



International Course and Field Seminar
Characterization and Engineering of Karst Aquifers
Trebinje, Bosnia & Herzegovina



International
Hydrological
Programme



The Hydro-Energy
System of Trebišnjica
HET, Trebinje

REPORT

of the Fifth International Course and Field seminar
“*Characterization and Engineering of Karst Aquifers*”

Trebinje, Bosnia & Herzegovina – Virpazar, Montenegro, 27. May – 05. June, 2018.



The fifth international course and field seminar *Characterization and Engineering of Karst Aquifers* was held in Trebinje, Bosnia & Herzegovina and Virpazar, Montenegro, between 27. May – 05. June, 2018. The course was organized by the Centre for Karst Hydrogeology of the Department of Hydrogeology, University of Belgrade - Faculty of Mining & Geology (hereafter FMG), the Geological Survey of the Republic of Srpska, Zvornik, and for the first time together the Regional waterworks of the Montenegrin coast. Support to this year Course had been provided by our hosts - Hydro-electric power plant system of Trebišnjica River (hereafter HET), the Regional waterworks of the Montenegrins coast, Geological survey of Montenegro and Municipality of Trebinje. This year, the Course was attended by 14 participants from 5 countries, while lectures were provided by 7 professors.

Experts who delivered their lectures during this year course were: Prof. Dr Zoran Stevanović, University of Belgrade, Serbia; Dr Petar Milanović, Ret. Assoc. Prof. University of Mostar, Bosnia & Herzegovina; Dr Derek Ford, Ret. Prof. from McMaster university in Canada; Dr Richard Parizek, Ret. Prof. from Pennsylvania State University; Dr Ognjen Bonacci, Prof. Emer. University of Split, Croatia; Prof Dr Dragan Milovanović, University of Belgrade,



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Serbia and Dr Saša Milanović, University of Belgrade, Serbia. This year a two participants from USA, namely Lee Anne Bledsoe from Crawford Hydrogeology Laboratory, Western Kentucky University and Lisa Ryan retired professional geologist as well as prof Dr Junbing Pu from the Institute of Karst Geology, CAGS & International Research Center on Karst, UNESCO, Guilin - China, and Dr Ljiljana Vasić, from Faculty of Mining and Geology, University of Belgrade provided lectures about their work and experiences obtained. As in the previous year, two junior experts from University of Belgrade Branislav Petrović and Veljko Marinović had opportunity to give their lectures about specific topics and research work in karst for their doctoral theses.

First meeting of the participants was held on May, 27th in the VIV hotel, when after common dinner and a welcome note, all participants together with prof. Stevanović and organising team took a walking tour in the city of Trebinje. Followed welcome cocktail was opportunity for Prof. Stevanović to introduce some of the lecturers, sponsors from HET and Geological Survey of the Republic of Srpska and also the organising team from FMG.



Walking tour of the Trebinje city



Welcome cocktail

The registration of participants took place on 28th May, at the conference hall of the HET in Trebinje. All participants received printed lecture notes and other course materials (bag, notebook, pencil, T-shirt, hat with the course logo as well as DVD with PowerPoint



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presentations of all lectures and various movies including one of the Trebišnjica River regulation).



Entrance to the HET and the conference hall

Opening ceremony started at 9⁰⁰ AM with the welcome speech of Željko Zubac, director of HED, Boban Jolović, Geological Survey of the Republic of Srpska, Zvornik, and Dr Saša Milanović from Centre for karst hydrogeology, Department of Hydrogeology, Faculty of Mining and Geology, University of Belgrade, who wished a productive work and pleasant stay in Trebinje and at HET to the participants. Also, prof. Zoran Stevanović once again wish welcome to all participants as well as to all lecturers and officially open the Course.



Opening ceremony

After the welcome address, Prof. Stevanović provided an introductory lecture "*Introductory note about course; Historical development of karstology and karst hydrogeology; Importance of karst and karst distribution worldwide; Geo-heritage sites; Dinaric karst*". He described the system of education at the Faculty of Mining & Geology to the participants and presented all course topics, a table of content and the course schedule. Also, he explained characteristics of Dinaric karst and its importance.



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First lecture of Professor Zoran Stevanović

After the first lecture, all participants introduced themselves and presented their interests and the reasons for attending the course. 14 participants from 5 countries, namely: USA, China, Bosnia & Herzegovina, Montenegro and Serbia.

