

# Research in the Field of Environmental Sciences at the University of Nova Gorica

By Polonca Trebše

Research at the University of Nova Gorica (formerly Nova Gorica Polytechnic) has been traditionally oriented towards environmental sciences. This is also evident from the fact that the Institution was founded in 1995 as the School of Environmental Sciences, where “environment” was always referred to from a very broad perspective. This is reflected in the activities of different research groups, which were established later as result of growth of the institution and which triggered the need for reorganisation and change of the institution's name. Research related to environmental sciences ranges from investigations at the molecular level to investigations of phenomena originating in the universe. Currently, environmental or environment-related research is conducted in four laboratories and two centres, which represent six out of seven research units at the University of Nova Gorica: the Laboratory for Environmental Research, the Laboratory for Astroparticle Physics, the Laboratory for Epitaxy and Nanostructures, the Laboratory for Multiphase Processes, the Centre

for Atmospheric Research and the Centre for Environmental and Sports Physiology.

In the first years after founding, our activity was primarily directed towards development of new analytical techniques and instrumentation for measurement of environmental parameters, and was very much dependent on collaboration and the availability of research equipment at other institutions, particularly the Jožef Stefan Institute; Wageningen University in the Netherlands; HASYLAB synchrotron radiation laboratories at DESY, Hamburg; ESRF in Grenoble; LURE in Orsay; ELETTRA in Trieste; and international collaborations such as DELPHI at CERN, Geneva, Switzerland; and the Pierre Auger Collaboration, where a substantial amount of our research was carried out. By attracting and employing many young scientists, graduate students and professors from all over

Slovenia, we succeeded in building new research laboratories with state-of-the-art scientific equipment (gas chromatographs with FID, ECD and MS detectors, HPLC chromatograph with DAD and fluorescence detectors, ion chromatograph, fundamental and frequency doubled Ar lasers, excimer and pulsed dye lasers, LIDAR systems, atomic force microscope (AFM), simulation system for transport phenomena, etc.).

At present, the major part of the environmental research at the University of Nova Gorica is conducted in the Laboratory for Environmental Research, where basic research activities are directed into different research fields. These include the development of laser-based methods, bioanalytical methods and ecotoxicological tests for identification and determination of toxic compounds and their effects on the environment, investigation of photochemical and microbial degradation, as well as the transport of pollutants in the environment, and the investigation of antioxidants in agricultural products, foodstuffs and biological systems. The activity of the laboratory has also recently extended into the preparation and characterisation of new materials which have potential applications in environmentally friendly systems, such as membranes for fuel cells and utilisation of alternative energy from biomass. Among our important research achievements, we must mention the development of highly sensitive analytical methods based on photothermal techniques, such as ther-



Assistant Professor Dr Polonca Trebše



Junior researcher analyzing GC chromatograms (Photo P. Trebše).



Fieldwork with students (Photo Jana Laganis).

