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INSTITUTE FOR MEDICAL RESEARCH AND OCCUPATIONAL HEALTH

Annual report



2021

14. ORGANISATION OF THE INSTITUTE

Date and place of founding: 27 Dec 1947 in Zagreb.

Founder: Prof Andrija Štampar, president of the Yugoslav Academy of Sciences and Arts.

Status: public research institute under the Ministry of Science and Education of the Republic of Croatia.

Fields of research: toxicology, radiation and chemical weapon protection, environmental radioactive contamination, air quality, determination of drug abuse, occupational medicine, distribution of metals and inorganic and organic pollution in the environment, and the exposure of human beings to environmental contaminants, as well as various psychogenic factors.

Types of registered fields: scientific, professional, teaching, and publishing.

The mission of the Institute is to become:

- a research institute of excellence in central and south-eastern Europe that shifts the boundaries of discovery regarding anthropogenic impacts on health and the environment
- a standard and role model of academic distinction and quality.

The vision of the Institute:

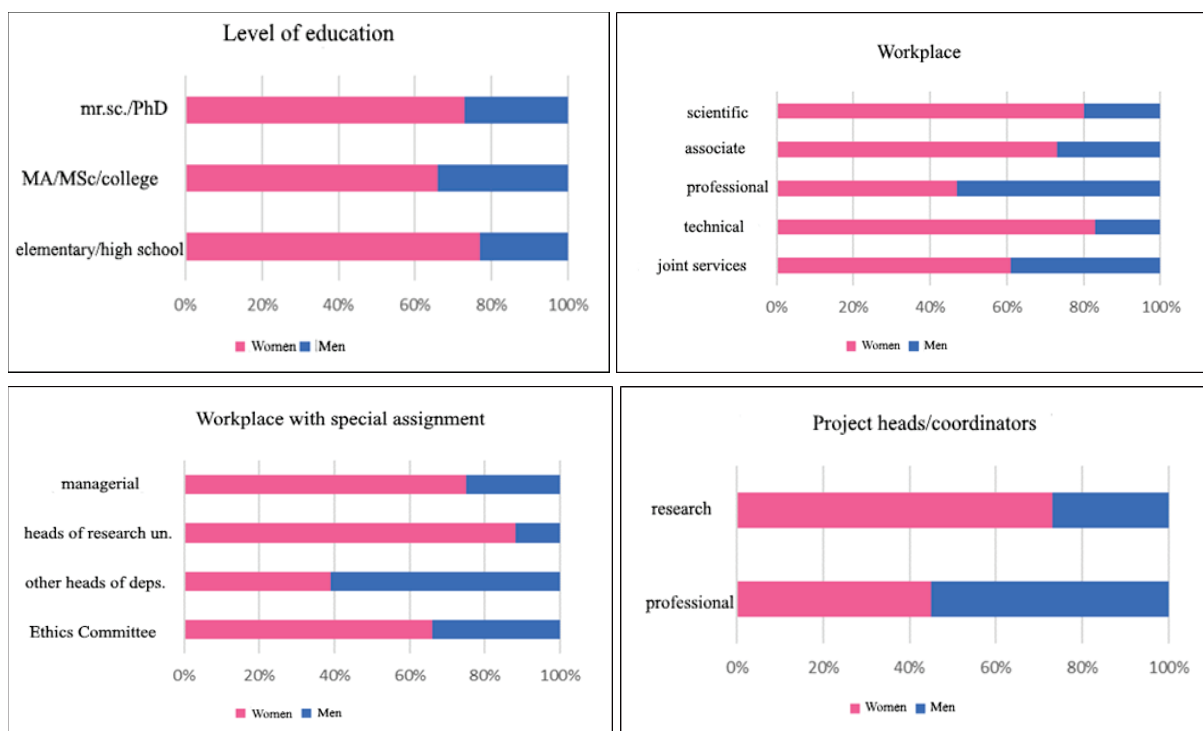
- insist on high standards of scientific excellence
- create new values in science
- ensure the transfer of knowledge to the wider community
- contribute to the economy through research outcomes
- educate future experts in the fields of fundamental and applied sciences.

