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Title: *STUDY OF ANTHROPOGENIC POLLUTION AFTER THE WAR AND ESTABLISHING THE MEASURES FOR PROTECTION OF PLITVICE NATIONAL PARK AND BIHAĆ REGION AT THE BORDER AREA OF CROATIA AND BOSNIA – HERZEGOVINA*

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ABSTRACT

The objective of the project was the assessment of anthropogenic pollution after the war events and its consequences to the karst ecosystem in a border zone between Croatia and Bosnia-Herzegovina promoting the scientific-technical co-operation between these countries and some Member Countries of the European Union. The activities were focused on the hydrogeologically connected areas of the Plitvice Lakes National Park and neighboring karstic fields from the Croatian side, and the Una River catchment area in the Biha

region, Bosnia and Herzegovina. The project was oriented towards the end users: local authorities, enterprises, national parks and non-governmental organizations in the area. Therefore three specific case studies were chosen: on a tourist domain, a municipality domain and an industry domain.

Data collected by partners within the project, as well as physico-chemical and isotopic analyses of samples collected during three years of the project, served as a background for elaborating a hydrogeological model and further modeling of intrinsic vulnerability, hazard and risk assessment of surface and groundwater resources in the area of transboundary aquifers. All these data, as well as the results of previous studies, were incorporated into the Geographic Information System (GIS) and visualized and modeled through the ArcMap-ArcView software.

The case study performed on the tourist domain was directed to investigation of human influence to the area of Plitvice Lakes National Park. These investigations showed that the concentration of trace elements, as well as of organic matter, was mainly of natural origin. This conclusion can calm the park administration and local authorities, because they have been concerned about the influence of tourist activities and dense traffic connecting interior of Croatia with its littoral. The only indicator of pollution was shown by detergent-derived chemicals caused by the defects in the sewerage system from the hotels situated above Lake Kozjak in the last decades. Since recently the whole system was repaired, new measurements of the uppermost sediment layer should be done in the near future in order to see if these measures helped in reducing of detergent-derived chemicals.

The case studies performed on the municipality and industry domains were focused to the Una River catchment area in the Bihać area (Bosnia and Herzegovina) and to the springs used for water supply of this region. Since this region was practically isolated from the outer world during the war 1992—1995, many illegal waste deposits were formed, which — together with the possible pollutants coming from the abandoned military and industrial facilities — could have hazardous impact on the water quality. The measurements showed that the major pollutants in the river water are ammonia, nitrites and phosphates. However, the main springs in the Bihać area satisfy current regulations for public drinking waters. Groundwater flow dynamics, residence times, recharge rates and mixing between hydraulically connected aquifers from both countries, essential for the protection of karst water, were also studied by using natural and anthropogenic trace substances (isotopes).

On the basis of investigations performed during the period 2003-2005 we suggested several rehabilitation measures, primarily to the Bihać area, which suffered much during the war activities, like the inauguration of the continual monitoring of surface and groundwater, protection projects for water-supplying springs, making the land-register of pollutants and improvement of purification of waste waters from

industrial facilities. Further dyeing experiments in order to determinate the transboundary hydrodynamic characteristics and protection zones should be made. In the Plitvice Lakes National Park the control of the sewerage system should be continued. The record of possible anthropogenic influence to the lakes could be made by future monitoring of pollutants in the uppermost layers of lake sediment.

FINAL SUMMARY REPORT

OBJECTIVES

The objective of the project was the assessment of anthropogenic pollution after the war events and its consequences to the karst ecosystem in a border zone between Croatia and Bosnia-Herzegovina promoting the scientific-technical co-operation between these countries and some Member Countries of the European Union. The activities were focused on the hydrogeologically connected areas of the Plitvice Lakes National Park, including karstic fields (poljes) Koreničko, Lapačko and Krbavsko, from the Croatian side, and the Una River catchment area in the Bihac region, Bosnia and Herzegovina. The project was oriented towards the end users: local authorities, enterprises, national parks and non-governmental organizations in the area. Therefore, three specific case studies were chosen: on a tourist domain (National Park Plitvice Lakes), a municipality domain and an industry domain (Bihać area).