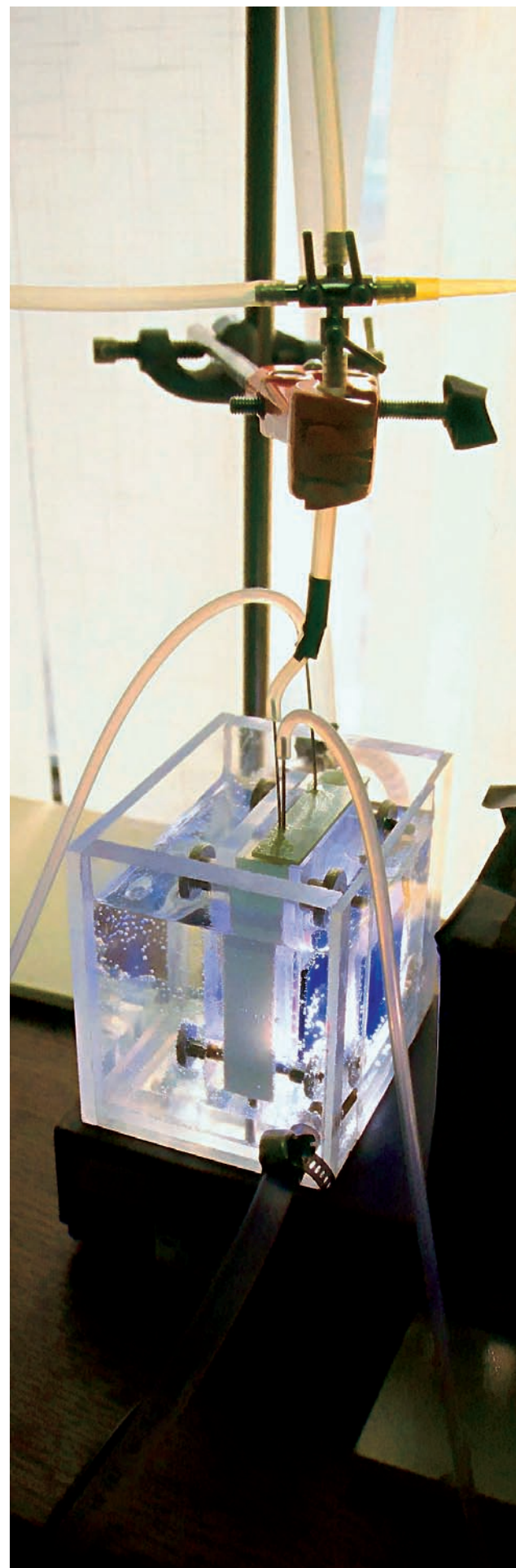
mal lens spectrometry (TLS), which we combine with bioanalytical techniques (acetylcholinesterase – AChE biosensors), flow injection analysis (FIA) and liquid chromatography. Besides the detection of toxic compounds (organophosphate, carbamate and neonicotinoid pesticides, chromate, etc.), the methods developed are applied to investigate the role of biologically active compounds such as antioxidants in different physiological processes. Carotenoids are, for example, the subject of our investigations related to photochemical cycles in plankton and aquatic plants and phytoplankton



cell lysis, while highly sensitive TLS detection of bilirubin is exploited to investigate the transport of antioxidants across cellular membranes and the function of associated transport proteins.

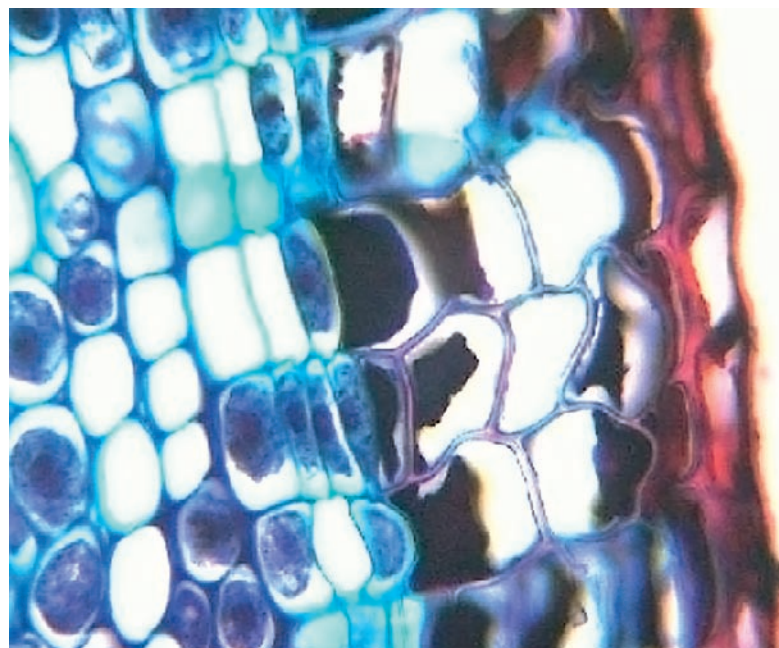
In the field of ecotoxicology we investigate the toxicity of organophosphorus and neonicotinoid pesticides. The effects of pesticides on terrestrial invertebrates (Isopoda) are studied based on activities of different enzymes, such as acetylcholinesterase and glutathion-S-transferase and energy reserves (lipids and glycogen) in organisms. In addition, changes in concentrations and the transformations of organophosphorous and neonicotinoid pesticides are monitored in the laboratory and in the natural environment during field experiments. The application of such organisms as indicators of environmental pollution is of major interest to us. Because of their nutritional value, we investigate various groups of antioxidants such as anthocyanins and hydroxycinnamic acids in certain fruit species like sweet cherries and white grapes. We are primarily interested in the research of the local cultivars, and special attention is devoted to the impact of environmental factors on polyphenol content, such as growing position, weather and orchard or vineyard handling.

