	•	V	V	V

Note: Importance is marked as C (crucial), V (very important), M (moderately important) and L (less important). The potential for this information is collected at different levels and is presented as: • = possible, o = difficult possible, x = not possible. The scales are: N (national level), R (regional level), L (local level) and LS (local specific level). M denotes the method used for spatial data collection where: Pl = point (local) data related to individual specifics (eg landslides), Ps = sample of points that characterize spatial units (eg soil types, vegetation types), Pn = points in the network to be interpolated, Sc = data based on surface characteristics (eg landslide polygons, buildings), Cs = complete surface coverage, L = line data.

Table 1. Overview of input data sources and their relevance for quantitative risk analysis for different landslide mechanisms (F = fall, SL = shallow landslides and debris flows, LSL = large slow landslides), (modified according to Corominas et al., 2013), continued

Basic source	Data group	Examples	M	Scale				Relevance		
				N	R	L	LS	F	SL	LSL
Area mapping	Landslides	Type, relative age, speed of movement, state of activity, initiations, transport of materials, zones of deviation, area, depth, volume, consequences.	Sc	o	•	•	•	C	C	C
	Geomorph-ology	Characterization of landslide shapes, processes, surface material.	Cs	o	o	•	•	L	V	V
	Soil types	Textures, soil classification, boundary area mapping, conversion to engineering soil types.	Cs	o	o	•	•	L	C	V
	Lithology	Lithological mapping, meteorological zones, border area mapping, formations.	Cs	o	o	•	•	C	V	V
	Structural geology	Depth measurements of cover plane and discontinuity, stratigraphic reconstructions, mapping curve, structural reconstruction.	Cs	o	o	•	•	V	L	V
	Vegetation	Vegetation type, density, leaf growth area index.	Cs	o	o	•	•	L	V	M
	Land use	Types of land use, characterization of vegetation by land use.	Cs	o	o	•	•	V	V	V
	Elements of risk	Typology of construction, structural system, foundation systems, classification of roads and pipelines.	Sc L	o	o	•	•	V	V	V
Archival studies and data from the past	Landslides in the past	Historical data on location, date of origin, trigger mechanisms, size, volume, range length.	Sc Pl	o	o	•	•	V	V	C
	Damage data	Historical data on economic losses and affected population with dates, location and characterization.	Pl	o	o	o	o	V	V	V
	Meteorolog-ical data	Precipitation (continuous or daily), temperature, wind speed, humidity.	Pl	•	•	•	•	V	V	V
	Land use change	Historical maps of land/cover use for different periods.	Pn	•	•	•	•	M	V	V
	Elements of risk	Historical maps of buildings, transport infrastructure, economic activities and population characteristics.	Cs	•	•	•	•	V	V	V
	Digital height values	Topographic maps with isohypses, digital relief models.	Sc L	•	•	•	•	V	V	V
	Thematic maps	Geological, geomorphological, channel networks and other existing thematic maps.	Cs	•	•	•	•	V	V	V

Note: Importance is marked as C (crucial), V (very important), M (moderately important) and L (less important). The potential for this information is collected at different levels and is presented as: • = possible, o = difficult possible, x = not possible. The scales are: N (national level), R (regional level), L (local level) and LS (local specific level). M denotes the method used for spatial data collection where: Pl = point (local) data related to individual specifics (eg landslides), Ps = sample of points that characterize spatial units (eg soil types, vegetation types), Pn = points in the network to be interpolated, Sc = data based on surface characteristics (eg landslide polygons, buildings), Cs = complete surface coverage, L = line data.

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Basic source	Data group	Examples	M	Scale				Relevance		
				N	R	L	LS	F	SL	LSL
Remote sensing	Aerial photography and high resolution satellite imagery	Interpretation of images for mapping and characterization of landslide locations, geomorphology, land/cover use, mapping of risk elements.	Sc Cs	o	•	•	•	C	C	C
	Multispectral images	Image classification methods for landslide mapping, land/cover use, normalized vegetation difference index, leaf growth index for a specific area.	Sc Cs	•	•	•	•	M	V	M
	Digital elevation data	Aerial stereophotogrammetry, space stereophotogrammetry, LIDAR, InSAR.	Cs	•	•	•	•	C	C	C

Note: Importance is marked as C (crucial), V (very important), M (moderately important) and L (less important). The potential for this information is collected at different levels and is presented as: • = possible, o = difficult possible, x = not possible. The scales are: N (national level), R (regional level), L (local level) and LS (local specific level). M denotes the method used for spatial data collection where: Pl = point (local) data related to individual specifics (eg landslides), Ps = sample of points that characterize spatial units (eg soil types, vegetation types), Pn = points in the network to be interpolated, Sc = data based on surface characteristics (eg landslide polygons, buildings), Cs = complete surface coverage, L = line data.

QUANTITATIVE RISK ANALYSIS METHODS FOR LANDSLIDES

For the purposes of quantitative risk analysis (QRA) it is necessary to have an accurate input of geological and geomechanical data and a quality digital terrain model for a particular observation area in order to perform a good assessment of possible scenarios, event calculation and relevant return period (Lee and Jones, 2004). The risk for a landslide scenario can be expressed analytically based on the formulation $R=P(M_i)P(X_j|M_i)P(T|X_j)V_{ij}C$, where R is the risk due to the occurrence of a landslide of strength M_i on the risk element located at a distance X from the source of the landslide, $P(M_i)$is the probability of landslides of a certain strength Mi, $P(X_j|M_i)$ is the probability of the landslide to a point located at a distance X from the source of the landslide with intensity j, $P(T|X_j)$is the probability element at site X at the time of landslide, V_{ij} is the vulnerability of the landslide element of strength and intensity, while C is the value of the hazard element. Elements of risk are population, buildings, economic activities, including public services or any other persons directly exposed to hazard in a particular area (UN-ISDR, 2004).

To perform a quantitative risk analysis, it is necessary to know all the parameters for calculating the parameter R for a particular type of landslide, because each landslide has a specific probability of occurrence, intensity and probability of impact. Global hazard areas can be determined by collecting a specific risk for different types of geohazards and their intensities. Two alternative types of analysis are used to determine risk: deterministic and probabilistic analysis. Deterministic risk analysis uses average or at least favorable values of risk components (worst case scenario) which gives a univariate result expressed by average or maximum risk. On the other hand, for probabilistic risk analysis, all or only some of the risk components are assumed to be consistent with the probability distribution so that the results are presented under probabilistic conditions, using representations of (cumulative) probabilities and consequences (Corominas et al., 2013; Pine, 2008).

DISCUSSION

Risk analysis can relate to a single building, feature or area. Area analysis is a very demanding process in terms of collecting the data needed to determine risk. Spatial analysis is usually performed at the regional level and conducted on a GIS platform with maps used to illustrate risk. The analysis does not necessarily require an estimate of the frequency in the source area, but the list of events reaching the infrastructure should be as complete as possible. Geohazard analysis is usually performed using analytical and/or numerical models and includes the calculation of spatial parameters that affect the probability of occurrence of a certain size or reached speed of the exposed geohazard element. The calculation of the exposure depends on the scale of the analyzed area and the type of potentially exposed hazard elements. When exhibiting, there is an important difference between static (buildings, roads, other infrastructure, etc.) and moving elements (vehicles, people, etc.). With specific spatial and local scales, and when the trajectory is included in the analysis, such a process is limited only to the risk elements located on the potential trajectory of the rock mass landslide. Debris flows can affect larger areas in relation to rock mass landslides, due to their increased mobility, ie the influence of fluids as an integral part. Spatial surface exposure can be calculated as the ratio of the affected area to the total area. Spatial exposure can also be seen as a function of flow kinematics, ie the hydrodynamic impact that affects an individual structure during the debris flow propagation. To analyze the risk of landslides and adopt spatial planning, it is necessary to understand the mechanisms of landslides that may occur in the area under consideration. Several geohazard scenarios are considered, together with their potential consequences, so that the relevant components of direct and indirect risk can be assessed quantitatively.

CONCLUSIONS

The risk of the consequences of geohazard can be described through three basic components: hazard, exposure of at-risk elements and their vulnerability. They can be characterized by spatial or non-spatial attributes. In determining the risk analysis of geohazard consequences, the procedure is performed through the following steps: (i) geohazard analysis which includes analysis of intensity, probability of rock mass slip and its potential reach, (iii) identification of risk elements including number of occurrence, value and degree of exposure, (iv) vulnerability analysis and (iv) risk assessment. The susceptibility to the occurrence of possible geohazards in a given area can be determined on the basis of geomorphological mapping, empirical or semi-empirical evaluation systems, as well as deterministic and statistical methods.

Methods for determining the propagation of debris flow and mudflow can be divided into two main categories, namely empirical methods and physical methods. Empirical methods are relatively simple methods that allow a rapid assessment of the propagation of debris flow and mudflow based on the relationship of topographic slope factors and the length of the flow range. On the other hand, physically based methods are complex methods that use numerical (kinematic) simulations of motion and propagation of debris flow and mudflow. The intensity of such phenomena in nature with a significant initiated volume of rock mass is a necessary factor in hazard assessment and is expressed by the kinetic energy of hydrodynamic impact that such phenomena cause through the process of downstream propagation on slopes or within channels.

Due to the growing consequences of climate change in the world, more and more frequent occurrences of rock material propagation resulting from longer periods of precipitation and drought can be expected. In this regard, in the future it will be necessary to develop relevant maps of hazards and risks of debris flows and mudflows, and thus to make an adequate selection of an appropriate method for assessing geohazards and risks of such possible occurrences. Considering the methods of geohazard and risk assessment that are applicable in the world, the size of the area of application and an adequate scale should be considered. Geohazard zoning at national, regional and local scales is carried out using simple methods based on heuristic or empirical procedures (adopting only a few parameters for assessment), unfortunately neglecting the time component. When assessing hazard on a large scale, it is proposed to adopt a quantitative method over a qualitative one, which separates the assessment of hazard and risk. Today, high-resolution 3D images of terrain (aerial and terrestrial images using LiDAR technology) or photogrammetric images using SfM technology (Structure from Motion Technology) are available for conducting highly sophisticated deterministic spatial simulations of the movement and propagation of debris flow and mudflows for the purpose of risk determination. For this reason, appropriate methods of geohazard assessment for these phenomena should be adopted by introducing modern deterministic methods, while heuristic methods can serve as an auxiliary tool for verification and validation the terrain results.

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VISUALIZATION OF AVERAGE ANNUAL PRECIPITATION IN SERBIA FOR THE PERIOD FROM 1946 TO 2019

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Abstract: Precipitation is one of the key players in analysing of natural hazards such as droughts and floods. Thanks to a reliable source of precipitation data on precipitation in the territory of Serbia, a good analysis of data and its visual presentation can be performed. Based on the data collected from meteorological stations, it is necessary to process and visualize them and do an assessment and possibly a warning. This paper presents the application of GIS (geographic information system) which enables visualization of average precipitation annual data in Serbia for the period 1946-2019.

Keywords: *GIS application, precipitation, Serbia*

INTRODUCTION

Climate changes which have been studied and analysed in plenty of publications have a great impact on the environment (Ekström et al., 2005; Kjellström, 2004; Philandras et al., 2011). The main goal is to provide information that should help in the further process of planning, decision-making as well as reducing the harmful impact on the environment. This monitoring of climate change impacts requires an interdisciplinary approach, where IT experts still need to be involved to create web applications and systems that should provide data collection, storage, management and analysis for climate change research.

Climate change is a long-term process, the analysis requires the processing of a large amount of data (big data) collected over a long period of time-related to a specific area of the world. The amount of collected data is quite large due to the measurement of various meteorological parameters. Data sources can usually be collected from manual or automatic meteorological stations, satellite observations, radar data, and smart mobile devices.

Processing a large amount of data is a very demanding process which, due to the longer period of time and the observation in which the data are collected, it is necessary to devise appropriate methods for their processing. Therefore, the Geographic Information System (GIS) can be used as a part of climate data processing (Gad and Tsanis, 2003). One of the approaches to data analysis is a spatio-temporal analysis for example precipitation data (Martins et al., 2012; Ruiz Sinoga et al., 2011; Tosic, 2004).

Nowadays, there are a large number of quality tools in the field of GIS systems (ArcGIS, QGIS (Quantum GIS) and SAGA GIS) that have been developed to provide support in the analysis of collected data. Such tools provide opportunities for general statistical analysis such as mathematical or scientific. These tools have support for various types of analysis of vector and raster spatial data.

Data from different sources are often linked in order to obtain more accurate results in climate change analysis. The most common sources of precipitation data are meteorological radars, satellite observations, and sometimes rain gauges.

The research, design and practical implementation presented in this paper was the development of a specialized GIS application using some of the statistical software such as R to present average annual precipitation data in Serbia.

MATERIALS AND METHODS

Study area

Serbia is selected as a case study and monthly precipitation time series from 28 meteorological stations from the period 1946-2019 were analysed. The data have been collected from annual publications of the Republic Hydrometeorological Service of Serbia. A map of Serbia with designated measuring stations in Serbia through a GIS application using the R language and its packages is presented in Figure 1.

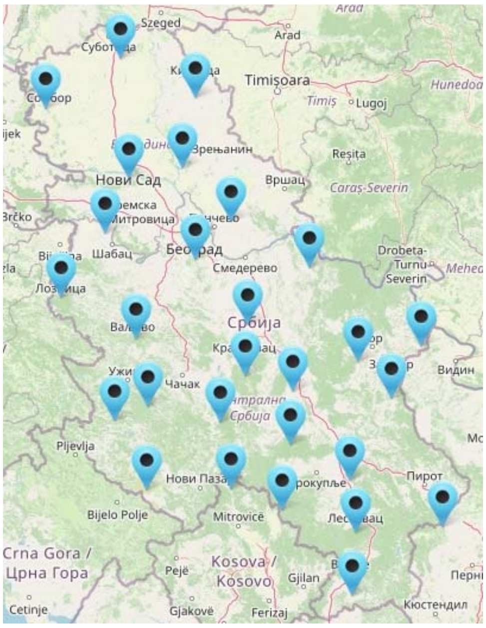


Figure 1. GIS application in the programming language R for displaying data from meteorological stations in Serbia

The geographical description and statistical parameters (mean, standard deviation and coefficient of variation (CV)) for the annual precipitation data of the selected meteorological stations are given in Table 1. The coefficient of variation is ranged from 17.3% (Zlatibor and Loznica) to 32.2% (Kopaonik). The majority of Serbia has a coefficient of variation less than 20%.