ACTIVITIES

Project was executed by 6 partners coming from 2 Member States (Spain and Germany) and 2 Western Balkan countries (Croatia and Bosnia-Herzegovina).

Partner No.1 (*Universitat Autónoma de Barcelona, **UAB**)* was the co-ordinator of the Project and responsible for Project organization and co-ordination. They performed measurements of cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) in water and trace elements (B, Al, Cr, Sr, Mn, Fe, Ni, Cu, Zn, Cd, Ba, Pb) in water and sediments, as well as qualitative and semiquantitative X-ray diffraction analyses of the sediment samples.

Partner No.2 *(Institut für Geowissentschaftliche Gemeinschaftsaufgaben, Hannover, **GGA**)* was partly responsible for the Hydrogeological recognition of the area. They measured anthropogenic (^{137}Cs, ^{134}Cs, ^{241}Am) and natural (^{210}Pb, ^{214}Pb, ^{214}Bi) radionuclides; stable isotopes ^{2}H, ^{18}O in surface and spring waters, $\delta^{13}C$ in sediments, noble gases and $^{3}H/He$, CFC (chlorofluorocarbons) and SF_6 in water.

Partner No.3 *(Ruđer Bošković Institute, Zagreb, **RBIZ**)* was responsible for sampling and helped the co-ordinator in contacts with Croatian and Bosnian partners. They performed *in situ* measurements at the Plitvice Lakes National Park and partly at Una River, measurements of organic and inorganic carbon, anions (F, Cl, NO_2/N, NO_3/N, HPO_4^{2}/P, SO_4^{2}, HCO_3), cations (NH_4^{+}), tritium in precipitation and spring waters, polycyclic aromatic hydrocarbons, ^{14}C in atmospheric CO_2, physico-chemical measurements of two depth profiles, ^{14}C, ^{13}C and ^{18}O in sediments and organic fraction in sediments.

Partner No.4 *(Geological Institute, Zagreb, IGEO)* was responsible for elaboration of the Geographic Information System and hydrogeological modeling.

Partner No.5 *(Geological Institute of BiH, Sarajevo, GeoBiH)* was responsible partly for hydrogeological recognition and partly for investigation of industrial influence to water quality and water supply capacities of the Bihać area.

Partner 6 *(Biotechnical Faculty, University of Bihać, **UBihac**)* was responsible for sampling and laboratory analyses at the Una River area, and partly for investigation of industrial influence to water quality and water supply capacities of the Bihać area. They performed *in situ* physico-chemical measurements and sampling of spring and surface waters in the Una River area for stable isotope and tritium analyses.

RESULTS

Project organization and co-ordination

The general administration of the consortium has been carried out by the project co-ordinator (Partner 1) and the assistant co-ordinator (Partner 3) who took care of the co-ordination among the partners from Croatia and Bosnia-Herzegovina. The partners from Croatia and Bosnia-Herzegovina met regularly during the field trips and occasionally in Zagreb, when partners from Bosnia submitted samples for analyses. The efficient information flow between the members of the consortium was achieved by regular exchanging of e-mails. At the end of each year the assistant co-ordinator visited Barcelona in order to help the principal co-ordinator in preparation of the annual and final report. Four consortium meetings were organized (see the Management report).

Hydrogeological recognition

The watershed of the Una River, belonging to the Bihać region, represents a sensitive and vulnerable karstic environment. Karstic aquifers in this area are hydrologically connected with water flows in the Lika region on the Croatian side: the Korana River catchment area, including the Plitvice Lakes National Park, and the karstic fields (poljes) Koreničko Polje, Lapačko Polje and Krbavsko Polje.