One of our latest interests is focused on the synthesis and use of  $\text{TiO}_2$  thin films for environmental applications, which have already been tested in our laboratory for degradation of specific pollutants. We use a sol-gel technique for preparation of such films. By modifying the conditions of the sol-gel meth-



Photocatalytic cell (Photo U. Černigoj).

od and addition of a specific surfactant and by high calcination temperature, we are able to change the morphology and structure of the films. In addition, we are working on thin films prepared in a low-temperature sol-gel process, which is more suitable for substrates like plastics. For the determination of the structure of thin films, different spectroscopic and microscopic techniques are applied. For example, the surface roughness of nanostructured  $\text{TiO}_2$  films is characterised by atomic force microscopy, an invaluable tool for characterisation of nano materials. The atomic force microscope is the latest achievement of the Laboratory for Epitaxy and Nanostructures, where it is mainly employed to assess the morphology of single-molecular-layer organic semiconductors, which are fabricated in the Laboratory by organic molecular deposition using an ultra-high vacuum evaporation chamber. In addition, the nanoscale electronic properties of organic semiconductor thin-film transistors are investigated using a conductive atomic force microscope and a Kelvin probe. Relevant results were recently achieved in the area of photocatalysis,



Cork formation (Photo Jana Laganis).

**Virgin forest at Rajhenavski Rog – field work in ecology (Photo Jana Laganis).**

where our experiments are focused on the application of  $\text{TiO}_2$  thin films as the catalyst for degradation of substituted phenols, textile and other dyes, pesticides and pharmaceuticals under simulated (UV light) and environmen-

tal conditions. New techniques for degradation of pollutants, such as pharmaceuticals, pesticides and endocrine disruptors in waste and drinking waters by laser light, ionising radiation and advanced oxidation techniques (i.e. ozone) are being investigated as well. In our endeavours toward the development of novel, sensitive and selective methods of chemical analysis, we exploit the advantages of the latest laser technology (for example, intra-cavity frequency doubled Ar-ion laser) and laser-based methods such as thermal lens spectrometry. By combining TLS and HPLC liquid chromatography, we have developed a highly sensitive method for determination of neonicotinoid pesticides (thiacloprid, imidacloprid, thiametoxam and acetamiprid), which





Endangered and protected crab species (*Macropodia longirostris*) (Photo Jana Laganis).

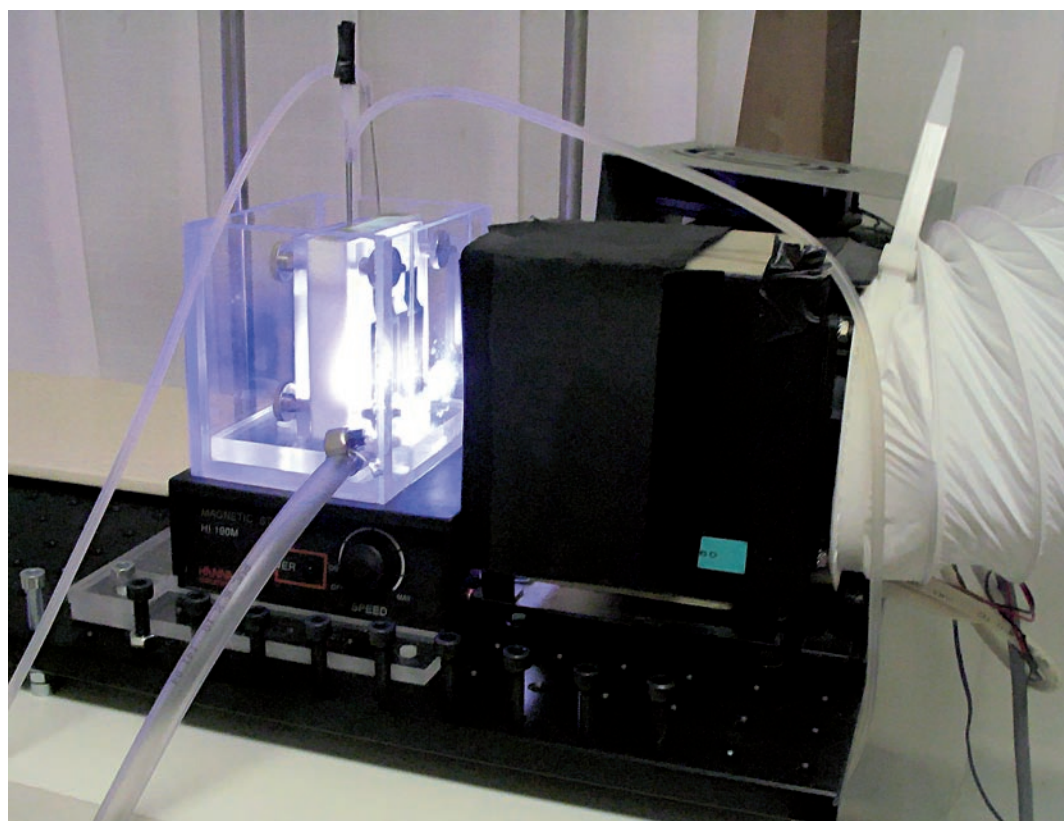
enables their quantification at concentration levels as low as 10 ng/mL, as demonstrated for thiacloprid. This is one order of magnitude lower compared to spectrometric diode array detection in HPLC.