List of participants

Name and Surname	Institution/Company/School	
Dragana VESIĆ	Faculty of Mining and Geology, Department of Hydrogeology	
Junbing PU	Institute of Karst Geology, CAGS & International Research Centre on Karst, UNESCO, Guilin - China	
Saša STOJADINOVIĆ	Faculty of Mining and Geology, Department of Hydrogeology	



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Marko VIDAČIĆ	Faculty of Mining and Geology, Department of Hydrogeology	
Časlav PANTELIĆ	Faculty of Mining and Geology, Department of Hydrogeology	
Lee ANNE BLEDSOE	Crawford Hydrogeology Laboratory, Western Kentucky University	
Jovana RAŠUO	Faculty of Mining and Geology, Department of Hydrogeology	
Nikola TRMČIĆ	Faculty of Mining and Geology, Department of Hydrogeology	
Lisa Ryan	Retired professional geologist	



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Marija ORBOVIĆ	Faculty of Mining and Geology, Department of Hydrogeology	
Miloš GRUJIČIĆ	Faculty of Mining and Geology, Department of Hydrogeology	
Nela PETRONIJEVIĆ	Institute for Technology of Nuclear and Other Row Materials	
Marijana Petrović	Electric power industry in Serbia (EPS)	
Nenad NIKOLIĆ	Institute for Multidisciplinary Research	

The next lecture was delivered by Prof. Dragan Milovanović: *Carbonate and non-carbonate rocks: mineralogy, depositional environments and classifications.*

Three more lectures were held in the afternoon session when Prof. Milovanović lectured on *Chemical factors of karstification and Role of tectonics*, and after him Prof. Stevanović continued with two lectures: *Porosity and permeability of karstic rocks; Karstification process and its features: Surface and subsurface karst landforms*, while the last lecture for



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that day was *Groundwater circulation in karst: recharge, flow types and directions, discharge.*



Professor Dragan Milovanović

On the second day (29 May) started field trip to Montenegro, and all participants, lecturers and organising team was moved to the Montenegro. Firstly, students were guests in the building of the Montenegrin Electro-Power Industry, where they met their hosts, Mićko Radulović, Milan Radulović, Milan Vlahović and Vaso Mrvaljević, who delivered small presentation about hydrogeology and geology of Nikšić area and showed model of reservoirs in this area.



Visit of the Montenegrin Power Industry

During that day and field excursion, participants of the course had opportunity to see all objects and reservoirs of Nikšić polje, to understand general hydrogeology of this area, to see dams and reservoirs, combat water losses, engineering solutions, as well as to see the Glava Zete spring and Hydro Power Plant. During the day, participants had lunch in small local restaurant, where they enjoyed in local food and wine.



Visit of lake and estavelle



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Cylindrical dam around sinkhole and tunnel to Glava Zete



Cylindrical dam around sinkhole and Slano reservoir



Slano dam and spillway and Hidro Power Plant Glava Zete



Spring Glava Zete



At the end of the day, participants visited the “Bolje Sestre” spring in Malo Blato in the Skadar Lake Basin, which is tapped for the Regional Waterworks for the Montenegrin Coast. Prof. Dr Zoran Stevanović, together with Prof. Dr Mićko Radulović and Marijana Zenović main engineer of production gave a small verbal presentation about geological and hydrogeological setting of the area of this sublacustrine spring. Afterwards, M. Zenović have informed guests about “Bolje Sestre” spring water exceptional quality that fulfils all requirements for water bottling and other source technical details.



The “Bolje Sestre” spring in Malo Blato

The minimum discharge of the spring exceeds the long-term demands of the Montenegrin Coastal Region. However, if the consumption of water continues to grow the system will be built up, so it may reach the optimal capacity of 1600 l/s. The water intake area has been built in the form of a coffer dam made of reinforced concrete with the special flow regulation system which prevents lake water from entering the spring zone (prevents mixture of surface and groundwater).

The intake structure – the coffer dam of spring “Bolje Sestre”

The regional water supply system consist of the two main sections:

- The Continental section – facilities for water production and its transport
- The Coastal section – system of distribution water along Montenegrin coastal region.

After introduction with the history of research and development of the system, guests and their hosts took a tour through the facilities for water production: pumping section, UV disinfection area, laboratory for monitoring of basic physical and chemical parameters.



Participants and their hosts in the facilities for water production



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Visit to the laboratory for monitoring of groundwater quality

After the tour through the facilities, prof. Dr Zoran Stevanović held a meeting about the system itself, possibilities for technical and management improvements, and possibilities for water export and marketing potential. After discussion, he divided participants into three smaller groups and gave them tasks for tomorrow to define the best solution for research and tapping of “Bolje Sestre” spring in Malo Blato. Participants ended their field trip day in the Virpazar on the Skadar Lake.