We collected 30 scanned topographic maps, scale 1:25000, of the whole investigated area, which served as the basis for locating geomorphologic, geological, hydrogeological and other significant elements. All previously obtained data on dyeing tests of sinking waters were reinterpreted from geological and hydrogeological point of view. Branching of all ponors exists in more directions, except for Vidrovac — Krbavsko Polje and Mazin — Lapačko Polje, which have only two privileged communications in different hypsometries. Ponors in lower levels (Vučjak, Željava) have less dispersion water links than those in higher levels (Prijeboj, Koreničko Polje). Ponors with greater distances from springs and in higher levels (Mazin, Krbavsko Polje) have connections with the largest springs only (Ostrovica, Klokot), these links are probably deeper and these paths toward Klokot have separate channels than those from Koreničko Polje, as from Mazin to Ostrovica also. Privileged and concentrated paths of groundwater circulation are determined: Gornji Lapac → Ostrovica, Donji Lapac → Ostrovica, Brezovac → Ostrovica, Krbavsko Polje → Klokot, Koreničko Polje → Klokot, Rastovača → Klokot. Lower velocities from all links to Ostrovica than to Klokot indicate the paths to Klokot are with greater karstification, which results in its stronger yield. Ponor (sinkhole) Donji Lapac besides dominant link to springs in the Una River valley communicates also in the inverse sense to the spring in Gornji Lapac.

Velocities to Klokot are always similar during different water levels from various karstic fields (poljes), what implicates similar type of karstification from different poljes

with several separate passages. Velocities from ponors in karstic plateau in lower altitudes (Vučjak, Željava) and closer to springs are something greater than previous.

The largest quantities of run out tracers are registered in the powerful springs, Dinaric strike of tectonic structures – NW-SE gives greater speeds related to inverse direction NE-SW.

Relation of hydraulic gradients and velocities of sinking waters do not have any mutual dependence. Proved deeper karstification, much lower than local erosion base (Klokot), indicates the presence of great static groundwater reserves and thereby the possibility of longer mean residence time and better autopurification of waters in karstic media from Lika to Una River valley.

All collected data were the basis for establishing the Hydrogeological Data Base which will be the basis for Geological Information System, hydrogeological model of terrain and working out the vulnerability maps of the area.

Sampling and measurements

Sampling of precipitation for stable isotopes and tritium measurements and sampling of atmospheric CO_2 for ^{14}C measurement were organized since July 2003 on a monthly basis. Surface water samples were collected seasonally during 2003 and 2004 at 15 sampling points (springs, lakes, streams between lakes and tributaries) that included eutrophic and non-eutrophic waters. In addition, in September 2004 sampling of water of two depth profiles on lakes Prošće (25 m) and Kozjak (45 m) were performed. *In situ* measurements were done at each 1 m depth, while other chemical analyses were performed at each 5 m.

Sampling points of spring and surface waters in both Plitvice Lakes National Park area and Una River catchment area (including Bihać region) were chosen during the *kick-off* meeting in April 2003. However, during the time the microlocations of some sampling points were modified after the agreement within the consortium, so some sampling points were added and other rejected for further analyses.

Undisturbed lake sediment cores, approximately 40 cm long, were retrieved during the autumn field trip from 1 to 3 November 2003 by scuba divers from the bottom of 4 different lakes: Prošće, Gradinsko, Kozjak, and Kaluđerovac. Five locations were chosen and from each location three half-meter cores were taken. In Lake Kozjak two locations were selected: K1, in the middle of the lake, where no eutrophication process is observed, and K2 near the mouth of Rječica Brook, with much expressed eutrophication process. This process was also observed on lakes Gradinsko and Kaluđerovac. The cores were immediately frozen and transported to the Ruđer Bošković Institute in Zagreb, where they were cut to sub-samples and distributed for subsequent analyses. Additional samplings of sediment from the location K-2 with expressed eutrophication process were performed in July 2004.

Geographic Information System and elements for establishing a hydrogeological model

During the first and second year of the project, activities of Partner No.4, together with hydrogeologists from Sarajevo (Partner No.5) were focused to collection, preparation and organization of data, which served as a background for elaborating a hydrogeological model and further modeling of intrinsic vulnerability, hazard and risk assessment of surface and groundwater resources in the area of transboundary aquifers between the Plitvice Lakes catchment area (Croatia) and the Una River catchment area

in the Bihać region (Bosnia and Herzegovina).