Among other approaches to enhanced sensitivity of photothermal methods, we also use ionic liquids, which belong to the group of “green solvents”. On one hand, this is important because it reduces emissions of volatile organic compounds into the environment, but, on the other, as we have demonstrated by performing the first measurements

of the thermo-optical properties of ionic liquids (thermal conductivity, temperature coefficient of refractive index), they also provide a favourable medium for photothermal measurements, which offers up to 25 times the sensitivity of TLS detection in aqueous solutions.

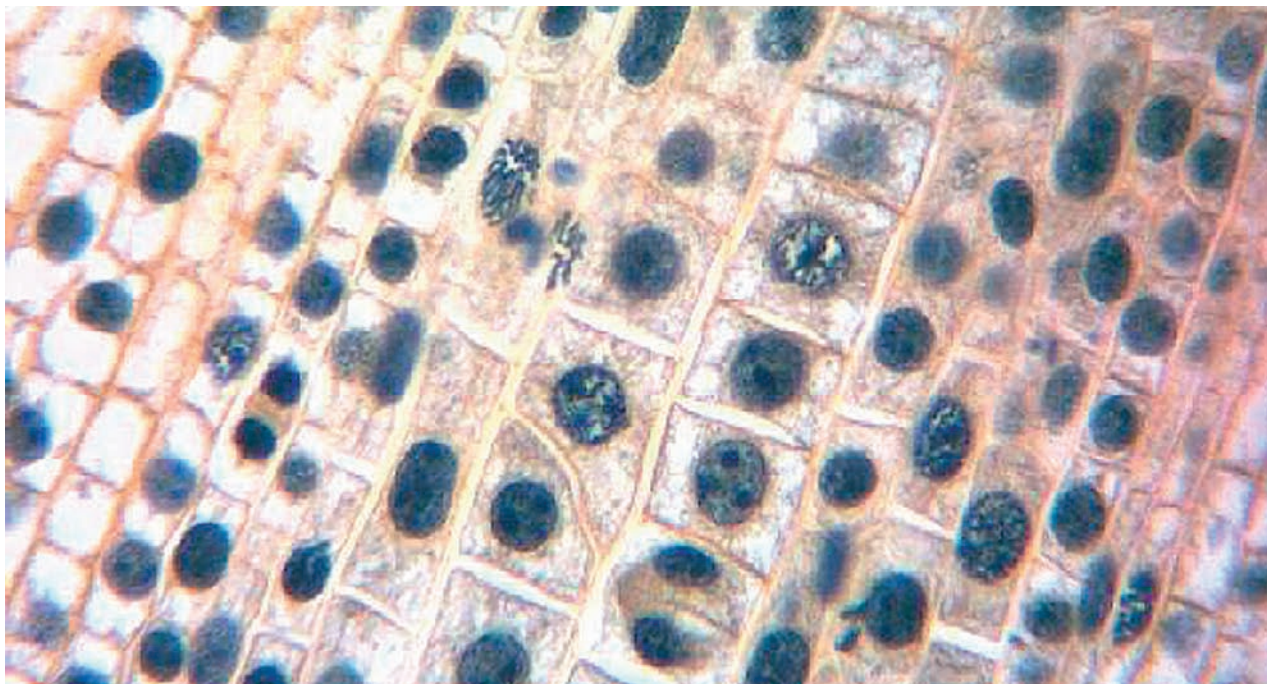
The most recent application which demonstrates the importance of highly sensitive analytical methods is the investigation of the transport of bilirubin, an important endogenous antioxidant, across the cellular membrane of he-