Table 1. Geographical descriptions and statistical parameters of the meteorological stations used in the study for the period 1946-2019

Station name	Longitude (E)	Latitude (N)	Elevation (m a.s.l.)	Mean (mm)	Standard deviation (mm)	CV (%)
1. Banatski Karlovac	20°48'	45°03'	89	629.5	141.6	22.5
2. Belgrade	20°28'	44°48'	132	693.8	137.2	19.8
3. Crni Vrh	21°58'	44°08'	1027	792.4	155.5	19.6
4. Cuprija	21°22'	43°56'	123	660.1	125.6	19.0
5. Dimitrovgrad	22°45'	43°01'	450	641.0	123.6	19.3
6. Kikinda	20°28'	45°51'	81	553.0	123.7	22.4
7. Kopaonik	20°48'	43°17'	1711	767.7	247.2	32.2
8. Kragujevac	20°56'	44°02'	185	638.2	117.0	18.3
9. Kraljevo	20°42'	43°43'	215	755.6	137.5	18.2
10. Krusevac	21°21'	43°34'	166	652.0	139.7	21.4
11. Kursumlija	21°16'	43°08'	383	646.3	135.1	20.9
12. Leskovac	21°57'	42°59'	230	625.0	114.0	18.2

13. Loznica	19°14'	44°33'	121	829.2	143.8	17.3
14. Negotin	22°33'	44°14'	42	648.7	146.1	22.5
15. Nis	21°54'	43°20'	204	587.0	116.2	19.8
16. Novi Sad	19°51'	45°20'	86	621.7	151.0	24.3
17. Palic	19°46'	46°06'	102	556.4	118.0	21.2
18. Pozega	20°02'	43°50'	310	753.8	141.6	18.8
19. Sjenica	20°01'	43°16'	1038	731.8	138.8	19.0
20. Smederevska Palanka	20°57'	44°22'	121	646.1	124.4	19.2
21. Sombor	19°05'	45°47'	87	597.2	128.1	21.4
22. Sremska Mitrovica	19°38'	44°58'	82	619.8	119.3	19.3
23. Valjevo	19°55'	44°17'	176	783.9	145.6	18.6
24. Veliko Gradiste	21°31'	44°45'	80	670.2	142.5	21.3
25. Vranje	21°55'	42°33'	432	608.9	117.7	19.3
26. Zajecar	22°17'	43°53'	144	610.3	125.1	20.5
27. Zlatibor	19°43'	43°44'	1028	965.6	167.4	17.3
28. Zrenjanin	20°21'	45°24'	80	579.2	122.6	21.2

Precipitation data in Serbia

Annual precipitation amounts increase on average with altitude. In the lower regions of Serbia, the annual precipitation ranges from 540 to 820 mm. In areas with an altitude of over 1000 m, the stations have an average of 700 to 1000 mm of precipitation, and in some mountain peaks in the southwestern parts of Serbia, precipitation goes up to 1200 mm (Figure 2). In most parts of Serbia, the continental precipitation regime prevails, with a larger amount in the warmer part of the year, and in the southwestern parts, most precipitation is measured in autumn (Gocic and Trajkovic, 2013, 2014). The rainiest month is June, with an average of 12 to 13% of the total annual precipitation.

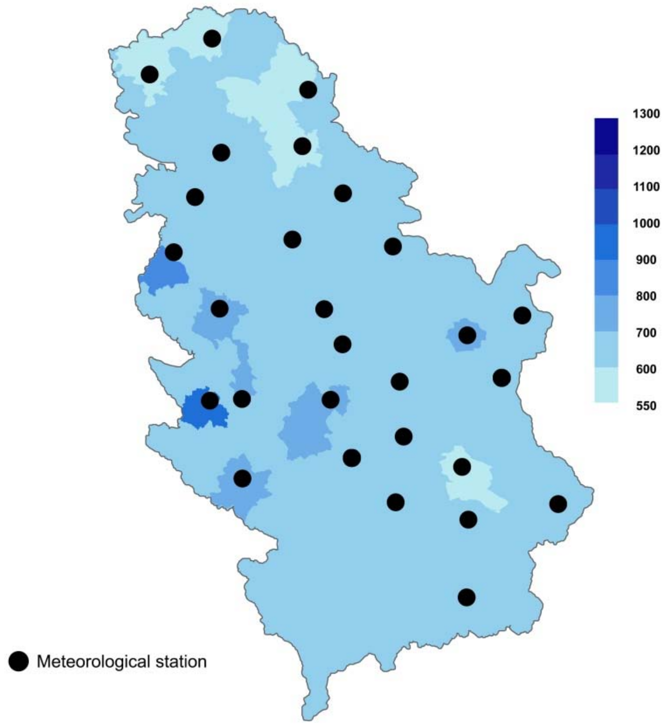


Figure 2. Spatial distribution of mean annual precipitation in Serbia for the period 1946-2019

R programming language and used packages

R programming language as an open-source programming language and software environment is used for statistical computing and creating graphics. Input data for the calculation of annual precipitation, standard deviation and other statistical indicators are given from more Excel documents to R programming language. In order for the data to be used for further analysis, it was necessary to transfer them from Excel to a file that uses the programming language R.

Using R language packages such as shiny, RSQLite, and sqldf data can be loaded and visualize (Figure 3). Information related to a specific location such as average annual precipitation can be read for the selected station.

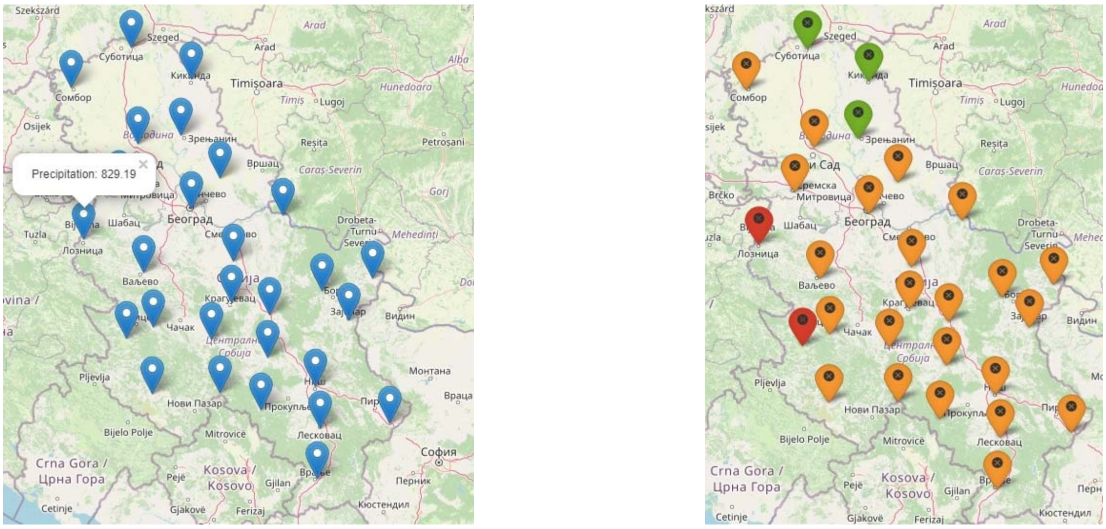
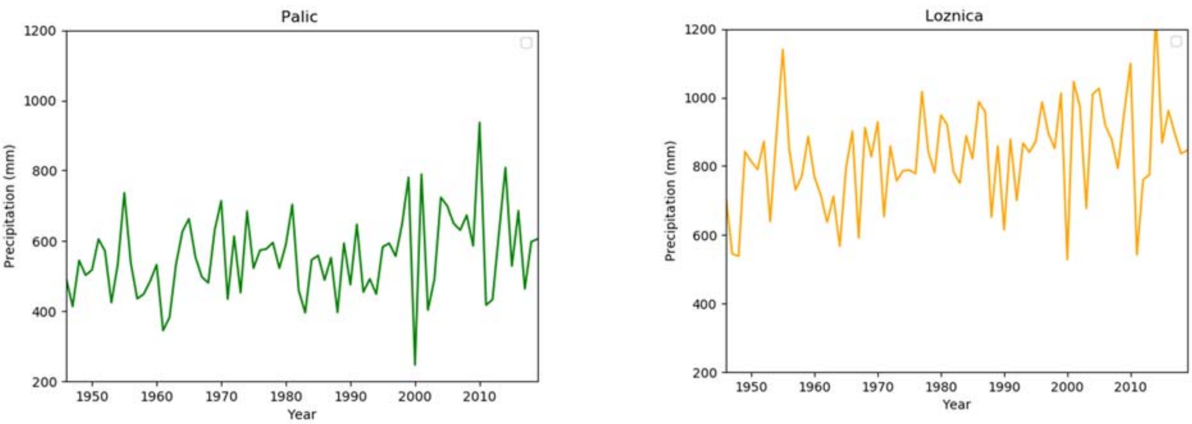


Figure 3. GIS application in the programming language R for displaying the average amount of annual precipitation from meteorological stations in Serbia

VISUALIZATION OF AVERAGE ANNUAL PRECIPITATION

The time series of annual precipitation of the selected five meteorological stations in Serbia (Palic, Loznica, Cuprija, Nis, Vranje) are presented in Figure 4. In order to analyse the collected data, the last graph contains the data from all five stations. The average annual precipitation of selected stations varied between 553 mm (Kikinda) to 965.6 mm (Zlatibor) for the period 1946-2019.



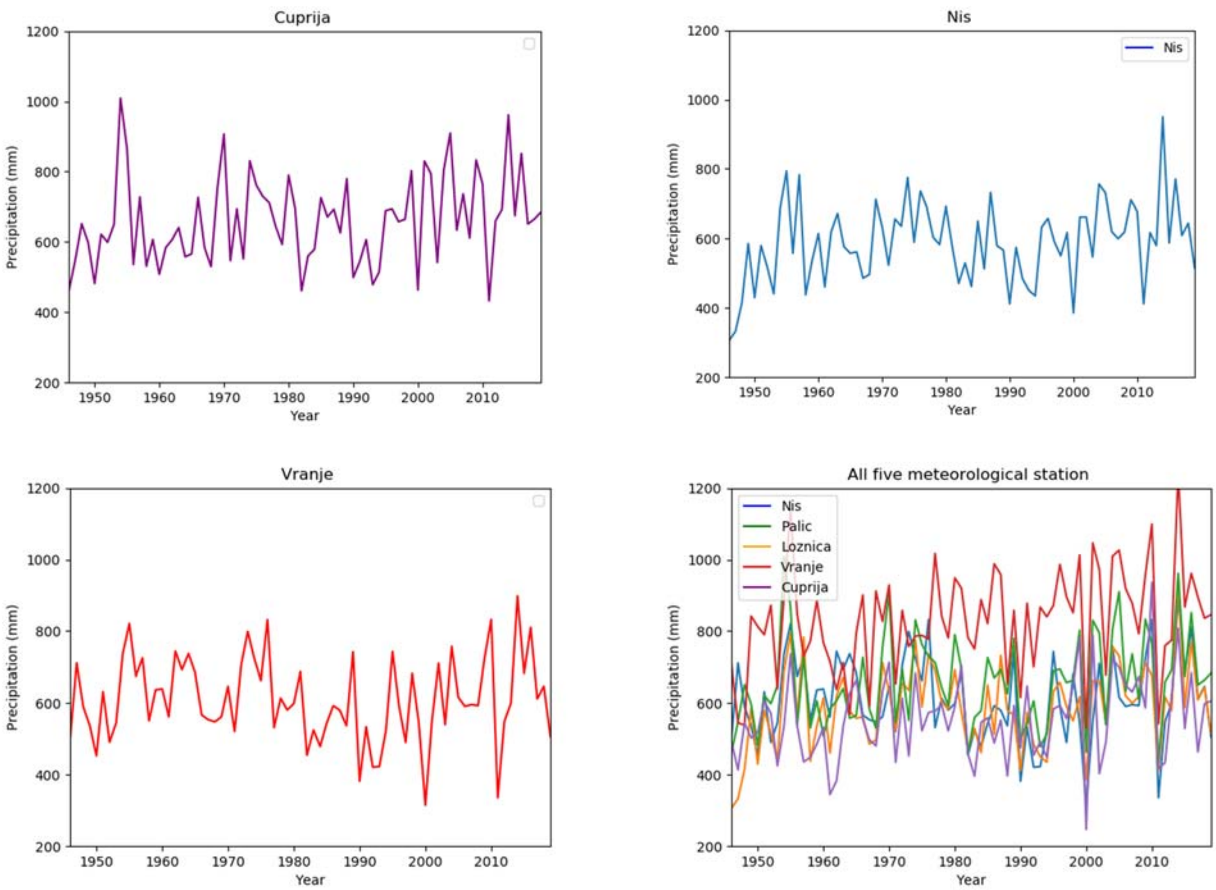
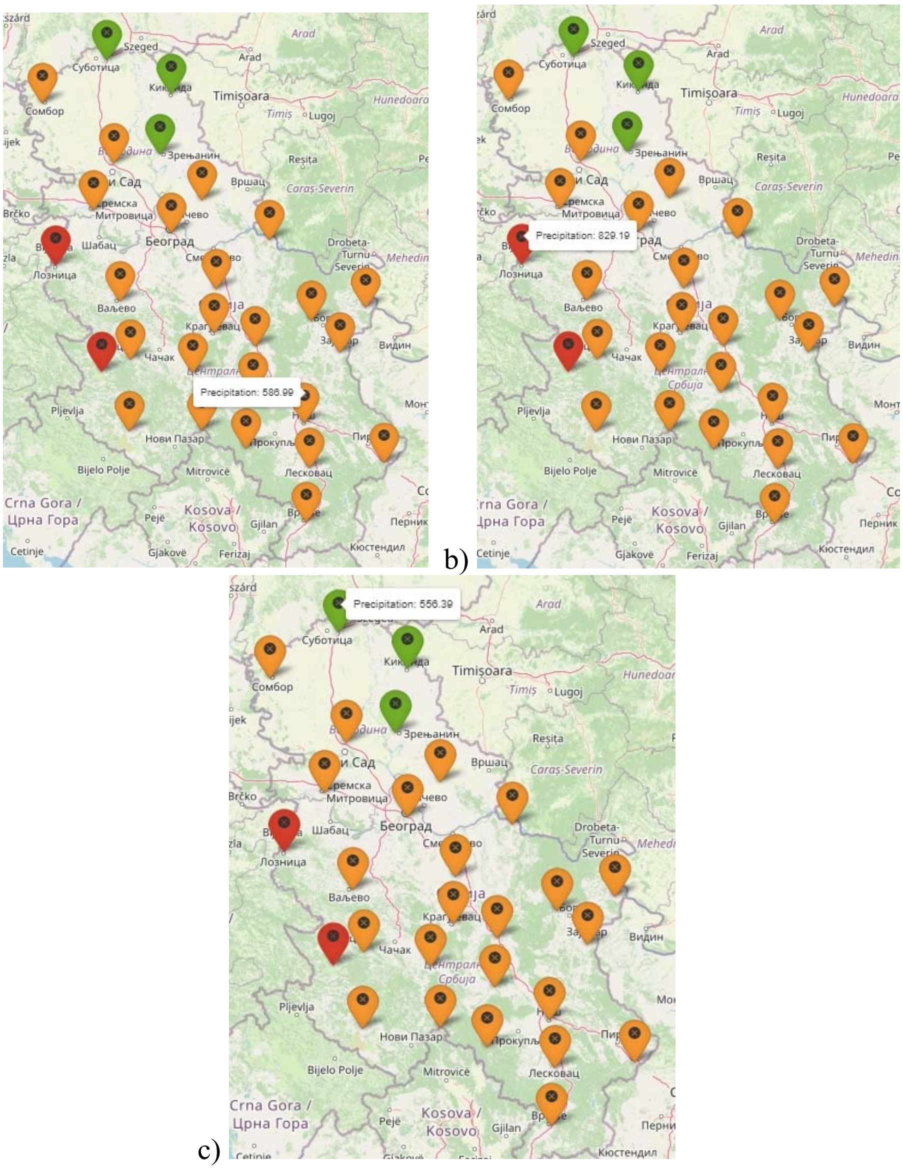


Figure 4. Annual precipitation time series at five selected meteorological stations

The annual amount of precipitation is shown on the map of Serbia in different colors i.e. for precipitation below 580 mm the representation of the meteorological station is green, for precipitation between 580 and 800 mm the meteorological stations are presented in orange, and for precipitation over 800 mm the stations are presented in red.