All relevant data collected during the field work (1st and 2nd report period) and the results of previous studies have been incorporated into the GIS form suitable for an intrinsic vulnerability and risk modeling and assessment. At the end of the 2nd reporting period hydrogeological map scale 1:100,000 and the structuring of data base were completed. All hydogeological data (hydrographic surface network, results of tracing tests, water objects and karst morphological elements — springs, lakes, wells, swallow holes, pits etc.) were elaborated on map 1:25,000 with the amounts and accurancy of data appropriate to satisfy the scale of final map scale 1: 100,000.

Analysis and data management was performed within the Geographic Information System (GIS) with the aid of Arc/Info software (ESRI Cal. USA) and the analysis results can be visualised and modelled through the ArcMap-ArcView software.

The interpretation produced important data for establishing the hazard spatial distribution and data about vegetation characteristics important for modeling an intrinsic vulnerability of waters and groundwater. During the 3rd reporting period intrinsic vulnerability and risk assessment of surface waters and groundwater were completed.

Within the whole study area, approximatelly 2752 km^2 large, following thematic maps were prepared:

1. Hydrogeological map and data base, scale 1:100,000;
2. Land use map, scale1:100,000;
3. Unclassified and classified hazard maps and data base, scale 1:100,000;
4. Intrinsic vulnerability map, scale 1: 100,000;
5. Risk map, scale 1:100,000.

In spite of the fact that restriction of vulnerability, hazard and risk assessment originated from the quantity and quality of data and the applied method, used approach shows many advantages for end-users:

- Formation of general base with all existing, geological, structural, morphological and hydrogeological data about surface water and groundwater resources relevant for intrinsic vulnerability assessment, distribution of different types of hazards and its potential impact – risk assessment on surface water and groundwater quality.
- Obtained maps and data bases are very useful tool for land use planning regarding the surface and ground water protection and water authorities of both countries can use such data for urgent decision making.
- The structure of data bases and layers prepared in GIS-forms allow their further application for other purposes in the future.

Investigation of anthropogenic influence to the Plitvice Lakes National Park

The Plitvice Lakes consist of a series of 16 lakes separated by tufa barriers and waterfalls. In this very complex aquatic system calcium carbonate precipitates intensively, forming tufa barriers in the presence of microphytes and macrophytes. The area was proclaimed as a National Park almost 60 years ago and included into the UNESCO World Heritage List in 1979. We tried to identify the sources of eutrophication process in the Plitvice Lakes area to see whether it is a consequence of anthropogenic pollution or a natural process.

The results of physico-chemical measurements of water at 15 sampling points along a flow distance of about 12 km, including sites with very intense $CaCO_3$ precipitation, show that temperature, pH, alkalinity, and hence the saturation index of $CaCO_3$, show significant change in downstream flow and also some seasonal variations. The results show that the carbon exchange process along $CO_2 \rightarrow HCO \rightarrow CaCO_3$ plays an important role for tufa precipitation. Concentration of dissolved organic carbon (DOC) is higher in lake waters where eutrophication process is significant (1—2 mg/L) then in non-eutrophicated water, *e.g.* in spring waters (0.3—0.5 mg/L). Additionally, DOC values are also higher in some "clean" stream waters, where tufa does not precipitate in spite of otherwise favorable physico-chemical conditions for calcite precipitation, such as the high degree of supersaturation. In this case probably DOC inhibits tufa deposition. The concentration of dissolved nutrient salts, as well as of trace elements in water, is very low for most sampling points. No systematic difference in concentration of these species between "clear" and eutrophicated waters was observed. $\delta^{13}C$ values of DOC in water of the Plitvice Lakes area steadily increase downstream from the karst springs ($\delta^{13}C$=12.5‰) to the river mouth ($\delta^{13}C$ =10.0‰). Simultaneously, the increase of ^{14}C activity of DIC in downstream flow in the same area was observed as the consequence of the exchange process between the atmospheric CO_2 and DIC in water at rapids and waterfalls.