STRUCTURE OF IMROH'S EMPLOYEES (31 DEC 2021)		Number of employees	%
Distribution according to funding source	State budget	143	88
	IMROH	5	3
	Croatian Science Foundation	15	9
Distribution according to sex	Women	121	74
	Men	42	26
Employees with academic titles	PhD	76	47
Employees with teaching titles	Assis Prof (6); Assoc Prof (3); Full Prof (2)	11	7
Employees with specialist titles	Epidemiology (1); Occupational Medicine and Sports (2)	3	2
Employees on scientific work positions	Permanent Scientific Advisor	15	9
	Scientific Advisor	9	6
	Senior Scientific Associate	17	10
	Scientific Associate	17	10
	Total	58	35
Employees on associate work positions	Postdoctoral researcher	11	7
	PhD student, Assistant	20	12
	Total	31	19
Employees on professional work positions	Professional Advisor	3	2
	Senior Professional Associate	3	2
	Professional Associate	10	6
	Total	16	10
Employees on technical work positions		27	17
Employees in Shared Services		31	19
TOTAL NUMBER OF EMPLOYEES: 163			

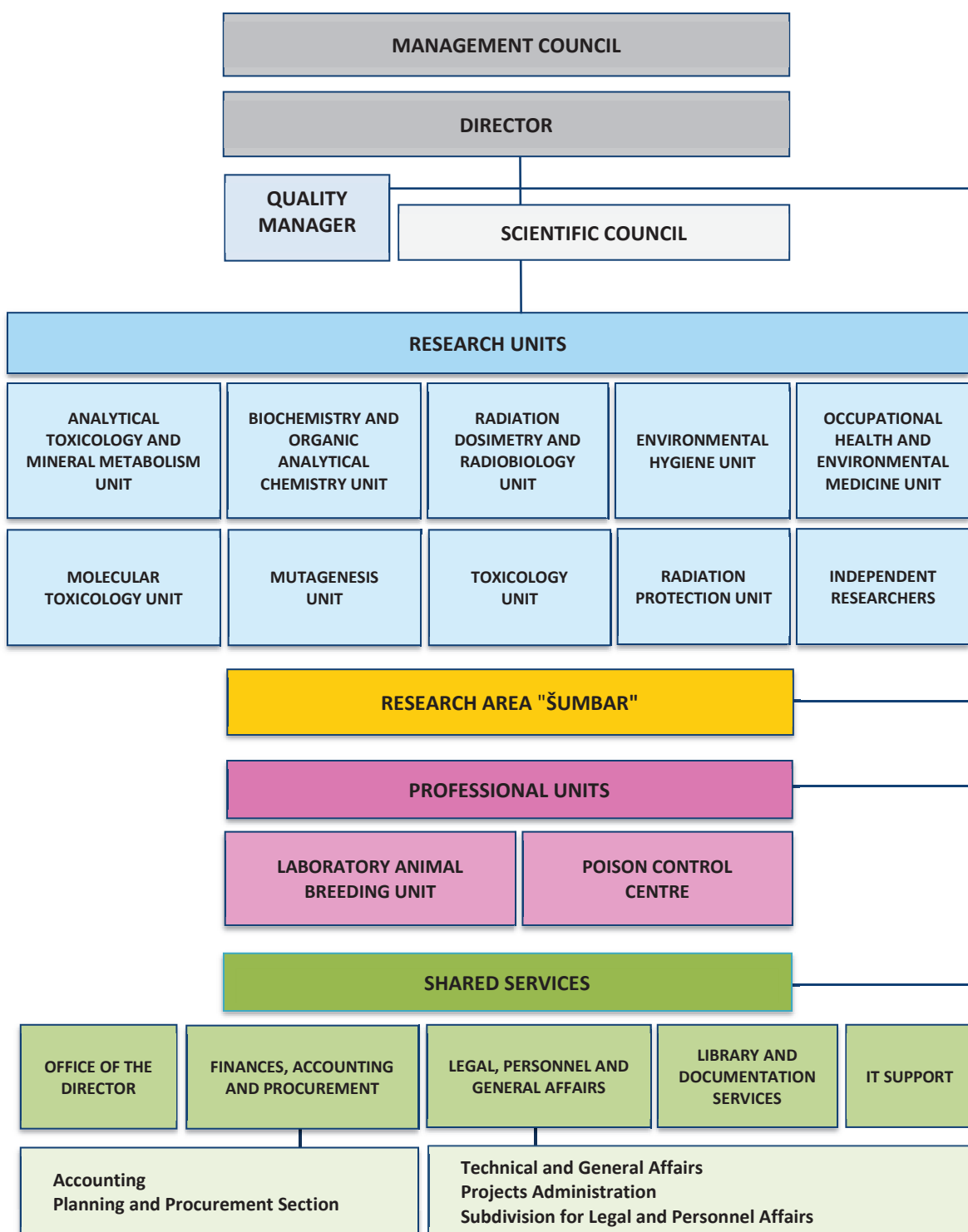
Gender Equality Plan 2022–2025

On 22 December 2021, IMROH announced its Gender Equality Plan (GEP) 2022–2025 for the purpose of harmonising its institutional activities with the political guidelines of gender equality in Europe, taking into consideration institutional capacities and the national legislation in science and education. The GEP emphasizes five action priorities and recommends 45 activities that will contribute as much as possible to fulfilling the goals of the EU Gender Equality Strategy 2020–2025. In a wider sense, the main goal is to combat any and all discrimination among IMROH's employees, regardless of their sex, race, ethnicity, nationality, language, religion, convictions, functional capabilities, sexual orientation, gender identity, and age. The successful implementation of the GEP ensures a variety of perspectives, talents and skills for efficient and innovative work tasks. The GEP is open towards all employees and associates of IMROH.