Figure 5 shows the average annual precipitation for the following stations: a) Nis presented in orange, b) Loznica presented in red and c) Palic presented in green measuring station of the city of Cuprija represented in orange.

a) b)



c)

Figure 5. Average annual precipitation for the following stations: a) Nis presented in orange, b) Loznica presented in red and c) Palic presented in green

CONCLUSIONS

In this study, the approach for visualizing average annual precipitation data for 28 meteorological stations in Serbia for the period 1946-2019 is presented. The spatial distribution of precipitation data can help us to better plan water resources. The obtained results can be useful for the planning and management of water resources and agricultural production. The presented application can be a part of the hydro-information system for drought analysing.

Further research should be oriented towards monitoring natural hazards depending on precipitation data such as drought and flood and how to find mathematical and soft-computing methodologies to predict them.

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SUITABILITY ASSESSMENT OF PHOTOCATALYTIC TREATMENT FOR PHARMACEUTICAL REMOVAL - STRENGTH, WEAKNESS, OPPORTUNITIES AND THREATS (SWOT) ANALYSIS

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Abstract: The overuse of pharmaceutical compounds causes their continuous introduction into the aquatic environment, causing occurrence of the phenomenon of pseudo-persistence which indicates that the rate of introduction of emerging contaminants into the aquatic media is significantly higher than their half-lives. Pharmaceutical components can cause potential long-term toxicity on aquatic and terrestrial organisms having in mind that they are designed to be biologically active even in low concentrations and can bioaccumulate in biota. Conventional treatments are not capable to remove pharmaceutical contaminants to a satisfactory level. Favorable and excellent photocatalytic performance of newly nanostructured photocatalysts (ZnO/SnO_2, ZnO/TiO_2 and ZnO/In_2O_3) in the decomposition of pharmaceuticals has been proven. Further, a detailed SWOT analysis of photocatalytic technology was presented in order to provide assessment of potential strengths that can lead to numerous opportunities to transfer technology on large-scale regardless to its weakness and threats. Many suggested strengths of the photocatalytic process indicate a high potential for its implementation in real systems for wastewater treatment.

Keywords: suitability, nanopowder mixtures, photocatalysis, pharmaceutical residues, SWOT analysis, wastewater

INTRODUCTION

The main sources of pharmaceuticals in aquatic media are inadequate wastewater treatment plants, wastewater discharges from industries and hospitals, agriculture, animal husbandry and soil leaching. The configuration of the original municipal wastewater treatment plants contributes to the emission of pharmaceutical pollutants into the recipient, having in mind the inefficiency of the primary and secondary treatment for their removal.

The most dominant route of administration involves the use of drugs for human purposes, where pharmaceuticals in their original or metabolic form are introduced into sewage systems, then discharged directly into the recipient through effluents. Due to the inconsistency in the physicochemical characteristics of the pharmaceutical compounds, the efficiency of pharmaceutical removal may differ (Al-Baldawi et al. 2021).

Allowed limits for discharging pharmaceutical residues into aquatic environments are not yet legally regulated. Although pharmaceuticals are released into the environment in high level, there is a significant shortcoming in the legislation (Luo et al. 2014; Oller et al. 2011; Santos et al. 2010). Currently, the simultaneous effect of several pharmaceutical compounds on aquatic organisms has not yet been fully investigated. Evaluation of the effect of individual pharmaceutical components is very complex in the presence of other pharmaceutical compounds. Many ecotoxicological tests have shown that diclofenac has a negative effect on various animal species (Lonappan et al. 2016; Naidoo et al. 2010). Organic microcontaminants are always present in the mixture in aquatic recipients. The complex nature and dynamic behavior of pharmaceuticals poses a danger to aquatic organisms. There are no established regulations that define the maximum allowable concentrations for the release of pharmaceuticals into aquatic matrices.

Non-steroidal anti-inflammatory drugs (NSAIDs) are defined as emerging micropollutants and represent the group of pharmaceutical compounds that are most frequently detected in aquatic ecosystems. Advances in the development of analytical methods for the detection of organic compounds at low concentration levels have contributed to the detection of NSAIDs in drinking water as well. The presence of this group of pharmaceutical components in drinking water is caused by soil leaching and through treated effluents from wastewater treatment plants (Kaur et al. 2016).

Primary and secondary wastewater treatments are not designed for a satisfactory removal percentage of pharmaceutical contaminants (Fallas et al. 2012). Activated sludge processes are the most used biological methods for the degradation of pharmaceuticals in wastewater. The low removal percentage of pharmaceutical components by applying conventional treatments requires the application of more efficient and modern technologies, such as advanced oxidation techniques (Kaur et al. 2016). Advanced oxidation techniques are based on the application of highly active oxidation species such as hydroxyl radicals, superoxide ions and hyper peroxyl radicals. The high oxidative and non-selective power of radicals enables the decomposition of a wide range of organic pollutants. The goal of advanced oxidation techniques is the conversion into smaller molecules such as carbon dioxide and water thus achieving complete mineralization of the pollutant. Advanced oxidation processes (AOPs) are specifically explored and applied to eliminate pollutants that are highly chemically stable or resistant to complete mineralization in conventional treatments (Villarin Jimenez, 2017).

Previous study has proven that newly developed photocatalysts composed of binary metal oxides systems (ZnO/SnO_2, ZnO/TiO_2 and ZnO/In_2O_3) had great potential to minimize concentration levels of NSAIDs and decompose them at maximum levels (Novakovic et al. 2019). The purpose of SWOT analysis is to identify strengths and weaknesses, as well as external opportunities and threats of selected wastewater treatment (Al-Baldawi et al. 2021). With the SWOT technique, the strength of any treatment or project can be improved, as well as weaknesses can be minimized (Bidhendi et al. 2020). The aim of this study was to determine the advantages and disadvantages of photocatalytic treatment of non-steroidal anti-inflammatory pollutants using a new nanostructured material in real systems.

MATERIALS AND METHODS

As an example, it will be present the photocatalytic degradation of pharmaceutical mixture with newly synthesized nanomaterial ZnO/SnO_2. Photocatalytic treatment of pharmaceutical mixture (ketoprofen, naproxen, diclofenac and ibuprofen) was performed with nanostructured photocatalyst ZnO/SnO_2 on laboratory scale. The analyzed nanompowder mixture was synthesized by mechanochemical solid-state method in molar ratio 2:1 (Ivetić et al. 2016). Photocatalytic decomposition of pharmaceutical mixture was conducted over a one-hour period exposed to UV irradiation. All used chemicals were analytical grade. At different time periods, aliquots of 1 mL pharmaceutical solutions were taken and filtered through 0.45 membrane filters to remove the rest of nanomaterials. Aliquots were transferred into 1 mL HPLC vials and analyzed on HPLC DAD system (Agilent 1260, USA). The selected concentration of NSAIDs was 5 mg L^{-1}, while concentration of nanomaterial was 0,40 mg mL^{-1}.

The SWOT analysis is conducted with the aim of determining the significant factors that need to be considered when planning the application of the proposed wastewater treatment burdened with pharmaceutical residues. The internal and positive factors represent strengths which describe advantages, while internal and negative factors present shortcomings of analyzed photocatalytic treatment. The external factors include opportunities (positive) and threats (negative) for future large-scale transfer of analyzed advanced oxidation process to wastewater treatment facility.

RESULTS AND DISCUSSION

The results of photocatalytic decomposition of the pharmaceutical mixture are shown in the Figure 1. The results indicated the good correlation with the pseudo first-order according to Langmuir—Hinshelwood model.

In competitive pharmaceutical system, the fastest degradation rate was recorded for ketoprofen. The total degradation of ketoprofen was achieved in short irradiation time (20 minutes). Diclofenac was completely removed in 40 minutes.

The most recalcitrant NSAID was ibuprofen whose satisfactory percentage of transformation was not achieved throughout the one-hour treatment. This fact indicate that formation of photocatalytic by-products is slow hence the percentage of degradation is lower. The presence of other pharmaceuticals had negative effect on reduction of naproxen whose decomposition was not achieved within 60 minutes. The most intensive decomposition of pharmaceutical mixture was followed in order ketoprofen > diclofenac > naproxen > ibuprofen.

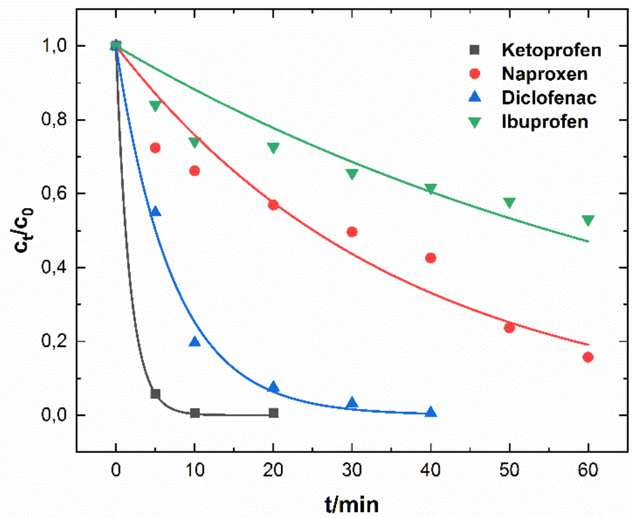

Figure 1. Photocatalytic decomposition of pharmaceutical mixture by ZnO/SnO_2 (c_0- initial concentration of pharmaceuticals (mg L^{-1}), c_t – concentration of pharmaceuticals at analyzed time intervals (mg L^{-1}), t – irradiation time (min))

The comprehensive analysis of strengths, weakness, opportunities and threats of applied photocatalytic treatment were presented in Figure 2. The overriding strength of examined AOPs is simple and short time of synthesis of nanostructured materials. The preparation of nanostructured mixtures has been implemented for two hours without addition of chemicals which can be strong advantage in economic terms. The mechanochemical method is not often used for the preparation of photocatalysts, although it is a simple, sustainable and eco-friendly method as it is not based on the application of toxic organic solvents (Ivetić et al. 2015; Ralphs et al. 2013).

The strong point of studied photocatalytic treatment is non-use of chemicals compared to some types of advanced oxidation treatments where hydrogen peroxide (H_2O_2) is used which requires additional costs. Unlike treatment such as adsorption, which is based on the transfer of pollutants from one phase to another (from liquid to solid phase), large amounts of toxic solid waste are not generated when photocatalysis is applied (Djellabi et al. 2021). After conducting detailed experimental research in field of photocatalytic decomposition of pharmaceuticals, a very low concentration of nanomaterials is enough for efficient decomposition.

When evaluating the overall efficiency of photocatalytic decomposition of organic micropollutants via nanoparticles, it is necessary to consider the influence of inorganic constituents such as anions present in real wastewater samples. The examined nanomaterials showed good performance and stability in presence of dominant inorganic ions such as nitrate, phosphate, chlorine and sulphate. The one of the important benefits of nanostructured mixtures is the possibility of a simple regeneration process and their re-use in multiple photocatalytic cycle.

One of the significant concerns related to photocatalytic treatment is the generation of toxic intermediates and the toxicity of the nanomaterials themselves. However, by experimental toxicity procedures, it was proved that the formed intermediates did not demonstrate a cytotoxic effect on the tested medium, which indicates the biocompatibility of the analyzed advanced oxidation method. The new nanostructured mixtures demonstrated excellent performance features such as reduction of recombination process unlike individual metal oxides. The main highlight of process is possibility of application of natural solar light (as renewable and sustainable energy source) which is essential for initiation of photocatalysis.

In addition to the numerous strengths of the tested wastewater treatment process, there are several shortcomings. The main weakness of the application of new nanomaterials is the incomplete mineralization of the analyzed nonsteroidal anti-inflammatory pharmaceuticals to carbon dioxide and water after one hour of treatment, although a complete decomposition of diclofenac and ketoprofen was achieved. The separation of used nanostructured materials after elimination of micropollutants from wastewater is a practical problem. It is necessary to implement technical solutions for the separation of used nanomaterials. Suspended photocatalytic systems excels high mass-transfer and efficiency, but it hard to separate nanoparticles. The supported photocatalysts have advantage in sense of nanoparticles recovery, but they have lower efficiency level. Ibuprofen was defined as resilient pharmaceutical pollutant whose decomposition was not achieved in 60 minutes exposure to UV radiation.

The major opportunity of photocatalytic treatment is minimization of discharge of pharmaceutical residues into aquatic environment which contributes to better quality status of recipient. Since pharmaceuticals are defined as resistant microcontaminants to primary and secondary wastewater treatment due to complex nature, photocatalysis could be a good choice to improve the existing performance of wastewater facilities. As the tested nanostructured mixtures have proven to be effective in the degradation of pharmaceutical components at high concentration levels, the treatment can be used in pharmaceutical industry. In addition, it can be used for treatment of hospital wastewater which encompasses pharmaceutical components in high concentration level compared to another wastewater types. Another advantage that can be highlighted is the reduction of the percentage of migration of pharmaceutical residues into municipal wastewater treatment plants thereby minimize the risk of reducing removal efficiency.

The greatest threat of advanced treatment such as photocatalysis is generation of hazardous waste after utilization and deactivation of photocatalysts. Once planning the application of photocatalytic treatment in real conditions, it is necessary to consider how to proper handle with the used photocatalyst at the end of the life cycle. As well, it is important to conduct a detailed cost benefit analysis which will include costs of installation and number of UV lamps having in mind the capacity of the wastewater treatment plants. It is also necessary to provide detailed training of employees to work on photoreactors, as well as for safe work on them. The possible drawback can correspond to presence of other stable and resistant organic pollutant causing the reduction the total removal percentage of pharmaceutical residues.