According to the chemical and isotopic measurement of water there is indication that the concentration of DOC is higher in the areas where the process of eutrophication is pronounced and that higher DOC concentration in water can inhibit the calcite precipitation in form of tufa. These measurements do not indicate recent anthropogenic pollution of lake waters, and higher concentration of DOC at some sampling points can be a consequence of input of natural organic matter (humus) to the lake water.

The chronology of the pollutant input was established by measuring activities of anthropogenic (^{137}Cs) and natural (^{210}Pb, ^{214}Pb, ^{214}Bi) radionuclides, which gave us the sediment accumulation rate and thus the age of specific sediment layers. For the smaller lakes higher sedimentation rates are obtained for the anthropogenic tracer ^{137}Cs. In contrast sedimentation rates in the larger lakes give similar values for ^{137}Cs and ^{210}Pb. One possible explanation for the higher sedimentation rates in the smaller lakes is the higher water temperature during the warm months and accordingly quicker carbonate precipitation than in the bigger, colder lakes. By measurements of ^{14}C in sediment cores we found the increased values of ^{14}C at the depths between 5 and 15 cm, which are the consequence of the bomb-produced ^{14}C in the period 1949-1963 and they correspond to the peak values in ^{137}Cs activity.

The relative composition of minerals for each sediment core shows prevalent presence of calcite, except for the core taken near the mouth of a tributary to Lake Kozjak, where there is significant presence of dolomite and quartz too. Also the content of organic matter is the highest in this core as the consequence of transport of terrestrial material. At the same location the concentration of most trace elements including phosphorus is the highest causing the high degree of the eutrophication process in this area. Trace elements and organic matter content decrease from the uppermost lake downstream to the lowest lake. This fact indicates that the most of trace elements in sediments could be of natural origin due to transport from the main springs and their steady deposition along downstream lakes.

Content of trace elements along the 40 cm sediment cores from all sampling sites is much below maximum concentrations permitted for metals in soils in European

Union. There is no significant difference among the trace element concentration in the upper segment of all cores, corresponding to last 50 years when higher anthropogenic influence can be expected, and the lower part of the cores, corresponding to the period 100-200 years before present.

The increasing concentration of some organic compounds in the recent/surface lake sediments, e.g. linear alkylbenzene sulphonates, reflects an increasing input of detergent-derived chemicals. The higher concentration of detergent derived chemical could be caused by the defects in sewerage system from the hotels situated above Lake Kozjak in the last decades. On the contrary, the concentration of some oil-derived chemicals (polycyclic aromatic hydrocarbons) shows decreasing trend in the last decades.

Assessment of the industrial influence to water quality in Bihać area

On the basis of reports of Partners No.1, No.2, No.3 and No.6 main springs in the Bihać area (Klokot, Privilica, Ostrovica and Toplica) satisfy current regulations for public water-supply drinking waters in Bosnia and Herzegovina. NH_4^+, NO_2 and HPO_4^2 showed only occasionally concentration above maximal permitted concentration. Physico-chemical analyses of all tapped springs in the Bihać region were made by the Public Health Institute — Bihać in 2003 and 2004, and the results satisfy the present regulations.

Presence of microorganisms in each spring as indicator of faecal pollution does not point at the anthropogenic influence on water. One could not define clear difference on bacteriological correctness of waters before and after the war, because the state of protection was very similar in both periods and not any improvement of quality of all spring waters after the war was shown.