**TiO<sub>2</sub> films irradiated by UV light, thus promoting the degradation of organic matter in water (Photo U. Černigoj).**



patic cells and the role of transport proteins in the cellular membrane. By applying TLS we achieved an LOD of 1 nM bilirubin and enabled measurement of its uptake by HepG2 cells under normal physiological conditions, where the maximum concentration of bilirubin is limited to 50 nM by its low solubility. This concentration is inaccessible by conventional spectrometric methods. In collaboration with Prof. Sabina Passamonti's group from the University of Trieste, we have demonstrated that the uptake of bilirubin is significantly increased by the presence of lactate and ethanol, which reduce the NAD<sup>+</sup>/NADH concentration ratio in hepatic cells and trigger the transformation of bilitranslocase into its high-affinity conformation. The role of the membrane protein bilitranslocase in the transport mechanism of bilirubin was studied by measuring the uptake of bilirubin in hepatic cells in the presence of substrates of other organic anion transporting proteins, such as digoxin. This had no effect on the uptake of bilirubin, and for the first time experimentally confirmed the role of bilitranslocase in the transport of bilirubin across the cellular membrane. Our activities in the field of applied research are oriented primarily towards the application of photothermal and bioanalytical techniques for food quality control. In this regard, newly developed analytical methods are applied to determine characteristic carotenoids which serve as indicators of the quality and origin of olive and other vegetable oils, and fruit juices. AChE-based photothermal biosensors are presently being tested for large-scale application in fruit juice production, where they will be used as a rapid and low-cost screening method for the presence of organophosphate pesticides.

We have recently initiated several studies on the ecological energetic properties of terrestrial ecosystems. This reflects the so-called systems ecology approach to the evaluation of sustainable management, where estimation of ecosystem integrity is the most important. The central interests of our activities in this field are studies of ecosystem growth and development processes, and self-organizing properties of ecosystem evolution. We apply modern techniques ranging from thermal remote sensing of ecosystem surfaces to estimation of the information stored in genome size. Special attention is paid to nonlinear thermodynamic parameters as systems indicators (e.g. specific exergy, exergy dissipation, inclusive Kullback index and



**Mitosis in the root apex of Allium (Photo Jana Laganis).**

energy). Relationships between these indicators and ecosystem growth and development processes are evaluated with different ecological modelling tools, including STELLA, EcoPath, etc. New approaches are also being exploited in investigations of the pollution of soil with heavy metals. In this regard we examined several urban areas in south England (Cornwall), where the soil is contaminated with an extremely high level of arsenic (up to 15%) as a result of the historical mining, processing and refinement of arsenic ores in purpose-built calciners. The results showed that arsenic is mostly associated with amorphous phases or adsorbed species, which represents high environmental risk and implies a potential leaching of arsenic into drinking water sources or uptake by locally grown crops and which consequently poses a danger to the public. Assessment of the chemical form of arsenic and its speciation was crucial in this case. For this reason EXAFS (Extended X-ray Absorption Fine Structure) and XANES (X-ray Absorption Near Edge Structure) x-ray absorption methods for analysis of the atomic and molecular structure of sampled soil were exploited. EXAFS is often the only practical way to study the arrangement of atoms in materials without long-range order. Traditional diffraction techniques cannot be used in such cases, and EXAFS is therefore a powerful tool in the non-destructive analysis of environmental samples. The results of this research are expected to initiate the development of effective remediation strategies and management of such highly polluted