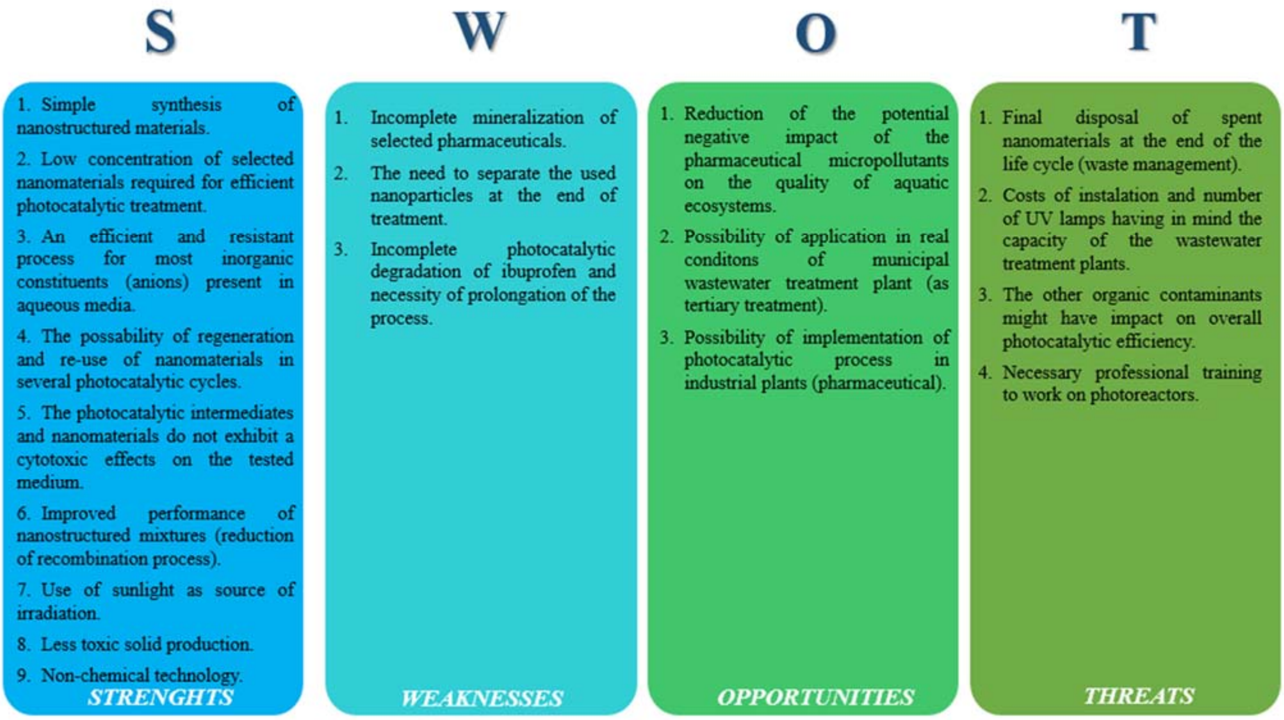

Figure 2. SWOT analysis of photocatalytic treatment

CONCLUSION

Pharmaceutical active compounds represent a wide range of emerging micropollutants which are continuous introduced in water compartments. Pharmaceutical residues at low concentration levels have long-term toxicity effect on aquatic organisms including carcinogenic or teratogenic and endocrine disrupting effects. The diverse and complex nature of pharmaceutical pollutants has a significant impact on their removal efficiency in wastewater treatment plants. Photocatalytic technology with analyzed nanostructured mixtures has been proven to be an effective technology for decomposition of non-steroidal anti-inflammatory pharmaceuticals.

With performed SWOT analysis for selected advanced oxidation method, a large number of strengths was determined which can be mirrored through simplicity of nanomaterial preparation not demanding high energy consumption, stability of nanomaterials under simulated condition which include presence of inorganic constituents such as anions present in real wastewater and non-chemical usage. Besides numerous strengths, photocatalytic technology has a few drawbacks. One of major threats is final disposal of used nanomaterials after end of life cycle. The proper waste management of deactivated photocatalyst must be provided and some possible practical solution for use of waste nanomaterials in other propose.

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POSSIBILITIES OF APPLICATION OF HEC RAS TWO-DIMENSIONAL MODELS FOR PREDICTION OF BRIDGE PIER SCOUR

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Abstract: As a result of current intensive infrastructural development and construction in Montenegro, more roadways are being built over rivers. Numerous recent examples of bridge pier failures have brought the topic of proper defense against possible negative effects of destructive nature of water into focus again. Determining the possibilities of applying HEC RAS two-dimensional hydraulic models for predicting bridge pier scour, represents the main research subject of this paper. The most significant results of hydraulic computation to be used for further consideration include water velocities at the vicinity of bridge piers founded in the river bed, as well as flow depths. Aforementioned data acquired from the model can be succeeded by a comprehensive study of predicted pier scour depths (based on available sets of empirical formulae) and drag force distribution. Research results are suitable for defining effective measures to mitigate potential harmful impact of water on bridge piers founded in the river bed. Research results and proposed ways of their implementation may simplify the proper choice of the bridge profile and contribute to determination of directives regarding the design of bridge piers, which need to be analysed in the context of hydrodynamic forces posed by water action. In addition to this, obtained data and conclusions could be efficiently and effortlessly implemented into everyday engineering practices to secure stability, safety and durability of bridge structures.

Keywords: bridge pier stability, erosion countermeasures, HEC RAS, local scour, riverine systems, two-dimensional numerical models.

INTRODUCTION

Stability issues of structures that are built in the open channels of river flows are mainly caused by the action of watercourses. This impact can be direct, as hydrodynamic forces caused by water flowing around the parts of the structure, or indirect, as the water can significantly change the morphology of the river bed and reshape cross-sections in the area of structure foundation. Both of these effects can be very harmful because they alter the design conditions according to which the structure was designed and built.
These effects can be taken into account and computed through the use of two-dimensional numerical flow models, and thus obtain useful results that would be applicable for further analysis of erosion effects. The local scour of bridge pier foundation is an issue that requires special consideration when analyzing the general stability of the bridge. The paper presents a methodology for the calculation of scour, based on the results obtained from the HEC RAS model. When the values of the basic hydraulic parameters are known, it is possible to estimate the stability of the bridge piers positioned in the stream bed.

THEORETICAL BACKGROUND

Local erosion involves removal and transportation of sediment in the vicinity of bridge piers, abutments and embankments. It is caused by the local acceleration of water flow when it encounters an obstacle in the stream that generates turbulence and vortices. The mechanism of local erosion of piers and abutments is reflected through the creation of vortices at their base. (Cantero-Chinchilla et al., 2018) Figure 1 shows a schematic representation of the flow field around a narrow cylindrical pier. The horseshoe vortex at the bridge pier base is the result of the current impact on the upstream pier surface (which represents an obstacle) and then the acceleration of the flow in front of the pier nose. The vortex moves the sediment from the foundation zone of the pier, and thus an erosion hole is formed. As the scour depth increases, the vortex intensity decreases, and thus the sediment erosion of the foundation zone fluctuates. Finally, a balance is established between the deposition of sediment that the flow carries along and the sediment erosion from the erosion hole. For clear water erosion (without sediment transport), the excavation of material at the pier bottom stops when the shear stresses caused by the vortex drops below the critical values of the shear forces, at which sediment particles are transported from the foundation zone.

Factors influencing the intensity of local erosion processes in the vicinity of bridge piers and abutments are: flow velocity, flow depth, pier width, pier length, riverbed soil configuration, pier nose shape, presence of floating debris and suspended sediment, etc.

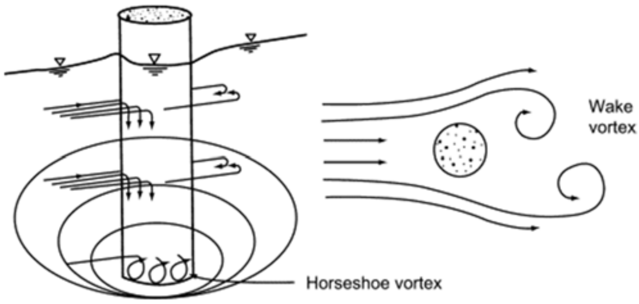


Figure 1. Horseshoe and wake vortex around cylindrical bridge pier
(https://pt.slideshare.net/AymanMansour1/scour-around-bridge-piers)

HEC-18 methodology for scour prediction

One of the most commonly used methodologies for local scour evaluation is the HEC-18 equation (Arneson et al., 2012). By comparing the results of this equation with the collected field data, it was concluded that this equation in a very small number of cases underestimated the actual scour depth. However, in a certain number of cases, the values calculated by this equation proved to be greater than the actual depths measured in the field. The mentioned equation, which can be used both for clear water erosion, as well as erosion of the stream that carries a significant amount of sediment, calculates the maximum scour depth - denoted by ys.

The HEC-18 equation is (1) (Arneson et al, 2012):

$$\frac{y_s}{y_1} = 2.0 K_1 K_2 K_3 \left(\frac{a}{y_1}\right)^{0.65} Fr_1^{\,0.43} \qquad (1)$$

Where:
y_s – scour depth (m),
y_1 – flow depth directly upstream of the pier (m),
K_1 – correction factor for pier nose shape,
K_2 – correction factor for angle of attack of flow,
K_3 – correction factor for bed condition,
a – pier width (m),
L – length of pier (m),
Fr_1 – Froude Number directly upstream of the pier : $Fr_1 = V_1/(gy_1)^{1/2}$,
V_1 – mean velocity of flow directly upstream of the pier (m/s)
g – acceleration of gravity ($9.81 m/s^2$)

Effects of floating debris on erosion processes

Large floating debris that accumulates on bridge piers (Figure 2) creates an additional barrier to flow, and changes the geometry of the pier, significantly increasing its effective width compared to the case when piled up and stuck debris would not be present.
Some previous studies indicate that the formation of debris and sediment deposits on bridge piers is one of the main causes of bridge structure failure. In one third of the total number of analyzed cases of bridge structure collapse across the UK, Ireland and the USA, this effect was of the greatest importance (Diehl, 1997).

Figure 2. Accumulation of substantial amount of debris (trees, branches, leaves, sediment) on the upstream face of the pier. The debris piles up along the pier, reducing the flow profile.
(https://bridgemastersinc.com/protecting-bridges-flood-damage/)

Scope of application of 2D models and their distinctive features in relation to 1D models

The concept of 2D modeling has been present for several decades, but its use was limited, as this kind of computation was too arduous for computer configurations available at the time. Due to the advancement of information technology, this is no longer the case, although even today it takes a bit more time to form a 2D model compared to the 1D model.

The 2D hydraulic calculation, thanks to suitable terrain data, provides the possibility to determine the direction of water flow when it is not possible to determine it in advance unambiguously. Figure 3 shows the basic difference between 1D and 2D modeling. In both cases, the hydraulic parameters are averaged along the depth (in the vertical direction of the *z* axis). However, in the 1D model, the water surface elevations and flow velocities are constant (averaged) over the flow width, while in the 2D model a distribution of velocities and depths along the cross-section can be obtained.

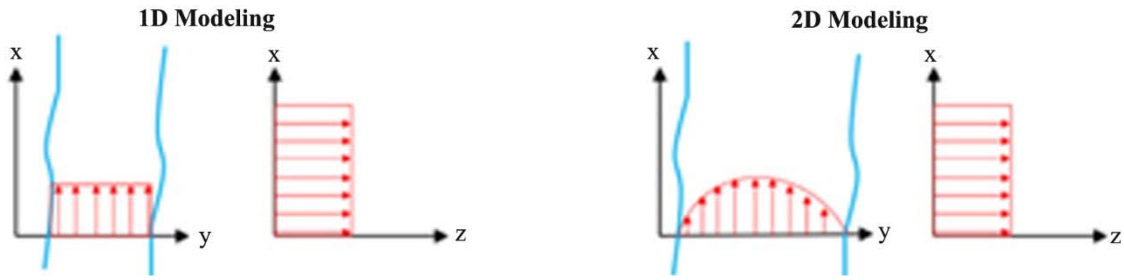


Figure 3. The main difference between 1D and 2D models
(https://engineerpaige.com/2d-modeling-in-hec-ras-a-quick-start-guide/)

In certain situations, building a 2D model can be highly beneficial. Some of these cases include :

- Situations where the boundary between the main channel and the overbank is not clearly defined
- When the flow direction is not obvious or predictable (analysis of wide floodplains for high discharge rates)
- In urban areas
- For dam failure analysis
- Areas around bridge openings, which are characterized by significant contraction/expansion of the flow, can be more realistically represented using 2D models.

HEC RAS (Hydrological Engineering Center's River Analysis System), developed by the American agency USACE (U. S. Army Corps of Engineers) is a software specially developed for modeling flow in open channels and riverine systems, which offers the possibility of building two-dimensional hydraulic models.

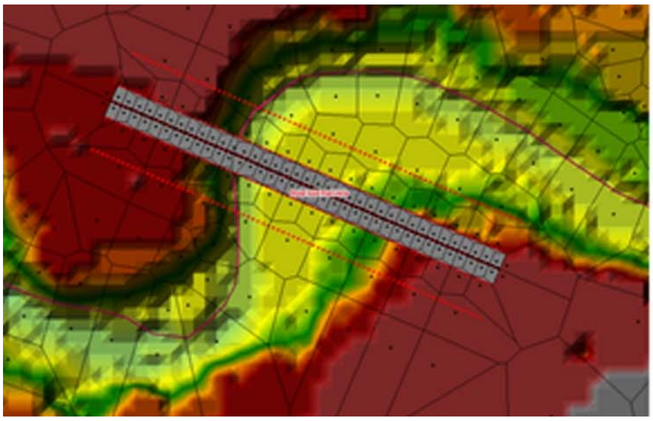
The basic equations that describe the fluid motion and on which the software computation is based, are: the continuity equation, the Navier-Stokes equation, and the energy equation. The two-dimensional calculation in HEC-RAS is based on the principle of dividing the modeled area (calculation domain) into finite volume elements (cells) (Brunner, 2021). By iteratively solving the system of previously mentioned equations, the numerical value of the water surface elevation (and other relevant hydraulic parameters) is determined for each cell of the domain individually.

DESCRIPTION OF THE HYDRAULIC MODEL AND REVIEW OF THE COMPUTED RESULTS

In order to present the possibility of using the results from HEC-RAS to assess the stability of bridge piers, a two-dimensional model of part of the river Ribnica (right tributary of the river Morača in the urban zone of Podgorica) was built.
Hydraulic analysis was performed - flow calculation in modeled sections for the relevant design flow (return period T = 100 years). Assigned boundary conditions include the available runoff hydrographs in the measured cross sections for the rivers Ribnica and Morača (Institute of Civil Engineering, 2006).