Measurements of spring and river waters showed that the major pollutants in water were ammonia, nitrites and phosphates. Increased ammonia concentrations in Una River downstream from Bihać are indicators of pollution of faecal waste waters, soil erosion and of filtered waters from waste dumps, etc. Waste waters are being left without being processed before, and the final collector of all these waste waters is Una River. The presence of ammonia concentrations in the spring water indicates the possible water pollution from the Croatian side (fields Krbavsko Polje and Koreničko Polje). In all tested water samples, there was only a small amount of nitrate concentrations detected. Sulphates occured in natural water in high concentrations. In springs they range from 3.9 to 6.6 mg/L, and in the water of Una River basin from 20.0 to 29.4 mg/L. The concentration of phosphates was detected in all researched water samples taken in September 2004 except in Una River in Ripač. In all researched waters maximal detergent content is 0.003 mg/L which cannot present the hazard to the ecosystem stability in Una River basin. In some water samples, there was no detergent content found.

Wastewaters of the urban sewage of town Bihać outflow to Una River in Vrkašić, downstream of the town without any treatment. The same situation is with all other industrial waste waters in the Bihać area. No reliable data on locations and characteristics of illegal waste deposits exist in Bihać. Hygienic-sanitary state of resident houses is in general not satisfactory, faecal material pollute the soil, ground and surficial waters. Unknown consequences of contamination yet exist from toxic matters, which were stored in abandoned military facilities. The most important are the ex-airport and tunnels of Željava (close to Bihać) and Udbina (in field Krbavsko Polje, Croatia). Valid protection of water-supply springs and Una River is not possible without

finding the solution of waste water purification of town Bihać, settlements, and industry prevent illegal waste deposits, sanitation of terrain, regular exploitation of quarries and prevention measures in agriculture.

Investigation of water supply capacities in Bihać region

The understanding of groundwater behavior like residence times, their flow paths and mixing between different aquifers is essential for the protection of karst water in both countries. Also for the protection of karst water in both countries, knowledge on dynamics of groundwater flow, groundwater residence times, recharge rates and mixing between different aquifers is important. The concentrations of natural and anthropogenic trace substances can provide insights into these questions. In this study concentrations of stable isotopes ($\delta^{18}O$ and $\delta^{2}H$), chlorofluorocarbons (CFC-11, CFC-12, CFC-113), sulphur hexafluoride (SF_6), tritium (^{3}H), helium (He) and neon (Ne) as well as the isotope ratio of helium ($^{3}He/^{4}He$) were measured in spring, lake and surface water.

The dyeing experiments performed in the period between 1973 and 1989 showed that the water infiltrated from Koreničko Polje (close to Plitvice Lakes), Prijeboj and Krbavsko Polje in Croatia discharge in the springs Klokot and Privilica near Bihać. Measurements of stable isotopes content ($\delta^{2}H$ vs. $\delta^{18}O$) showed two different clusters: more positive values from Una River, and more negative values from Plitvice Lakes catchment area. The springs Klokot and Privilica which serve for Bihać water supply have the stable isotope signature of the Plitvice catchment area, suggesting a karst hydrologic connection between the two systems, as expected from dyeing experiments. The second infiltration area around Lapačko Polje and Mazin in Croatia feeds the Una River with its springs Una, Toplica and Ostrovica and obviously has more positive deuterium values. Connection of springs in Bihać region (Bosnia) with water from the Lika region in Croatia has been studied also by measurement of tritium activity. Results of tritium activity measurements in main springs used for water supply of town Bihać and surrounding places were compared with the values in precipitation taken at Plitvice Lakes. Mean value of spring Privilica is the closest to the mean value in precipitation. On the other hand, this spring has the smallest fluctuation in tritium activity, indicating the greatest long-term component of its aquifer. Mean values of tritium activity in springs Toplica and Ostrovica and Klokot do not correspond such well to the mean value in precipitation. However, their fluctuations correspond to each other, indicating the bigger influence of short-term component in aquifer. Spring Klokot shows the fastest response because of the shortest MRT, which is in concordance with the stable isotope measurements.

The complexity of the karst system requires an approach using several such tracers, since one alone leaves too much ambiguity in interpretation. A multi-tracer approach was applied for the determination of mean residence times in ten springs. For groundwater dating in many cases a two-component model is used, describing the mixture between two water contributions of different age. For example this can be the combination of an exponential model for the “young” and a piston flow model for the “old” component. As expected from the hydrological point of view, the springs show very different mean residence times. The “young” water component in the springs shows MRTs between 0.1 and 0.8 years, whereas the “old” component is between 2 and 130 years (*cf.* pages 12-15 in final report of P2). The information about the residence time of water in an aquifer is very important regarding the eventual pollution and storage capacities of the aquifers.