Meeting and discussion of prof. Dr Stevanović and participants of the course

The next day was reserved for the half day field work on the of “Bolje Sestre”. Firstly, participants presented their solutions for the task prof. Dr Stevanović gave them day before. After that, they had opportunity to make pumping test as well as tracer test with NaCl in the zone of the spring which was led by Dr Milan Radulović, Assistant Professor on the Faculty of Civil Engineering in Podgorica, Montenegro.

Firstly, they measured groundwater level in the piezometer as well as basic physico-chemical parameters of water from the piezometer and from the spring in order to define initial values of electrical conductivity, pH value, temperature, dissolved oxygen as well as turbidity. After that, they started with pumping test and measured drawdown of groundwater level, end after end of pumping, they measured recovery of groundwater level.



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Pumping test led by Milan Radulović



Measuring of basic physico-chemical parameters of groundwater

Tracer in amount of 8 kg of NaCl was injected into the piezometer near the spring (around 8 m distance), after which participants started to monitor electrical conductivity on the spring. According results, they calculated groundwater velocity and approximate groundwater discharge of spring.



Preparation and injection of NaCl into the piezometer



Monitoring of electrical conductivity on the spring



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After field experiments, prof. Dr Dragan Milovanović held a verbal presentation about geology, lithology, petrology and tectonic of this region, after which participants were returned in the classroom, where prof. Stevanović introduced to them: prof. Dr Peter Milanović, retired professor from University in Mostar and retired professor Richard Parizek, from Pennsylvania State University from USA. They addressed to participants and delivered small verbal presentations about karst, problems in karst and their experience with research in karst regions.



Lecture of prof. Dr Milovanović



Prof. Petar Milanović and Prof. Richard Parizek

During the visit of the “Bolje Sestre” spring in Malo Blato, participants, lecturers and organising team also had a meeting of welcome done by Goran Jevrić the Executive Director of the Regional Waterworks for the Montenegrin coast and Saša Radulović the State Secretary in the Ministry of Sustainable Development and Tourism. They addressed the guests with words of welcome emphasizes how they were glad that the students and the world's experts are their guests, who recognized the importance of the regional water supply project for the water supply of the Montenegrin coast. For that occasion, prof. Stevanović on behalf of the Centre for karst hydrogeology and CEKA course, awarded the Certificate of appreciation for sponsorship and support to the Regional Waterworks For the Montenegrin coast.

Afterwards, Dr Zoran Stevanović, Dr Richard Parizek and Dr Mićko Radulović gave their statements to the local TV station.



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Welcome speeches of Goran Jevrić the Executive Director of the Regional Waterworks and Saša Radulović the State Secretary in the Ministry of Sustainable Development and Tourism



Awarding of Certificate of appreciation for sponsorship and support to the Regional Waterworks for the Montenegrin coast.

During the afternoon, participants were enjoy the cruise on the Skadar Lake, which was organized by the Geological Survey of Montenegro. During the cruise, they had the opportunity to listen lectures from Veljko Marinović, from Centre for karst hydrogeology, Milan Radulović, Dragan Radojević and Neda Dević from Geological survey of Montenegro and Momčilo Blagojević Director of the Ministry of Agriculture and Rural Development, about Skadar Lake, geology and hydrogeology, as well as biodiversity of this area. Once again, prof. Stevanović awarded the Certificate of appreciation for sponsorship and support to the Geological Survey of Montenegro. After the cruise, the lunch was organized in local restaurant in Virpazar.



Lectures on the cruise



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Awarding of Certificate of appreciation for sponsorship and support to the Geological Survey of Montenegro

Third day in Montenegro was reserved for visiting Kotor city in the Boka Kotorska bay and karstic springs located on the Montenegrin coast (Gurdić and Škurda in Kotor city Spila Risanska, Orahovačka ljuta and Sopot). This excursion was led by prof. P. Milanović, S. Milanović and prof. Stevanović. Lunch in the Risan city was organised by the Regional Waterworks for the Montenegrin coast. After lunch, participants saw “Stone Sea” – “Angry” karst on Orjen Mountain, and Grahovsko karst polje, after which, together with lecturers and organising team were travelled back to Trebinje.