Bridge modeling in the HEC RAS two-dimensional model

For the purposes of analysing the flow field around bridge piers, a bridge with one pier (located in the main channel) was modeled. Figure 4 shows the input data regarding the geometry.



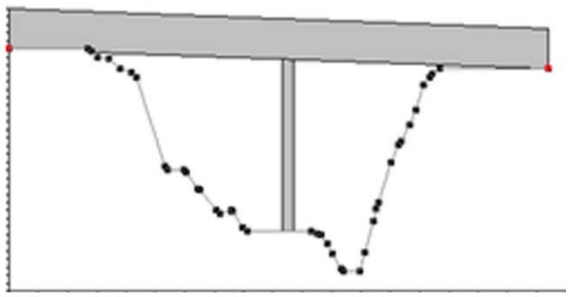


Figure 4. Modeled bridge profile within the 2D domain and geometry of bridge cross section

HEC RAS offers the possibility of modeling a rectangular debris formation accumulated on the upstream face of the bridge pier. The effects of debris and sediment buildup on the pier are modeled by specifying the width and height of the expected sediment formation (Figure 5). HEC RAS then adjusts the effective flow area of the cross section and the wetted perimeter in order to take into account the given parameters. The program alters the geometry of the pier, so that the occurrence of debris formation (as an additional barrier) is taken into account.

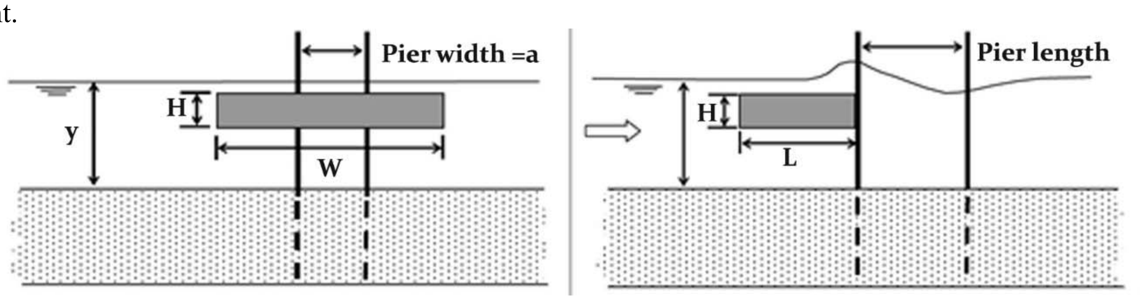


Figure 5. Schematic profile of a river in the vicinity of a bridge pier affected by debris accumulation
(Left) Looking downstream; (right) Longitudinal profile
(Lagasse et al, 2010.)

For the hydraulic computation in HEC RAS in the zone of bridge opening, the Yarnell equation was used - an empirical equation which calculates the change of water level from the cross section immediately upstream of the bridge structure, to the section immediately downstream of the bridge structure. The equation was developed based on over 2600 laboratory experiments in which the pier shape, width and length, the skew angle relative to the flow direction, the flow rate, etc. were varied (Yarnell, 1934).

Display of results

Most methods for calculating the local scour depth around bridge piers (including the HEC-18 methodology), as well as for determining the hydrodynamic forces on piers, use the basic hydraulic parameters as the input data, such as: the velocity and depth of flow, shear stress, Froude number, the afflux occurring at the bridge, etc. When the values of these parameters are known, it is possible (based on the previously given relations) to assess the stability of the pier positioned in the channel.
In order to obtain the mentioned parameters, a hydraulic analysis was performed for the unsteady flow regime, where the duration of the simulation corresponds to the time base of the hydrographs, which were assigned as boundary conditions (approx. T = 15 hours). The computational time step has variable duration and is dictated by the Courant condition, to ensure the stability of the calculation and the reliability of the results (Brunner, 2021).
The results given in Figure 6 and Figure 7 refer to the time of peak runoff because the relevant hydraulic parameters reach their maximum values at that time point.

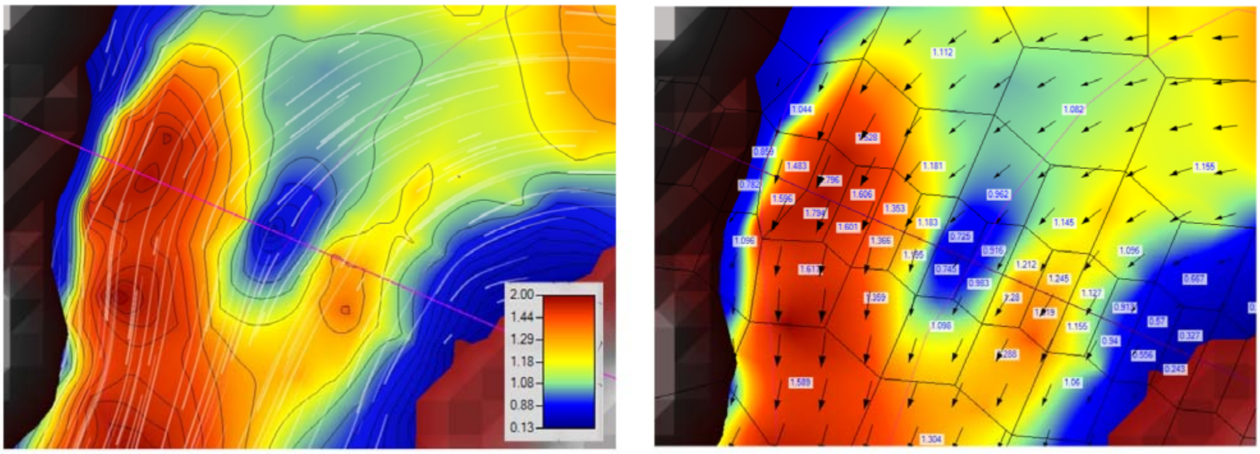


Figure 6. (left) Map of streamlines around the bridge pier along with lines of equal velocities (m/s); (right) Velocity vectors with velocity values (m/s)

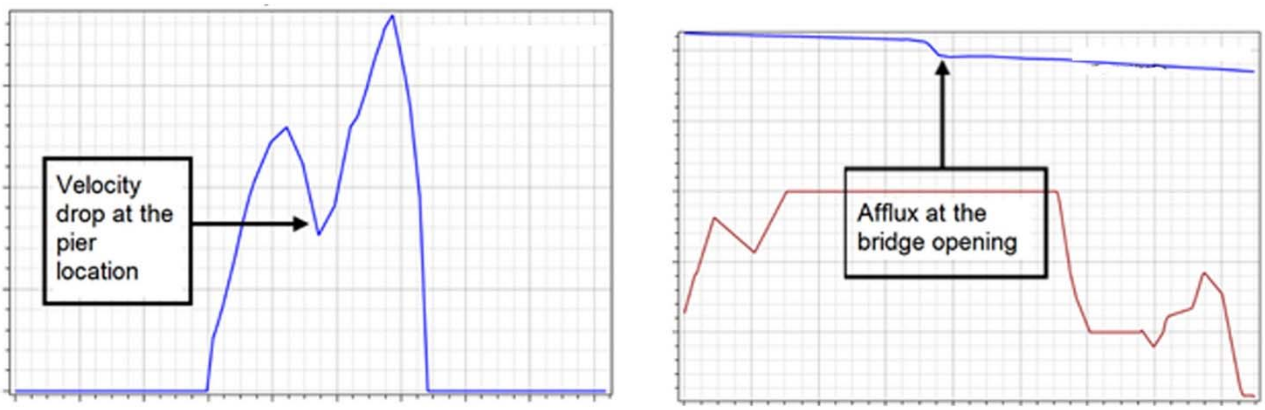


Figure 7. (left) Velocity distribution along the bridge cross section; (right) Longitudinal profile plot with water surface elevation

CONCLUSION

Since the complex mechanism of local erosion processes has not yet been fully explained and analytically presented, many scientists and experts have, during the past few decades, developed various empirical equations for evaluation of local scour around bridge piers, as this represents important input data to be considered in bridge pier foundation design. The HEC-18 equation is often used, since these relations have been calibrated through a series of collected field data and observations, and then verified on physical models in the laboratory. Regardless of the variety of variables included in these equations, as well as the complexity of their functional relations (mathematically speaking), in almost all proposed methodologies, the fundamental parameters included in the calculation are: flow depths (in the bridge profile), flow velocities, shear stress, Froude number and Reynolds number as an indicator of turbulence... These basic hydraulic flow parameters can be obtained by numerical modeling in HEC-RAS, specialized software for open flow analysis. Recently (with advances in computer technology), the advantages of two-dimensional modeling of watercourses have come to the fore, as these provide a more realistic distribution of velocities and other parameters across the river channel, and thus more accurately account for the actual field conditions. The advantages of building two-dimensional models are numerous, provided that the terrain data (used to delineate the research domain) of suitable resolution is available. However, it would be necessary to conduct model calibration using measured field data, so that a certain numerical model may be used for the prediction of floodplains and other hydraulic flow parameters (applicable for scour estimation), which may pose a problem for watersheds lacking field data.

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NATURE BASED STORMWATER MANAGEMENT SOLUTIONS FOR HOUSING AREA – CASE STUDY OF ROOF GARDEN IMPLEMENTATION

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Abstract: Roof gardens/green roofs are more and more present in built environment due to its diverse potential in mitigating negative environmental effects. Under the umbrella of the Nature Based Solutions, roof gardens are applied for precipitation detention in urban catchments. This research deals with housing area in the city of Niš, Serbia, where flat gravel roofs are converted to pitched ones. The assessment of water quantity retained in the roof, and released as runoff is conducted for the previous, present and potential rooftop condition i.e. roof garden. The specification from a manufacturer is used to simulate roof garden conditions. To assess the urban water cycle main components at the rooftop level, the daily water balance model is used for one year period. The simulation results for the pitched roof are assembled from the inclined roofs due to limitations of the applied simulation model. A set of roof efficiency indicators is introduced to quantify role of each rooftop cover to relieve the roof runoff load from the stormwater management system. According to three of four considered roof efficiency indicators, the roof gardens performed best in the studied area.

Keywords: Roof garden, green roof, nature based solutions, roof runoff indicators, pitched roof runoff.

INTRODUCTION

Increased attention to negative environmental effects in urban areas worldwide, has lead to the development of many planning, design, and maintenance strategies for their mitigation. Nature Based Solutions (NBS/NbS) represent a collective name for approaches designed by scientists and practitioners in many fields. For instance, the Integrated Stormwater Management (ISWM) in urban areas relies on the principle of atmospheric water safe detention in the urban catchment and gradual release into the recipient. Its relation with both natural and built environmental systems is more complex compared to conventional SWM systems, due to its measures and techniques that utilize terrain surface area for infiltration, retention and storage of stormwater. Consequently, ISWM greatly intertwines with landscaping architecture. Demiroz Kiray&Yildizci (2014) show a number of examples in this respect in their research results produced through the Sustainable Sites Initiative (SITES) Guidelines and Performance Benchmarks, including protection of water resources quantity, as one of the strategies to achieve sustainable outcomes in the landscape architecture. On the other hand, taking water quality as a design strategy, Aytac&Kusuluoglu (2014) conduct a parallel study of two highly populated urban areas in the U.S.A. and Turkey. Both studies generally overlap with the existing set of approaches emerging from ISWM with the aim to develop strategies and options for environmental protection, including Water Sensitive Urban Design (WSUD) and Sustainable Drainage Systems (SUDS). One of the most applied SUDS measures according to Gordon-Walker et al. (2007) is green roofs, besides the replacement of nonporous for porous pavement, the detachment of roof drainage from the conventional system, and replacement of conventional street and road gutters by swales. These measures refer to retrofitting of SUDS, the activity meaning replacement or/and extension of the existing SWM system.

Roof gardens (RG), also known as vegetative, and green roofs, are vegetative layers on the rooftops of two general types: intensive and extensive. The intensive RG are heavier, thicker, and walakble, compared to extensive RG that are thinner, thus lighter, and require minimum maintenance. The recognized benefits from RG are perceived as public, private and design-based benefits. Public benefits include improved air quality (Yang et al., 2008), moderation of heat urban island effects, and improved SWM potential (Stefanescu et al., 2013). Liu et al. (2015) show a simple linear reservoir conceptual model for simulating existing experimental extensive RG, enabling quantification of RG impacts on roof runoff volume and dynamics.

The research aim in this paper is to assess site-specific public benefits related to roof runoff for hypothetic RG implementation in the 'Krive livade' neighborhood in the city of Niš, Serbia.

MATERIAL AND METHODS

Study area

The selected neighborhood (Figure 1B) is a part of Blvd. Nemanjića housing area with a population of approximately 60,000. It was developed on the outskirts of the city in the 1970s as a typical socialist mono-functional housing area. The study area has a similar spatial-functional and urbo-morphological characteristics as the whole area, except that it appears in the form of semi-block while the rest of area is organized in the form of urban blocks. It is typical large housing estate, where urban pattern is based on repetition of group of buildings that have the same architectural and structural features, and generously dimensioned public open spaces (Figure 1C). The similarity of features and possibility to replicate the computational experiment for the whole area, are the main reason a compact group of buildings is chosen for the research (Figure 1C- dark grey feature).