Rehabilitation measures

The problem of water quality is especially emphasized in the Bihać region, because of the relative high population density, existing industrial facilities that were active before the war, and the consequences of war (1992-1995), when the whole region was practically isolated from the outer world. There is still no evidence about the factories which perform purification of waste waters. However, no studies about influence to the environment exist for the new-opened companies. No land register of pollutants has been set up and the systematic monitoring system does not exist.

The initial activities should be focused to the continuation of work on the Basic hydrogeological map of Bosnia and Herzegovina (1:100,000). Complex and continual monitoring of surface and groundwater should be inaugurated and protection projects of water supply springs should be made. The intake structures of main water-supply springs should be renovated and reconstructed. Monitoring of water quality should be established, as well as the land-register of pollutants. Records of all factories that should purify the waste waters should be made. Present waste deposits in watersheds of springs should be dislocated immediately. New sanitary waste deposits should be formed and uncontrolled usage of various protection means in agriculture should be prohibited. Special attention should be paid to the investigation of very dangerous pollutants from former military facilities (airport Željava). New locations for water-supply should be programmed by carrying out geological, hydrogeological, geophysical researches and investigation by drilling holes and wells. Future investigations should be focused also to dyeing tests in order to determine hydrodynamic characteristics and protection zones in Croatia and Bosnia-Herzegovina.

Although Plitvice Lakes National Park represents a very clean area and the authorities consider the ecology of great importance, the recent investigations pointed to some problems that should be solved. The higher concentration of detergent derived chemicals, which was observed in Lake Kozjak could be caused by the defects in sewerage system from the hotels situated above this lake in the last decades. Since recently the whole system was repaired new measurements of the uppermost sediment layer should be done in the near future in order to check if these measures helped in reducing of detergent derived chemicals.

CONCLUSION

General benefit of the Project was the reinforcement of the links in the field of RTD between Croatia and Bosnia and Herzegovina with two Member States (Spain and Germany), by promoting scientific and technological co-operation between organizations and researchers from these countries. The main result of the project was the conclusion that in general no anthropogenic contamination exists in the region of the National Park Plitvice Lakes. However, some kind of control monitoring should be applied by the authorities of the National Park. On the other hand, in the Biha

region (Bosnia and Herzegovina) we found many environmental problems, mainly as the consequence of war activities 1992-1995. The proposed Rehabilitation measures are listed in the Consolidated Scientific Report.

The benefits coming from this Project are obvious for the groups from Bosnia and Herzegovina, especially group from Biha

, because the scientific connections, broken during the war, were established again and the access to the new methodologies and technologies was enabled. For all groups

from Croatia and Bosnia-Herzegovina it was very useful to be acquainted with the European projects.