Visit of springs Gurdić and Škurda in Kotor city



Visit of springs Orahovačka ljuta, Sopot and Spila Risanska (down)



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The next day (June 1th), in the morning session, participants had an opportunity to learn practical aspects of karst hydrogeology, engineering concepts, and solutions. The first part was reserved for lectures, and the afternoon for a half-day excursion. Morning lecture was presented by Prof. Petar Milanović, topics are *Problems related to construction of dams, reservoirs and other structures and buildings in karst; Investigation, design, corrective measures, case studies.*



Morning lecture of Petar Milanović

During the half-day field trip, the students, together with the lecturers, visited intake for water supply of Trebinje (spring “Oko”) and Gorica dams. On the first stop prof. Petar Milanović gave a presentation about this the Oko spring which is situated several meters above the riverbed of the Trebišnjica River, upstream of the town of Trebinje and is used for city water supply.



First stop at spring “Oko” tapping structure

Second stop was Grančarevo dam, where Prof. Milanović delivered a presentation about hydrogeology and geophysical survey, dam design, constructive and monitoring elements as well as remedial works for leakage prevention. After visiting Grančarevo dam, students were transferred to another smaller dam – Gorica dam, situated 3 km upstream from Trebinje on Trebišnjica River. The tunnel for water transport to HE Plat near Dubrovnik (Croatia) as well as remedial works to reduce leakage from reservoir estimated in average amount of 5 m³/s were explained at the dam site.



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Visit to Grančarevo dam



Visit to Gorica dam

For the second year in a row, participants are also visiting the Main Hydrochemical Laboratory of HET, where Mr. Zdravko Mrkonja, Chief of the Laboratory, showed all instruments, equipment and explained what kind of analyses can be performed and how frequently Laboratory staff sampling and testing the water.



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Visit to HET Hydrochemical laboratory

After half-day field trip, students watched *DVD movie "Trebišnjica"*, after which famous Prof. Dr Richard Parizek held his lecture named *Case study: Appalachian Karst: Principles and Practices*.



Prof. Dr Richard Parizek's presentation

Morning session on the sixth day of course was reserved for presentations about methods in karst hydrogeology. Firstly prof. Stevanović gave a lecture: *Methods in karst hydrogeology – an overview; Geology, field reconnaissance and mapping, water occurrences inventory, remote sensing, geophysics and tracing tests, water occurrences inventory, GIS and database*; after which he continued with the lecture: *Methods in karst hydrogeology – climate, hydrology, water chemistry, statistics*. After coffee break Dr Saša Milanović finished morning session with lectures *Methods in karst hydrogeology – geomorphology, speleology, speleo diving, hydrogeology maps, GIS and database*.

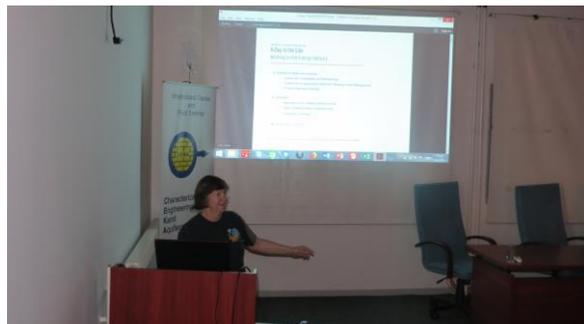


Lecture of Dr Saša Milanović



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Afternoon session was reserved for professional practice lectures. Firstly, Lee Anne Bledsoe delivered presentation named: *Investigations of groundwater flow in karst aquifers: Dye tracing case studies from the U.S.* After her, Dr Ljiljana Vasić presented lecture: *Quality dynamics at karst-springs. A challenge for drinking water supplies. Isotopic methods in karst, GW ageing – Kučaj-Beljanica (Serbia) case.* Lisa Ryan and Dr Junbing Pu also presented lectures about their professional practice.



Lee Anne Bledsoe, Ljiljana Vasić (upper figures), Junbing Pu and Lisa Ryan presenting lectures about their professional practice

Two junior experts give their lectures about specific topics and research work in karst which they are dealing with in their doctoral theses. Branislav Petrović delivered presentation: *Karst aquifer vulnerability; Anthropogenic impact and hazards; Karst Disturbance Index*, while Veljko Marinović talked about *Groundwater management and transboundary aquifers in karst: problems and solutions*. Day was closed with movie “*Forgotten species*” about protecting the nature, made by S. Milanović.



Lectures of young experts



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Next day (June 3rd) was One-day field trip and seminar which was guided by Prof. Petar Milanović, who provided explanations at every stop point. The trip started in Popovo Polje, one of the world's largest karst poljes. The first stop was the estavelle Pećina, after which trip was continued along the Popovo polje and Trebišnjica River, the largest sinking stream in entire Europe which is today completely regulated. The students had an opportunity to see riverbed which nowadays is covered with concrete blanket, and ponors that were previously utilized by local villagers as water mills. After, the excursion continued to the Vjetrenica cave, well known for its extreme windiness in the entrance area, as well as for the presence of protected endemic specie *Proteus anguinus* ("human fish") in its deep channels. After cave, participants visited nearby located Bio-speleological museum.