**Through the subalpine beech forest (Photo Jana Laganis).**



sites. A development of a similar environmental assessment methodology for lead-contaminated land around a former lead mine in the Meža Valley in Slovenia is in progress. We are examining the capacity of humic acids, the natural carbon-rich biopolymer constituent of soil, to interact with cyano-complexes and thus affect the leaching of complexes and prevent the consequent risk of contamination

of the water table. We showed that interaction between humic acids and ferricyanide complex led to formation of ferricyanide-humic micelles, and that the interaction did not imply changes in the original structure of the ferricyanide complex. For remote sensing of air pollution and physical processes in the atmosphere, we use the most recent laser technology. Our first steps in the field of remote sensing were, however, triggered by the need to control

the quality of the atmosphere when we investigated high-energy cosmic rays as part of the Pierre Auger Collaboration in which the Laboratory of Astroparticle Physics is involved. As a result, the first aerosol LIDAR in Slovenia was assembled. The instrument enables measurement of relative concentrations of aerosols and the absorptivity of the atmosphere at 355 nm at distances up to 25 km and with a spatial resolution of 10 m

and temporal resolution of 3 seconds. Such an instrument, which is computer-controlled from Nova Gorica, has been installed at the Pierre Auger Observatory for high-energy cosmic rays in Malargue (Argentina) – the largest observatory for cosmic ray research ever built. Our second LIDAR system has been assembled at Otlica near Ajdovščina where the Centre for Atmospheric Research is engaged in studies of aerosol transport in the higher troposphere. In collaboration with the University of Iowa, methods are being developed for indirect determination of emission rates, wind profile and vertical diffusivity of aerosols around highways, streets and other sources of pollution. The development of a mobile lidar for studies of air pollution transport in the atmospheric boundary layer is also under way.

The University of Nova Gorica is successfully working together with the Slovenian Agency for Radwaste Management (ARAO) and other regulatory bodies on a computer simulation of the foreseen Slovenian low and intermediate nuclear waste repository. Simultaneously, the enhancement of our own simulation capabilities for the assessment of the transport of radionuclides and other pollutants in different natural and technological systems is in progress. The simulation tools are based on the most advanced meshless numerical techniques, developed in the Laboratory for Multiphase Processes. These methods are also used in simulation systems for the steel and aluminium industries, and brick production, where the quality of the product and minimal environmental impact of the process are of great importance.

Our applied research in this field has resulted in an intense collaboration with the aluminium company Impol in Slovenska Bistrica for simulation of temperatures, velocities and concentrations in DC cast aluminium alloy billets and slabs. The collaboration is reflected in improved regulation algorithms and substantial enhancement of product quality and process yield. The computer-aided automatic optimisation of process parameters in the continuous casting of steel, related to domestic, Czech and Finnish steelworks, is underway within the European Concerted Research Action, designated as COST-526. A project on modelling hollow-brick manufacturing and usage was started for the Goriške Opekarne brickworks. All related industrial process modifi-

cations and upgrades are performed in close cooperation with industrial research teams.

Interest in health-related environmental issues has recently been extended to research projects at the Centre for Environmental and Sports Physiology. In the field of environmental physiology our research is focused primarily on human performance in normoxic and hypoxic environments, and takes into account both cardiovascular and respiratory systems. We have also been investigating the effects of particulate pollution on the respiratory functioning of asthma patients and “voluntary” dehydration levels occurring during exercise in warm environments. These projects involve research partners with different scientific backgrounds, from physiology, medicine, sport science, physiotherapy, etc. The field of environmental physiology enables us to focus on physiological responses in humans

**Sponge crab (*Dromia personata*) (Photo Jana Laganis).**

with respect to the different environmental factors which in one way or another affect the performance of our physiological systems.

The laboratories at the University of Nova Gorica are also part of the technological platforms Advanced Materials and Water and are active partners in EU co-financed national centres of excellence including the *Centre of Excellence in Environmental Technologies*, where we collaborate in the project Biological Treatment of Waste Waters with the work package Photochemical Degradation of Pesticides, *Centre for Advanced Processing, Technologies and Materials*, which includes development of new, environmentally friendly technologies in production of technologically important ceramic materials and the *Centre of Excellence in Nanoscience and Nanotechnology*, where we collaborate in the project *Nanostructured Surfaces and Interfaces*.

**Fieldwork in ecology (Photo Jana Laganis).**



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