The GEP is an official document drafted by the Committee composed of IMROH's management (Prof A. Lucić Vrdoljak – Director, Assist Prof I. Brčić Karačonji – Deputy Director), representatives of researchers (Assist Prof S. Stipičević, Assist Prof I. Vinković Vrček), and administrative staff (S. Stankić, M. Herman, A. Marković). The GEP has been published on IMROH's website, which is open to promoting the goals and results of the GEP's implementation.



Distribution by sex of IMROH's employees regarding their education, work position, manager position and leading role in research projects (31 Dec 2020)



The organisational scheme of IMROH

MANAGEMENT OF THE INSTITUTE	
MANAGEMENT COUNCIL	
CHAIR Prof Stipan Jonjić, MD, PhD, Faculty of Medicine, University of Rijeka	
DEPUTY CHAIR Prof Nada Čikeš, MD, PhD, School of Medicine, University of Zagreb	
MEMBERS Božo Pavičin, Croatian Chamber of Economy Nevenka Kopjar, PhD (Representative of the Institute's research staff) Branka Roić, BEc (Representative of the Institute's employees)	
DIRECTOR Prof Ana Lucić Vrdoljak, PhD	DEPUTY DIRECTOR Assist Prof Irena Brčić Karačonji, PhD, ERT
SCIENTIFIC COUNCIL	QUALITY MANAGER
CHAIR Assoc Prof Branko Petrincec, PhD	Zdenko Franić, PhD
DEPUTY CHAIR Davorka Breljak, PhD	

ETHICS COMMITTEE

CHAIR

Prim Jelena Macan, MD, PhD

MEMBERS

Assist Prof Adrijana Bjelajac, PhD

Assoc Prof Selma Cvijetić Avdagić, MD, PhD

Martina Piasek, MD, PhD

Prof Tomislav Mašek, DVM, PhD, Faculty of Veterinary Medicine, University of Zagreb

SECRETARY

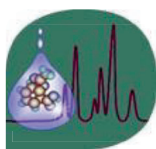
Jagoda Mandić

During 2021, the Ethics Committee received a total of 13 claims, which were all considered according to the criteria of the IMROH's Code of Ethics. Applicants were issued written opinions, except in two cases where additional documentation was requested, which was not submitted until the end of the year. During meetings and consultations via e-mail, ethical principles were considered in the following claim types:

- in a research project proposal of another research institution financed by the Croatian Science Foundation with cooperation from IMROH (1 claim)
- in proposals for IMROH in-house projects (3 claims)
- in proposals submitted by IMROH's researchers to EU HORIZON 2020 calls (1 claim) and other international research projects calls (2 claims)
- in a graduate thesis proposal with a mentor from IMROH (1 claim)
- in doctoral thesis proposals with a mentor from IMROH (3 claims).

15. RESEARCH UNITS

UNIT	CODE	HEAD	CONTACTS
Analytical Toxicology and Mineral Metabolism	604	Jasna Jurasović, PhD	Tel. (01) 4682 530 e-mail: jurasovic@imi.hr
Biochemistry and Organic Analytical Chemistry	609	Snježana Herceg Romanić, PhD	Tel. (01) 4682 553 e-mail: sherceg@imi.hr
Environmental Hygiene	610	Assist Prof Gordana Pehnec, PhD	Tel. (01) 4682 580 e-mail: gpehnec@imi.hr
Molecular Toxicology	606	Davorka Breljak, PhD	Tel. (01) 4682 622 e-mail: dbreljak@imi.hr
Mutagenesis	616	Nevenka Kopjar, PhD	Tel. (01) 4682 630 e-mail: nkopjar@imi.hr
Occupational Health and Environmental Medicine	615	Prim Jelena Macan, MD, PhD	Tel. (01) 4682 600 e-mail: jmacan@imi.hr
Radiation Dosimetry and Radiobiology	608	Ivica Prlić, PhD	Tel. (01) 4682 570 e-mail: iprlic@imi.hr
Radiation Protection	602	Assoc Prof Branko Petrinec, PhD	Tel. (01) 4682 658 e-mail: petrinec@imi.hr
Toxicology	603	Maja Peraica, MD, PhD, ERT	Tel. (01) 4682 640 e-mail: mperaica@imi.hr
Independent Researcher	387	Aleksandra Fučić, PhD	Tel. (01) 4682 522 e-mail: afucic@imi.hr
Independent Researcher	389	Ante Miličević, PhD	Tel. (01) 4682 524 e-mail: antem@imi.hr
Independent Researcher	373	Jasmina Sabolović, PhD	Tel. (01) 4682 526 e-mail: jsabolov@imi.hr



15.1. Analytical Toxicology and Mineral Metabolism Unit

EMPLOYEES OF THE UNIT

HEAD

Jasna Jurasović, PhD, permanent scientific advisor

RESEARCHERS

Alica Pizent, PhD, permanent scientific advisor

Zorana Kljaković-Gašpić, PhD, scientific advisor

Maja Lazarus, PhD, scientific advisor since 22 Jul 2021

Assist Prof Ivana Vinković Vrček, PhD, scientific advisor

Nataša Brajenović, PhD, senior scientific associate

Assist Prof Irena Brčić Karačonji, PhD, ERT, senior scientific associate (Deputy Director)

Anja Katić, PhD, scientific associate

Tatjana Orct, PhD, scientific associate

Blanka Tariba Lovaković, PhD, scientific associate

Maja Beus, PhD, postdoctoral researcher (HrZZ) since 3 May 2021

Ivona Capjak, PhD, postdoctoral researcher (8h/week) since 24 May 2021

Ankica Sekovanić, PhD, postdoctoral researcher

Antonija Sulimanec Grgec, PhD, postdoctoral researcher

Tanja Živković Semren, PhD, postdoctoral researcher

Andreja Jurič, PhD, assistant

Rinea Barbir, MSc, PhD student-assistant (HrZZ)

Lucija Božičević, MSc, PhD student-assistant (HrZZ)

Nikolina Kalčec, MSc, PhD student-assistant (HrZZ)