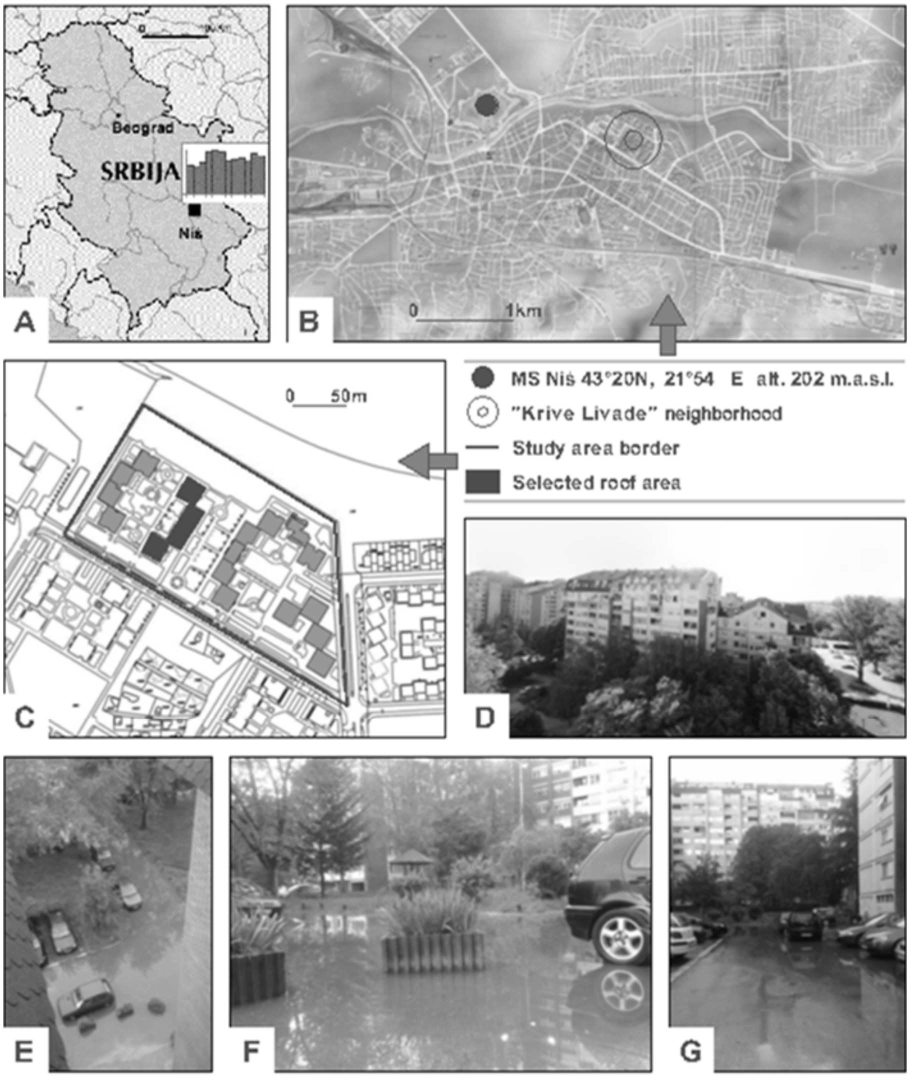

Figure 2. A- City of Niš in Serbia. B- City map. C- Study area plan. D- Typical pitched roof. E, F, G- Flooded carpark.

The neighborhood has undergone significant urban changes in the post-socialist period. From the mid-1990s there have been intensive changes in terms of transformation of the existing buildings through: 1) adaptation of the ground floor spaces into retail stores or other services; and 2) multi-story extensions on the top of the host buildings with flats exclusively intended for the market. The origin of the latter can be found in the initial urge for repairing flat roofs, the most critical issue of continuous decay and deterioration of ageing housing stock. However, due to the absence of urban renewal projects and unwillingness or economic inability of homeowners to invest in their maintenance, the existing buildings became a suitable “infrastructure” for market-driven housing activities, and an initial urge for reparation was soon turned into extensive construction of additional storeys with flats on the building tops (Vranić et al., 2015) with, as a rule, pitched roofs (PR) (Figure 1D). New (re)development increased population density which, in synergy with the absence of adequate parking solution, resulted in quantitative and qualitative decrease of public open spaces, including belonging vegetation (Vasilevska et al., 2014). Consequently, this situation imposed stress to the existing SWM system, exhibiting frequent pluvial flooding (Figure 1 E, F, G).

Methods

Three rooftop conditions are assessed concerning water quantity retained in the roof, and released as runoff: 1) flat roof (FR) - previous condition, 2) PR- present condition, and 3) RG. Assessment focus is a compact group of buildings in the study area (Fig. 1 C). To estimate the main urban water cycle components at the rooftop level a daily water balance model is used. Through the public domain software ‘The GreenRoof model’ (Raes et al., 2006) the simulation is run. There are three groups of input required for simulation: meteorological data, roof characteristics and program parameters.

Meteorological data

The model simulation period is one year. A ‘normal’ year 1997 is chosen - the annual precipitation total is 591.1 mm, while in the period 1981-2010 the average is 580.3 mm. This period is considered due to the reference evaporation (*ET0*) data availability for Meteorologic Station (MS) Niš (Fig. 1 B, the dot mark). Monthly *ET0* data are obtained by Penman-Monteith equation for the MS Niš (Gocić&Trajković, 2010, 2014). The model itself performs downscaling of monthly *ET0* to daily values by linear distribution. The daily precipitation data for rainfall input file are taken from the official data records (RHMSS, 2021).

Roof characteristics

The model compares water balance of two roofs at the time. Two sets of simulation are run using the FR as a reference: one to compare it to the RG, and the other to the PR. The FR is a fully exposed gravel roof. A fully covered extensive RG is used with 7 cm substrate layer depth according to the manufacturer’s specification (Optigruen, 2021). To adjust to local climate conditions, succulents and grasses are selected for vegetation cover, and according to the location surroundings, a fully exposed position. A standard roof area is the actual building top area of 1650 m^2. For the second set of simulations (the comparison of FR to PR), the model is run four times, once for each of the PR plains, modelled as a separate inclined roofs. The specifications for each run are: bitumen, 30° inclined roof, orientation, and area - East and West (600 m^2 each), North and South (each 225 m^2). For the final result, the total of results for substituting PR segments is considered.

Program parameters

The standard model values for evaporation and evapotranspiration (*Kc, p*) are accepted. In the ‘Green Roof’ tab, the substrate standard depth for flat RG is 7cm, while the standard parameters for water retention are changed both in substrate and drainage layer, from 2.5 to 3.0 $l/m^2/cm$ and from 2.0 to 9.0 l/m^2 respectively. The water storage layer is not included, to achieve water retention total (30 l/m^2) for 7cm substrate layer depth (Optigruen, 2021). In the ‘Rainfall on inclined roofs’ and ‘ET from inclined roofs’ standard correction is applied. Regarding *ET* for open/sheltered roofs, to adjust for local conditions, standard correction for fully exposed roofs is used.

Simulation

Specified simulation period is 01.01.-31.12. and initial water content on the roof is set to moderately wet conditions.

RESULTS AND DISCUSSION

The response from three studied rooftops regarding retention volume during the simulation period is shown in the Fig. 2 b. Expectedly, the PR holds the least water volume; it is followed by FR, because both are limited by specified water retention capacity. The RG water retention capacity is more sensitive to cumulative effect of consecutive daily rain depths, as in April 1997, than to individual heavy rain events, as in August (the annual daily maximum), or May (the second largest annual daily precipitation sum). This is also due to antecedent moisture condition in the substrate layer and *ET0*.

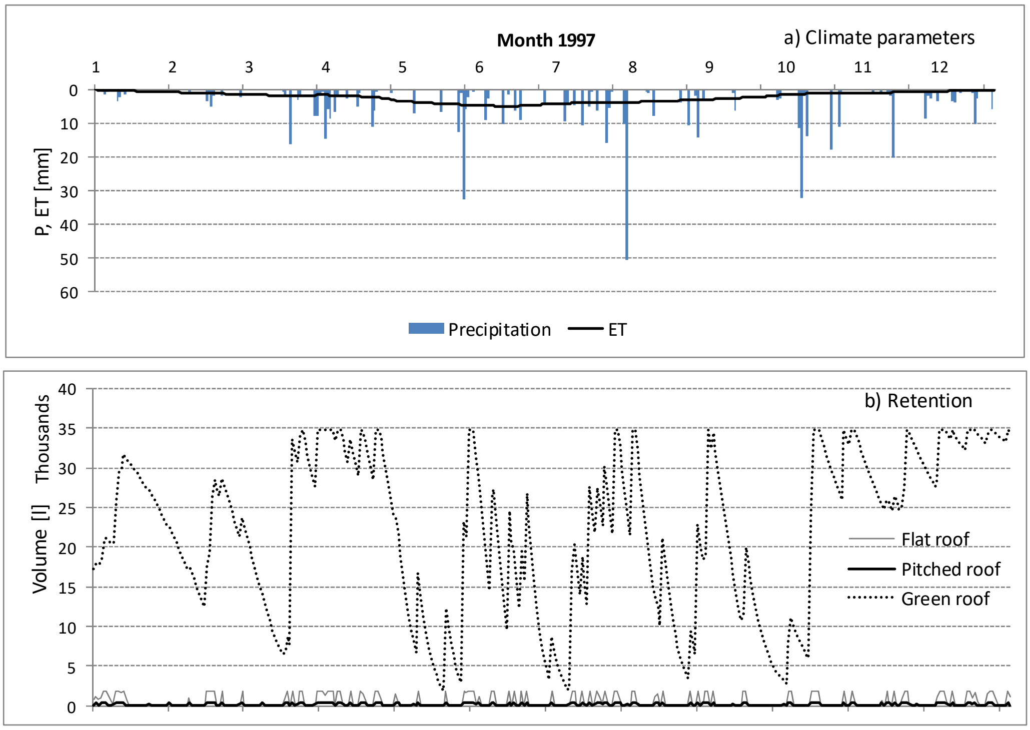

Figure 2. The model input meteorological data (a) and simulation results for the roof retention volume (b).

The individual runoff volumes from each rooftop are shown in the Figure 3 a, b and c for the study period. The runoff dynamics in the Fig. 3 shows both PR and FR are sensitive to the whole range of the observed precipitation depths (Fig. 2 a), the lowest daily precipitation sum to trigger runoff from PR is 0.3mm and 1.2mm for FR (Tab. 1). RG, as shown in the Figure 3 b, attenuates runoff most of the studied period, and exhibits the longest period without roof runoff (Tab.1). According to the runoff coefficient, RG acts as porous surface, while FR and particularly PR, as nonporous (Tab.1). FR shows the largest quantities of runoff from the daily precipitation (e.g. in May, August and October- Fig. 3c), followed by RG and PR (Tab.1).

Table 1. The roof efficiency indicators in the year 1997.

Roof efficiency indicator	PR	RG	FR
Min. precipitation triggering runoff [mm]	0.3	2.2	1.2
Max. number of days without runoff	17	83	32
Max daily runoff volume [l $\cdot 10^3$]	72.0	80.5	81.7
Runoff coefficient	0.95	0.43	0.82

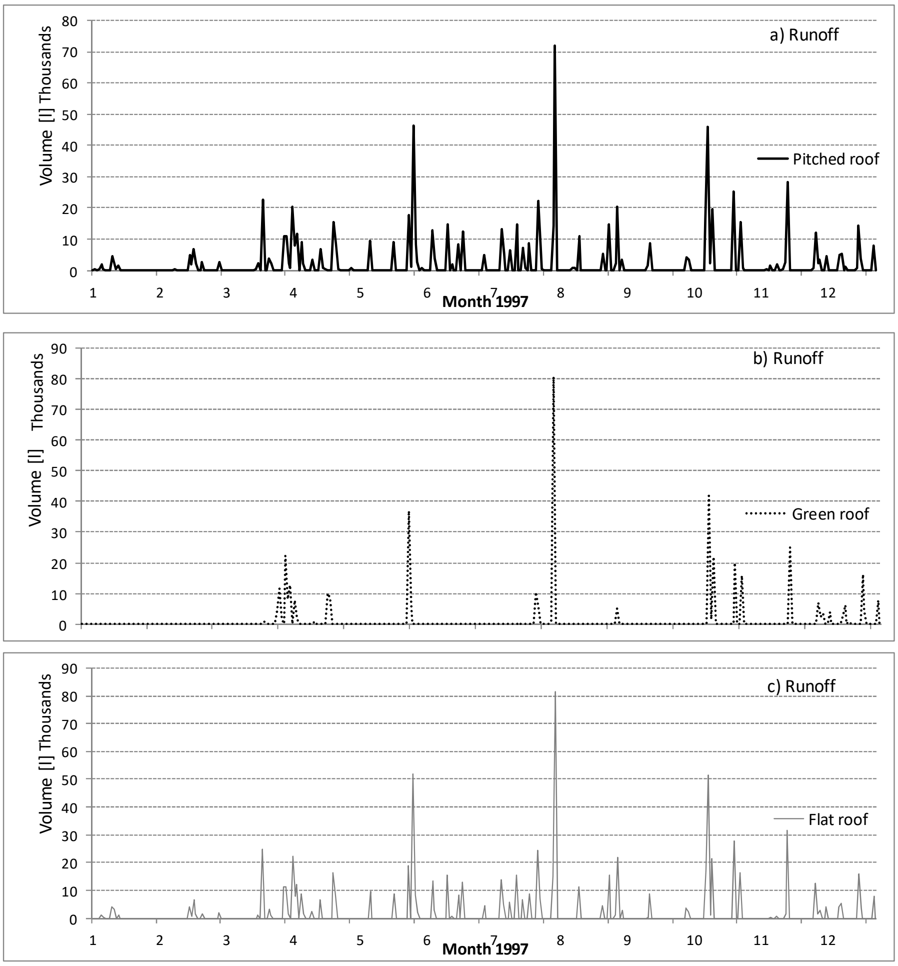

Figure 3. The model simulation results for roof runoff volume: a) PR, b) RG, c) FR.

CONCLUSIONS

In the presented research, three rooftop conditions are assessed in regard to water volume retained in the roof and released as runoff, for a compact group of buildings in the 'Krive livade' neighborhood in the city of Niš, Serbia. Besides the obvious water quantities that indicate performance of each rooftop during one year, a set of roof efficiency indicators is considered. Two new approaches for the role of roofs in SWM investigation are introduced: 1) assembling peached roof water volumes from the inclined roof segments of the water balance simulation model, and 2) roof efficiency indicators: minimum precipitation sum that triggers roof runoff, and maximum number of days without roof runoff. The importance of these approaches is in the capability: 1) to assess peached roof potential, and 2) to compare different types of roofs according to the site-specific conditions. For instance, in the study area, roof gardens are the best option, according to all of the indicators, regardless of maximum daily runoff volume, close to the one for flat roofs. Considering public benefit regarding SWM from roof garden implementation in the study area, it may be concluded that in the process of roof reconstructions, the chance to improve environmental status of the neighbourhood is missed. Furthermore, the public benefit could be quantified on annual basis through cost estimate of roof runoff volume sanitation at the wastewater treatment plant (Sainati et al., 2020), due to combined drainage system.

The research results show the importance of including roof gardens as technical elements in any contemporary SWM system preliminary design approach. Not only for housing areas, such an approach should be a part of the urban retrofitting design process. Due to limitations of land as a resource in urban areas, retrofitting interventions similar to the studied case are not only expected in the future, but happening right now. With a careful redistribution of porous and nonporous area in the urban catchments, the collective effect of lowering the catchment average runoff coefficient can be achieved. This is important for reducing stress from the existing SWM system, and application of the remaining set of technical elements in Nature Based Solutions that require less urban space due to decreased design volume.

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TRACING THE NITROGEN SOURCE IN GROUNDWATER

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Abstract: The knowledge of physico-chemical and microbiological composition of groundwater indicates its usability and required conditioning treatments, affecting, and determining the value and price of water. The importance of maintaining the quality and quantity of groundwater is obvious from the fact that more than 97% of the total quantities of fresh water on Earth is groundwater. Due to the slow groundwater flow, pollutants reaching groundwater persist for a long time, requiring considerable efforts and financial investments to restore original water quality. In the case of nitrogen inflow in groundwater, the prevailing conditions will determine its fate. The aim of the research emphasizes the necessity of comprehensive research including geology, groundwater recharge regime, physico-chemical composition, to decrease uncertainties of the nitrogen origin determination by a single point of view.