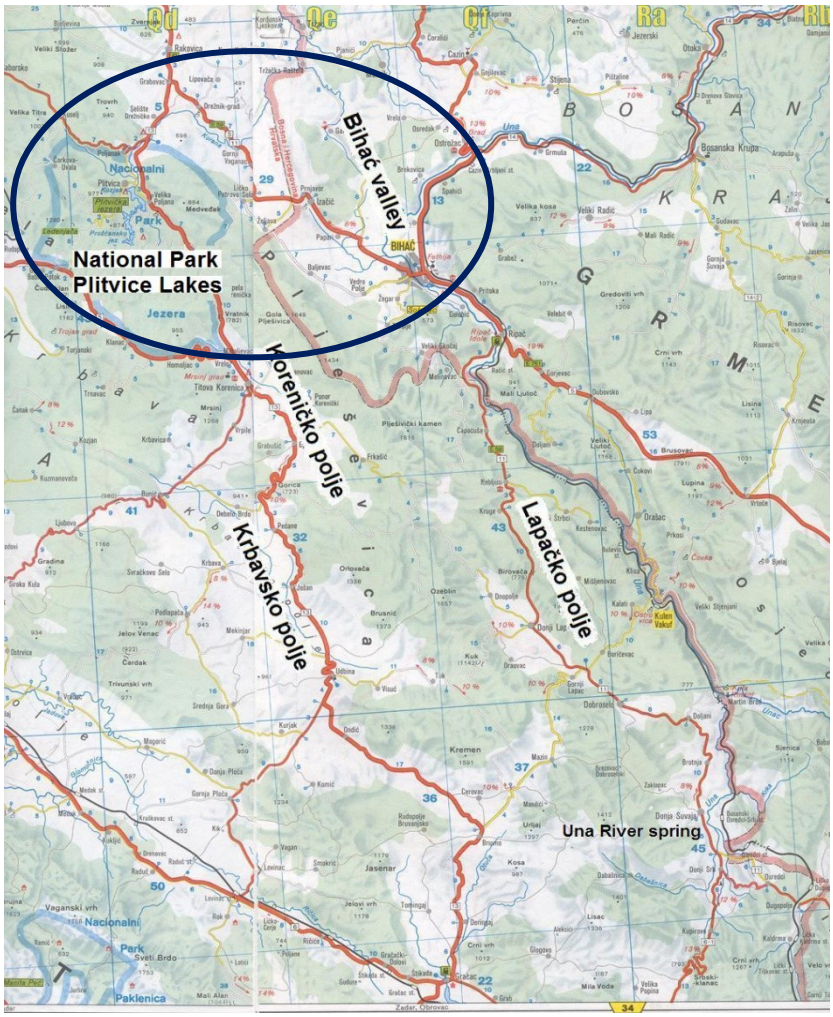
The results obtained within the project ANTHROPOL.PROT were used in proposals of new five-year projects of scientific investigation within the call of the Croatian Ministry of Science, Education and Sports that ended on March 10, 2006. Partner No.3 submitted the project entitled *"Natural radioisotopes in investigation of karst ecosystems and dating"* and Partner No.4 the project entitled *"Vulnerability of karst hydrogeological systems"*. Both projects take part of a broader scientific program *"Water in Karst – dynamics, geochemistry and isotopic processes"* led by the assistant co-ordinator of the project ANTHROPOL.PROT.

This project triggered several national and international projects focused to the problematics of karst water vulnerability. The project *"Investigation of the influence of the forest ecosystem of the National Park Plitvice Lakes to the quality of water in the lakes"* has been financed by the Plitvice Lakes National Park authorities. Besides the Ruđer Bošković Institute, other partners of this new project are from the Faculty of Forestry and State Meteorological Survey of Croatia in Zagreb. The project of technical co-operation with the International Atomic Energy Agency (IAEA CRO/8/006) entitled *"Application of isotope techniques to investigation of water resources and water protection in karst area of Croatia"* is also in progress. A new project with IAEA entitled *"Isotope tracers as a tool for groundwater vulnerability assessment in Split-Dalmatian County"* has been approved for the period 2007-2008. Also, as the results of investigations made within the EU project ANTHROPOL.PROT the area of Plitvice has been included recently as a new monitoring point of the IAEA project of Global Network of Isotopes in Precipitation (GNIP).

Several Ph.D. and diploma theses covering the problematics of anthropogenic influence to the transboundary karstic area of Croatia and Bosnia and Herzegovina are still in progress. The list of these academic activities is given in Dissemination activities of the Consolidated Scientific Report.

All the partners consider this Project to be a "successful story" because new links between the groups and new friendships between the persons were formed. The fruitful and friendly co-operation between the groups from four countries permits us to present a new project within the 7th Framework Program. Unfortunately, there was no enough time to prepare it for the last West Balkan Countries call within the 6th Framework Program with the deadline on March 6, 2006.

Maps of the area covered by investigations



Border area between Lika region in Croatia and Una River valley in Bosnia-Herzegovina