The estavelle Pećina and Trebišnjica River in Popovo polje



Vjetrenica cave and Bio-speleological museum



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After the cave tour, course participants visited the Buna Spring near Blagaj (Mostar) which, with its discharges in range of 3-300 m³/s, is listed among the thirty world's largest springs (Ford and Williams, 2007). Further on, the students were able to shortly visit Mostar city.



“Vrelo Bune” Spring



Mostar city

Next stop were Dabarsko and Fatničko polje with spring Vrijeka and estavelle Obod as well as the tunnel connecting Fatnica polje and the Bilećko Lake.



Dabarsko and Fatničko polje; tunnel connecting Fatnica polje and the Bilećko Lake



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On the last lecturing day (7th June), morning session started with lecture of prof. Stevanović: *Characterization of karst aquifers; Groundwater budget; Specific regime of karstic groundwater (quantity, quality); Safe yield*; after whom Prof. Ognjen Bonacci, continued with two lectures: *Water resources cycle in karst; Surface-groundwater interaction; Feasibility studies and engineering design; Environmental impact assessment; Case studies and Modeling of karst aquifer – Springs hydrograph analysis and stochastic models (exercise)*. Saša Milanović gave the last lecture in the morning session: *Case study: Leakage from reservoirs, specific research methods and remedial measures*.



Lecture of Prof. emeritus Ognjen Bonacci

Afternoon session was reserved for two lecturers. First one was the lecture of Derek Ford, an emeritus professor from McMaster University in Canada, who delivered lecture with title: *Spectacular and remote karst: National parks of Mackenzie Mts. in the Northwest Territories of Canada; glacial, periglacial, canyon and karst landscapes*. After him Neno Kukurić also delivered presentation titled: *IGRAC Mission: Transboundary aquifers: problems, solutions and experiences*.



Lectures of Prof. Derek Ford and Neno Kukurić

After afternoon presentations, students together with professors, had field work on Lušac spring, located in Trebinje city, guided by Ljiljana Vasić and Branislav Petrović. They showed directly on the spring how to make an inventory of the spring and how to properly measuring the spring flow and basic physico-chemical parameters with field portable laboratory equipment.



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Measurement of basic physico-chemical parameters with field portable laboratory equipment on the Lušac spring



Measurement of spring discharge using current meter

The final exam was conducted on the last day (5th June). It consisted of written test with 30 questions and verbal discussions. Eight students from Faculty of Mining & Geology attended the exam. Members of the examination panel were professors from the University of Belgrade Zoran Stevanović, Saša Milanović and Ljiljana Vasić.



Written part of exam

After the written test, the panel called students for verbal discussion. All of students that entered the written test passed the exam with grades in range from 6-10 (obtained points were from 53 to 92, out of maximum 100).

The closing ceremony was held in the same day in the afternoon. All attendants who completed the course received a Certificate of Attendance, and an additional Certificate which included final grade and credits (6 ESTC) issued by the University of Belgrade –



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FMG. All lecturers received Certificate of Appreciation for participation in the course. Also, Prof. Stevanović noted that the results of questionnaire indicated high overall evaluation of the course, and for example, evaluation of the question “The quality of content for the workshop” proofed that 85 % of participant said that the quality was Excellent, while 15 % said it was good. Also, for the question “What is your overall evaluation of the course (1-worst; 5-best)”, participants with the 75 % gave mark 5, and 25 % marked it with 4. Finally, Prof. Stevanović officially closed the fifth CEKA 2018 Course.



Closing ceremony

The awards for the best score on the final exam were given to the next students:

First Prize: Nikola Trmčić (grade 10, excellent)

Second Prize: Časlav Pantelić (grade 10, excellent)



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Third Prize: Saša Stojadinović (grade 10, excellent)

Fourth Prize: Marko Vidačić (grade 9, very good)



First Prize: Nikola Trmčić



Second Prize: Časlav Pantelić



Third Prize: Saša Stojadinović



Fourth Prize: Marko Vidačić

After the closing ceremony, good atmosphere has transferred to a local winery on farewell party, where the participants and lecturers were enjoyed local food and wines. Some of participants as well as students from Faculty of Mining & Geology had opportunity to take attend the following Symposium KARST 2018: Expect the Unexpected!





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Farewell party

Reported by
Dr Ljiljana Vasić



CEKA Team of the year 2018 !