Keywords: groundwater, isotopes, nitrogen

INTRODUCTION

Typical groundwater flow rates vary from 1 m/day to 1 m/year. Caused by the relatively slow groundwater velocity, comprehensive, complex, and specific processes of sorption, dissolution, convection, dispersion, and oxidation-reduction within the self-purifying potential of an aquifer are present (Dimkic et al., 2008). Unfolding of these processes usually leads to a significant improvement in water quality. Groundwater composition is conditioned by many factors: autochthonous (geological - aquifer type and genesis, recharge water quantity and quality) and allochthonous (sewage, industrial and agricultural pollution). Beside the difference in groundwater quality of different regions, the groundwater composition in terms of quality and quantity, may very between shallow and deeper layers of the same aquifer.

About 75% of the EU population uses groundwater for water supply. In Serbia the share of groundwater used for water supply is 75% and it indicates the importance of maintaining the groundwater quality. Over 50% of the groundwater used for water supply in Serbia comes from alluvial groundwater sources. The soil fertility and availability of irrigation water made alluvial zones suitable for agricultural production. For groundwater management, it is important to consider the value of the aquifer's self-purifying potential, which in the case of agrochemicals (fertilizers and pesticides) may be particularly significant (Živančev et al., 2020).

Crop yields and fertilizer application are in a strong positive correlation. Fertilizer application, along with the productivity factors such as selection of crop varieties, irrigation, mechanization, and pesticide application have an obvious reflection in crop yield trends across the world in the 20th century. The groundwater contamination by fertilizers may last for many decades. The importance of agricultural nitrogen emission to the environment is reflected through "Nitrate Directive "(ND). In the Annex II of ND, a Code of good agricultural practice with the objective of reducing water pollution by nitrates covers the following items: periods when the land application of fertilizer is inappropriate; the land application of fertilizer to steeply sloping ground; the land application of fertilizer to water-saturated, flooded, frozen or snow-covered ground; the conditions for land application of fertilizer near water courses; the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage; procedures for the land application, including rate and uniformity of spreading, of both chemical fertilizer and livestock manure, that will maintain nutrient losses to water at an acceptable level (Directive 91/676/EEC, 1991). ND adopted by all EU Member States, limits the concentration of nitrate to 50 mg/l in all freshwater bodies (Directive 91/676/EEC, 1991). The prescribed nitrate concentration in drinking water and groundwater in Serbia is also 50 mg NO_3/l ("Official Gazette SRJ", br. 42/98 i 44/99 i " Official Gazette RS", br. 28/2019, " Official Gazette RS", br. 50/2012).

Nitrogen transformations are mostly conditioned by oxygen content, concentration, and bioavailability of electron acceptors (and donors), the ratio of electron donor and acceptors, dominant microbial population, pH value etc. Geology determines initial groundwater oxygen content. Oxygen content dominantly determines whether the nitrogen will remain in the most stabile form (N^{+5}) or it will be reduced and lost from groundwater (N_2, N_2O). If the concentration of dissolved oxygen is above 0.5 mg/l (and Eh > 250 mV) the nitrogen will probably remain in it's the most stabile form (NO_3^-) which is unable to sorb on sediment particles. If there is lack of oxygen, the ratio of total organic carbon (TOC) to nitrates (and sulphide presence) will determine whether the nitrate reduction will lead to N loss (N_2, N_2O) or conservation (NH_4^+) (Dissimilatory nitrate reduction to ammonium - DNRA/ Assimilatory Nitrate Reduction to ammonium - ANRA). The processes and conditions for nitrogen transformation are explained in detail in Perović et al., 2017; Perović et al., 2020.

MATERIALS AND METHODS

The competitive and often overlapping oxido-reducing reactions in groundwater induce difficulties in determination of the N origin considering only one scientific point of view. Determination of N origin and discrimination of conditions suitable for N conservation or loss, are of great importance in groundwater management. Although many factors affect nitrogen behaviour and fate in groundwater, and there is a wide range of nitrogen sources, the oxygen content, the boron concentration, and isotopic signatures of NO_3^- and NH_4^+ are selected for further investigation.

Oxygen in groundwater is predominantly used for oxidation of organic substances and lower oxidation state minerals (mainly iron), which are sorbed to fine-grained materials. The deposition of fine-grained materials is less pronounced in upper part of river basins due to a higher water flow energy. Therefore, the oxygen content is generally significantly higher in aquifers in the upstream parts of a basin (coarse-grained material), whereas anoxic aquifers are found in lower river basins (Figure 1) (Dimkić, 2012; Perović, 2019). The coarse-grained aquifers, with significant oxygen diffusion, or aquifers with intensive water exchange, are considered as sensitive to nitrate contamination.

If the aquifer is formed in lower part of the stream where the river flow is decreased, the river deposited the fine-grained material which is rich in iron and organic carbon, inducing anoxic conditions groundwater (Perović 2019). The anoxic aquifers are rich in oxygen consuming substances, mostly reduced metal forms and organic carbon.

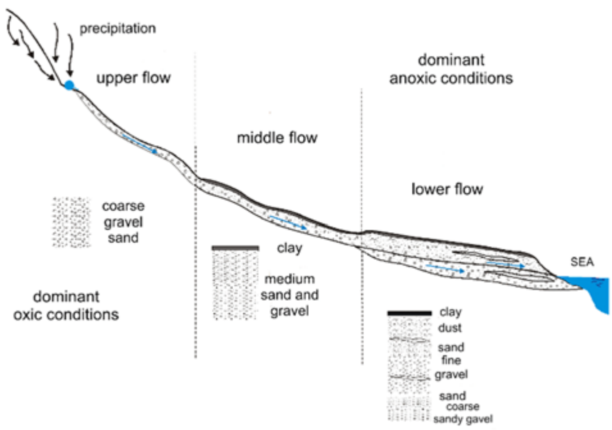

Figure 1 Schematic representation of an alluvial aquifer (Dimkić, 2012)

RESULTS AND DISCUSSION:

Mineralization of organic matter is accompanied by a decrease in pH and often consequent reductive dissolution of Fe^{3+} ions (iron oxide and/or iron oxyhydroxide). Increased acidity of the environment causes the appearance of Fe^{2+} cations and often the release of the mobile form of arsenic, the arsenite cation (As^{3+}), which is a common constituent of anoxic groundwater in layers rich in areno-pyrite or iron-arsenite ores (Berg et al., 2001; Wang et al., 2017). If the medium is rich in organic matter, mineralization can generate the release of mobile ions Fe^{2+}, NH_4^+ As^{3+} when the observed linear correlation mainly indicates the autochthonous origin of ammonium cations.

As indicators of groundwater origin and anthropogenic impacts on its quality (in terms of nitrogen pollution), the chloride (Cl), sodium (Na) and boron (B), along with the isotopic signatures of ammonia and nitrates are usually quantified.

Natural origin of B may indicate seawater intrusion, may originate from dissolving sandstones and igneous rocks, or may be found in certain evaporates such as borax (($Na_2B_4O_5[OH]_4 \cdot 8H_2O$) (Clark, 2015). Simultaneously elevated concentrations of B and NH_4^+ may indicate their common origin from sewage (Lindebaum, 2012). One of the most common anthropogenic uses of B compounds is the production of sodium perborate ($NaBO_3 \cdot nH_2O$), which is the component of whitening agents, in detergents, toothpastes and soaps. In liquid manure and septic tanks, B concentrations are significantly elevated (Nikolenko et al., 2018). High concentration of B followed by low concentration of NO_3^- is probably an indicator of anthropogenic influence (detergents), while moderate concentration of B followed by moderate concentration of NO_3^- is likely to indicate the influence of wastewater excrements (Widory et al., 2004).

One of the widely used approaches over the past few decades in nitrogen origin determination has involved stable isotope analysis. The heterogeneity of geochemical conditions, groundwater flow, wide range of nitrogen sources and agricultural practices, causes a significant range of the isotopic signature $\delta^{15}N$-NO_3^-. In in groundwater below agricultural areas the isotopic signature $\delta^{15}N$-NO_3^- varies from -8.3 to + 65.5 ‰ (Nikolenko et al., 2018). N originating from different sources is characterized by a different range of $\delta^{15}N$-NO_3^- as well as different enrichment factor, which can be used to determine the origin and relative contribution of NO_3^- source to its content in groundwater (Nikolenko et al., 2018). In groundwater, due to fractionation during physico-chemical or biological reactions (NH_3 volatilization, nitrification, denitrification), the isotopic composition changes. Thus, the isotopic signature cannot be unambiguous in nitrogen origin determination. The lowest values of $\delta^{15}N$-NO_3^- characterize mineral fertilizers, oxidation of soil organic matter, rainwater, respectively, while the highest values characterize manure or household wastewater, whose ranges may overlap (Table 1).

The range of data on the $\delta^{15}N$-NH_4^+ distribution in groundwater below agricultural areas is significantly more modest comparing to nitrates data. Published research have shown that the range of $\delta^{15}N$-NH_4^+ in aquifers is -8.5 to + 23.8 ‰ (Kendall 1998; Nikolenko et al., 2018). Organic fertilizers, manure, sewage, and wastewater from treatment plants are generally considered to be the main anthropogenic sources of NH_4^+ ions in groundwater below agricultural land (Nikolenko et al., 2018). The lowest values of $\delta^{15}N$-NH_4^+ characterize rainwater, while the highest values were observed for manure and sewage wastewater. Organic matter shows slightly higher values of $\delta^{15}N$-NH_4^+ isotopic composition compared to mineral fertilizers and rainwater (Nikolenko et al., 2018). Known to date research results suggest that isotopic signatures from different NH_4^+ sources may overlap due to the specificity of the environment in certain areas (Figure 2).

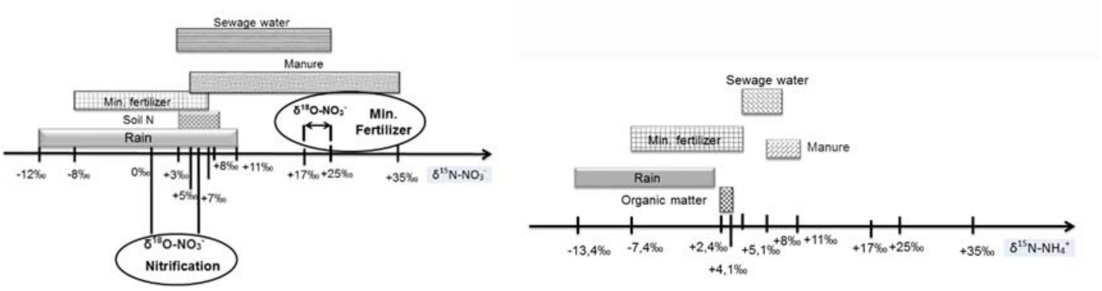

Figure 2 Characteristic ranges of isotopic signatures of stable N isotopes depending on source (Perović, 2019; Perović and Dimkić, 2021)

Table 1 Transformation processes, necessary conditions and expected fractionation range (Perović, 2019)

PROCESS	*CHEMICAL REACTION*	*NECESSARY CONDITIONS*	*FRACTIONATION (APPROXIMATELY,)*
Fixation	$N_{2(g)} + 3\ H_2O_{(g)} \rightarrow 2\ NH_3 + 3/2\ O_{2(g)}$	Lightning, Plant enzymes	0‰
Mineralization	$R - CHNH_2 - COOH + O \rightarrow R - CO - COOH + NH_3$	Decreasing pH, anoxic conditions until nitrification	0±1‰
Nitrification	$NH_4^+ + 1{,}5\ O_2 \rightarrow NO_2^- + H_2O + 2H^+$ $NO_2^- + 0{,}5\ O_2 \rightarrow NO_3^-$	pH decreasing, O_2 >1 mg/l	-18 to -29 ‰ to -35‰ produced NO_3^- will be depleted in $\delta^{15}N$
Denitrification	$5CH_2O + 4NO_3^- \rightarrow 2N_2 + 4HCO_3^- + CO_2 + 3H_2O$	O_2 <2,0 mg/l and Eh<250 mV; pH increase, high TOC, non-sulphidic, low C:N; low TOC, low Fe, high C:N	by 5-40‰ enrichment of remaining nitrate
	$10\ Fe^{2+} + 2\ NO_3^- + 14\ H_2O \rightarrow 10\ FeOOH + N_2 + 18H^+$	Low TOC, high Fe,	
	$5HS^- + 8NO_3^- + 3H^+ \rightarrow 5SO_4^{2-} + 4N_2 + 4H_2O$	Sulphidic, FeS, S^0 high TOC	
Dissimilatory nitrate reduction to ammonium — C>>n	$2H^+ + NO_3^- + 2CH_2O \rightarrow NH_4^+ + 2CO_2 + H_2O$	High TOC, non-sulphidic, high C:N-fermentative DNRA;	Remaining nitrate approximately enriches by +10‰, lighter NH_4^+ is produced
	$4HS^- + 4NO_3^- + 4H_2O + 4H^+ \rightarrow 4SO_4^{2-} + 4NH_4^+$	sulphidic, H_2S, high TOC,	
Anaerobic ammonium oxidation	$NH_4^+ + NO_2- \rightarrow N_2 + 2H_2O$	Low TOC, low Fe, low C:N (N>C), respiratory DN to NO_2^- then anammox	Like denitrification

*Eh – electrochemical potential

CONCLUSION

Nitrate pollution of shallow aquifers in Europe and in the world is a common, important, and well-studied problem. Beside the application of nitrogen-based mineral fertilizers, unregulated sewage discharges as well as sewage leaks, the existence of septic tanks and manure applications are the most significant sources of elevated concentrations of nitrogen compounds in groundwater. Considering the nitrogen loadings, to maintain the basic, autochthonous groundwater quality and to determine the vulnerability of groundwater to certain pollution the simultaneous complex analysis of agrotechnical, physico-chemical and hydrogeochemical data must be conducted. To trace the sources of contaminants, beside the groundwater recharge and groundwater flow, prevailing conditions of the environment and their impact on specific pollutant transformation must be considered.

In conducted research it is suggested that nitrogen sources in groundwater under agricultural areas should be studied by simultaneous analysis of concentrations levels of O_2, NH_4^+, NO_3^-, TOC; changes in concentration levels of anthropogenic tracers B, Cl, Na; by examination of state condition parameters (pH, redox potential) and isotopic signatures of stable isotopes of nitrogen and oxygen. Beside physico-chemical analysis groundwater flow and recharge should also be considered. Analysis of the ratio of stable isotopes of nitrogen (isotopic signatures) is a widely used method for identification of nitrate source in groundwater. As the isotopic signature of nitrogen can change under the influence of various complex biogeochemical mechanisms of transformation it cannot be exclusive in the source identification. Verification of the assumed transformation processes and nitrogen sources in groundwater is required by simultaneous, comprehensive, and complex analysis of physico-chemical, hydrogeological, and isotopic signatures.

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NATURAL WATER RETENTION MEASURES CONTRIBUTION TO INTEGRATED TRANSBOUNDARY TISZA RIVER BASIN MANAGEMENT-ENVIRONMENTAL AND FLOOD RISK MANAGEMENT OBJECTIVES SYNERGY

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Abstract: Contemporary water management incorporates number of criteria merged in a way to target economic development, social equity, and development. In the recent decades, Integrated Water Resources Management paradigm is incorporated in the polices and legislation with the Europe and Globally. Under the EU's WFD, the ICPDR is the platform for coordination for the implementation of the provisions of the Directive between Danube countries (including non-EU Member States and takes an active role in sub-basin planning. Transboundary cooperation within the Tisza River Basin generates the Updated ITRBMP 2019 that elaborates significant water management issues, water quantity and quality issues relevant for Tisza River Basin. To improve the synergy between EU WFD and EU FD objectives Tisza countries identified flood risk management measures that support EU WFD environmental based on commonly agreed methodology and official national data. Brief overview presented in this paper indicates that Tisza countries support natural water retention measures as a win-win measures for flood risk management that support WFD environmental objectives and address water quantity and water quality issues interlinkage of relevance for Tisza River Basin and integrated water resources management.

Keywords: EU WFD environmental objectives, flood risk management, integrated water resources management, natural water retention measures, Tisza River basin, transboundary water management

INTRODUCTION

The main goal of the contemporary water resources management is to address development, social equity, and environmental sustainability. To combat increasing pressures on water resources (water scarcity, pollution, climate changes, extreme hydrological events, land use changes, etc.) a new doctrine Integrated Water Resources Management (IWRM) is incorporated in policy and legal framework at national, transboundary, and global level. IWRM attempts to integrate prospects and processes of the hydrologic cycle, watershed features and economics, social interactions, and policies (Mayfield et al., 2004) considering external impact (Figure 1).

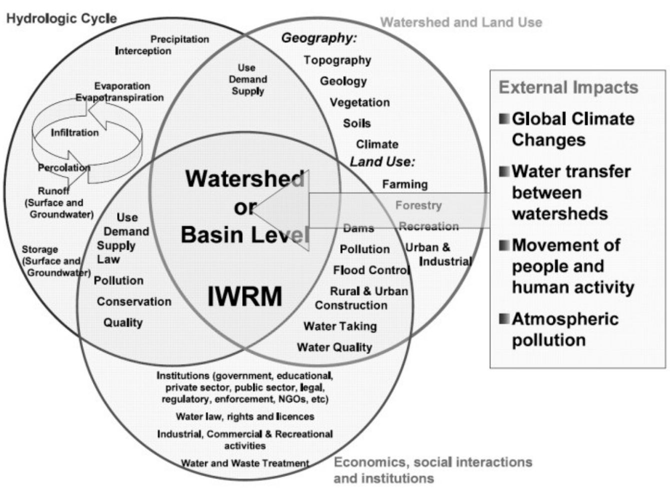

Figure 1. Conceptual IWRM integration (Source: Mayfield et al., 2004)

It is the understanding of basin retention opportunities that gets more and more important in contemporary water management due to its favourable contributions to sustainable development and integrated water resources goals achievement (Matić, 2019). Human activities, and climate change have caused an increase in the frequency of extreme climate events, including floods and droughts. At the same time, there is a clear need to implement measures that mitigates the negative impacts of fluctuating water availability on human economic activities and the environment (2015, GWP).
Natural Water Retention Measures (NWRM) are multi-functional measures that aim to protect and manage water resources using natural means and processes, therefore building up Green Infrastructure, for example, by restoring ecosystems and changing land use. NWRM have the potential to provide multiple benefits, including flood risk reduction, water quality improvement, groundwater recharge and habitat improvement NWRM policy document (EU, 2014). As a result, they contribute to achievement of the key EU policies such as the Water Framework Directive (WFD) and the Floods Directive (FD) among the others.
The main focus of applying NWRM is to enhance the retention capacity of aquifers, soil, and aquatic and water dependent ecosystems with a view to improve their status. The application of NWRM improves the quantitative status of water bodies and reduces the vulnerability to floods and droughts. It positively affects the chemical and ecological status of water bodies by restoring natural functioning of ecosystems and the services they provide (Strosser et al., 2015). The restored ecosystems, e.g., improved hydrologic ecosystem services (natural water retention capacity) contribute both to climate change adaptation and mitigation, and increase river basin resilience to hydrological extreme events and other changes due to human activities (Matić and Simić, 2017).
Improved planning processes coordination across different policy areas (e.g., River Basin and Flood Risk Management, but also nature protection, rural development, and land use/spatial planning) is identified as a pre-requisite to reinforce the chances of the NWRM multiple benefits considerations in the water and other sectors decisions making process. The links between the Floods Directive (FD 2007/60/EC) and Water Framework Directive (WFD 2000/60/EC) and potential benefits of NWRM and their contribution to integrated water resources management at the river basin level are elaborated in the Technical Report 078 (EU, 2014).
The largest sub-basin of the Danube River Basin is Tisza River Basin. Its transboundary water resources management is built on the Tisza countries (Ukraine, Slovakia, Romania, Hungary, and Serbia) co-operation within the scope of the International Commission for the Protection of the Danube River (ICPDR) Tisza Group. At the first ministerial meeting of the ICPDR countries (December 2004), ministers and high-level representatives of the five Tisza countries signed a Memorandum of Understanding (MoU), establishing the ICPDR Tisza Group for coordination and implementation of an international integrated Tisza River Basin cooperation under the umbrella of the ICPDR. More details regarding are available at the ICPDR Tisza Basin web page.
As presented in the following, this paper explains rationale of the NWRM measures integration in the Updated Integrated Tisza River Basin Management Plan 2019 (ITRBMP 2019) to provide synergy between flood risk management and environmental.

METHODOLOGY TO IDENTIFY ENVIRONMENTAL AND FLOOD RISK MANAGEMENT OBJCTIVES SYNERGY

The Tisza River Basin (Figure 2) drains an area of 156,869 km² is shared by Tisza countries and can be divided into two main parts: the mountainous Upper and the Lowland Tisza Basin. The Tisza River itself can be divided into three main parts: the Upper (- upstream from the confluence with the Somes/Szamos River),Middle (in Hungary which receives the which receives following tributaries: the Bodrog and Slaná/Sajó Rivers together with the Hornád/Hernád River, the Szamos/Somes River, the Körös/Crisuri River System and Maros/Mures River) and the Lower Tisza (located downstream from the mouth of the Maros/Mures River. This part of the Tisza receives the Begej/Bega River and indirectly other tributaries through the Danube – Tisza – Danube Canal system.

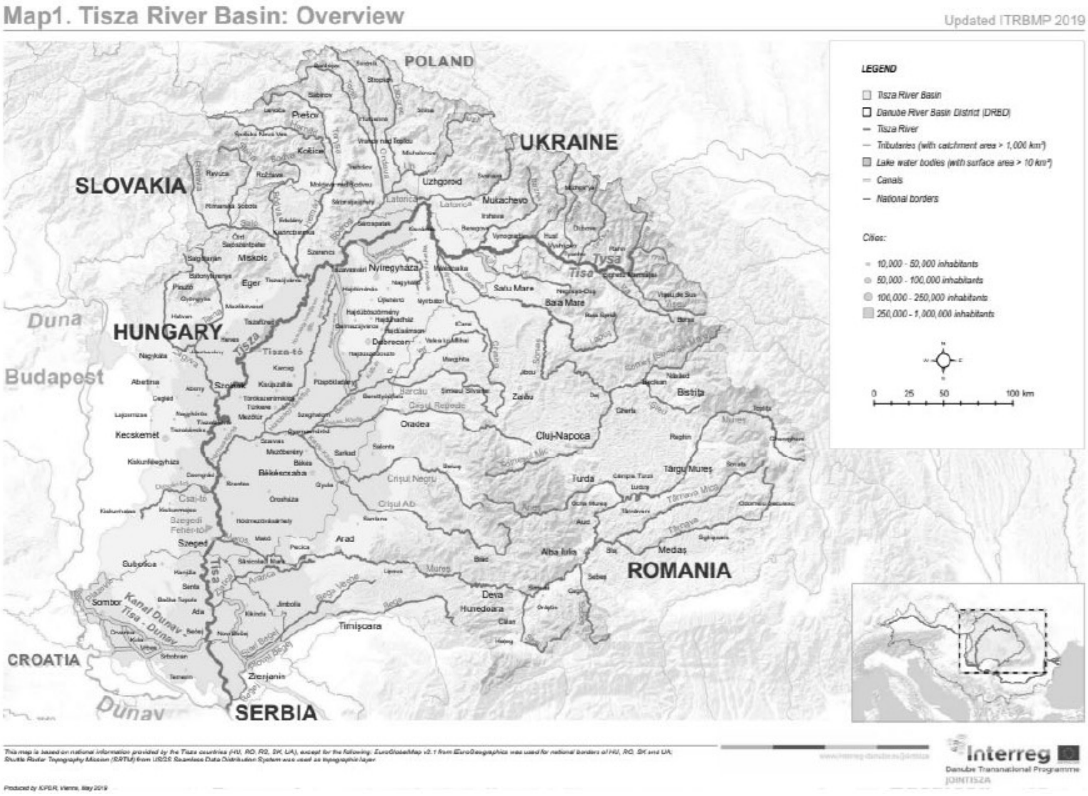

Figure 2. Tisza River Basin overview (Source: Updated ITRBMP 2019, maps, available at the: https://www.icpdr.org/flowpaper/viewer/default/files/nodes/documents/updated_itrbmp_2019_maps.pdf

Integration of water quality and water quantity issues

In addition to Significant Water Management Issues identified for Danube River Basin (pollution by organic substances, pollution by nutrients, pollution by hazardous substances, hydromorphological alterations and ground water management issues) in the ITRBMP (2011) the integration of water quality and water quantity related issues has been identified by the ICPDR Tisza Group (ITRBMP 2011) to be relevant for integrated river basin management within the Tisza River Basin as presented by Figure I.3 in the Updated ITRBM Plan 2019). It is underlined that key water quantity issues for water quality and good status of water bodies are flood and excess water, drought and water scarcity and climate change.

Updated ITRBMP 2019 incorporates elements of the flood risk management plan – flood risk reduction measures reported by Tisza countries through ICPDR DANUBE GIS database following the procedures.

As a subcategory of these measures Tisza countries collected data and information and reported the potential identified win-win measures associated to flood risk management that might lead to achieve the objectives of WFD in the Tisza River Basin.

Among the measures collected from the Tisza countries, those measures that support both the Water Framework Directive and the Flood Directive were identified, considering the interlinkage between the flood risk management and environmental objectives since these measures are considered as most suitable for achieving future integrated water management. During the identification of these measures, the achieved principles and the goals declared in the Danube River Basin Management Plan and the Danube Flood Risk Management Plan were also taken into consideration (Updated ITRBM, 2019).

The Tisza countries filed agreed templates to provide official national data and information on legislation, competent authorities, coordination, units of management, and criteria and approach on integration of the Tisza River Basin Management Planning and Tisza Flood Risk Management Processes.

Each country reported Potential measures associated to flood risk management that might lead to achieving the environmental objectives. For each measure the field of action (prevention, protection, public awareness,

preparedness, response and recovery/ reconstruction) is reported, associated with measure category, type of measure and measure description.
The summary results on win -win measures for flood risk management that supports EU WFD environmental objectives (Article 4) are discussed in the results with emphasis on the NWRM.

RESULTS AND DISCUSSION: A CLEAR PRESENTATION OF EXPERIMENTAL RESULTS OBTAINED, HIGHLIGHTING ANY TRENDS OR POINTS OF INTEREST.

Table 1. Summary of the potential identified win-win measures associated to flood risk management that might lead to achieve the objectives of WFD in the Tisza River Basin

No of measures	Field of action	Measure category
15	Prevention	Organizational measures (legislative, institutional
36	Protection	Natural water retention measures - associated to watercourses, wetlands, natural lakes, in accordance with Directive 2000/60 /EC, and other measures that advocate for increase of retention capacity
2	Public Awareness	Measures to increase community awareness
9	Preparedness	Preparedness measures /Improvement preparedness to reduce the adverse effects of floods
3	Response and Recovery/ Reconstruction	Post event recovery measures

As depicted in table 1 that presents summarised data, 36 measures are reported for flood risk management protection field of action by the Tisza River Basin. According to the ITRBMP 2019 (Table VII.2) they are categorized in the following way:
Natural water retention measures - associated to watercourses, wetlands, natural lakes, in accordance with Directive 2000/60 /EC;
Change or adapt land use practices (partial recovery of ecosystem functions or structures modified by changing or adapting land use practices) in urban areas;
Change or adapt land use practices (partial recovery of ecosystem functions or structures modified by changing or adapting land use practices) for forest management;
Other water retention measures.
With respect to type of measures there are 8 measures to restore retention areas (flood plains, wetlands etc.), 1 measure for Natural water retention measures in urban areas, 4 Natural water retention measures by changing or adapting land use practices in forest management, 5 measures to improve retention capacity at the level of river basin by creating polders and small retention reservoirs (made in the upper part of the river basin), and 1 measure type to improve retention capacity at the level river basin by increasing the safety of existing large dams / increasing the attenuation capacity of reservoirs towards projected capacity.
It is important to underline the note associated with win-win measures that support maintenance or increase of the natural retention capacity: Downstream cumulative effects of retentions along the Tisza in Hungary should be evaluated in the frame of bilateral cooperation between Hungary and Serbia. The Serbia is the most downstream country and given the foreseen increase in water use by agriculture, any significant changes or alteration in the water regime due to water retention measures has to be elaborated by national nominated experts in the bilateral commissions.

CONCLUSIONS

Integration of the win-win measures associated to flood risk management that might lead to achieve the objectives of WFD in the Tisza River Basin in the updated ITRBM reinforce synergy between flood risk management and environmental objectives. Proposed measures are extracted from the national catalogues of measures and in line with measures reported in the Flood Risk Management Plan for the Danube River district. It is indisputable that more than 70% of measures reported by Tisza countries are within the NWRM category, both in urban and rural areas. The implementation of the JOINTISZA project generates ITRBMP 2019 endorsed by Memorandum of Understanding signature by Tisza countries during a high-level Ministerial meeting (September, 2019). Given the multi benefits of the NWRM, their identification enhances Tisza countries cooperation with respect to transboundary water management visions and objectives, improve integrated water resources management, and support cooperation among various sectors relevant for flood risk and water resources planning and management. Implementation of proposed NWRM within the Tisza River Basin addresses the water quantity and quality issues interlinkage and measures relevant for Tisza River Basin SWMIs.

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