Barbara Pem, MSc, PhD student-assistant

Nikolina Peranić, MSc, PhD student-assistant (HrZZ) since 13 Sep 2021

TECHNICAL STAFF

Mladen Komesar, senior technician

Vesna Triva, senior technician

Snježana Mataušić, technician

Krešimir Nekić, technician

PARTICIPATING RETIRED RESEARCHER

Martina Piasek, MD, PhD, permanent scientific advisor

SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

Long-term research activities

Study of toxic and essential elements: health effects in the general population and assessment of environmental exposure

The levels of elements in the blood, serum and urine of subjects with testicular germ cell tumors and healthy subjects who had not been occupationally exposed to metals were measured and the possible contribution of exposure to environmental levels of toxic elements to testicular tumor development and the association between clinical and pathological data and concentrations of measured elements

were assessed (112). We presented the results of free amino acids quantitative profiling of elements levels in urine of men with testicular cancer and control subjects (311).

We continued research on toxic element levels in brown bears from the Dinara-Pindos population. Blood Pb levels were compared across captive and free-ranging brown bears from our Dinara-Pindos and Carpathian population sampled during the last nine years and presented at a national conference with international participation (216).

As part of our continuing studies on potential risks and health benefits of fish in the diets of vulnerable populations, we analyzed levels of total mercury (THg) and selenium (Se) in archive samples of wild bluefin tuna caught in the open waters of the central Adriatic. Based on the obtained results, the differences in the content of THg and Se and their molar ratio in different tissues/organs of tuna from the Mediterranean Sea, were estimated for the first time. Additionally, the influence of biological factors (length, weight and age) on the tissue distribution of Se and THg was studied (51). In collaboration with the Ruđer Bošković Institute, we presented the results on water quality and metal exposure in the upper part of the Krka River watercourse which is under the influence of wastewater discharges (268, 346).

In-house scientific projects (Chapter 16.1.A.3.)

1. Investigation of toxic effects of new psychoactive substances by biochemical and molecular-biological methods

We compared the toxic effects of mephedrone, ketamine, tetrahydrocannabinol, cocaine, amphetamine, methamphetamine, 3,4-methylenedioxymethamphetamine, 3,4-methylenedioxyamphetamine, phencyclidine, lysergic acid diethylamide, morphine, codeine, heroin, buprenorphine, and methadone on the human neuroblastoma cell line SH-SY5Y (47, 306, 352, 354).

2. Chemical and radiological characterisation of strawberry tree (Arbutus unedo L.)

We determined the activity concentrations of radionuclide in tea, leaf and fruit of strawberry tree (*Arbutus unedo* L.) by gamma spectrometric method. In collaboration with the Faculty of Chemistry of the University of Belgrade we determined the phenolic profile of Croatian strawberry tree leaves and fruit (128).

3. Bioactive potential, metal and nicotine content in edible boletes regarding the toxic metal burden of soil

Sampling of edible boletes and nearby soil from Croatia was restrained by bad growth conditions in autumn 2021, but sampling of mushrooms from EU import from the Croatian eastern border was carried out as planned.

4. Evaluation of reproductive toxicity of commonly used pesticides followed by chronic low-dose exposure in vivo

The parameters of oxidative stress and concentration of essential elements were measured in the testes and epididymis of male Wistar rats exposed to low doses of insecticides α -cypermethrin and imidacloprid and herbicides terbutylazine and tembotrione. In collaboration with the Mutagenesis Unit, we estimated the toxic effects of exposure to these pesticides on primary DNA damage (111, 231).

5. Assessment of the effects of MT2A +838 G/C and MT2A –209 A/G gene polymorphisms on the levels of toxic and essential elements at childbirth

We determined the genotype frequency of MT2A –209A/G and started a study on the potential effects of metallothionein MT2A gene polymorphisms on element levels in the biological samples of mother-infant pairs (maternal blood, cord blood and placenta) collected during the project METALORIGINS, HrZZ-IP ($n = 156$) and archive samples from the previous studies in the Unit ($n = 268$). The effects of maternal MT2A –209 A/G gene polymorphisms and cigarette smoking were estimated on the levels of toxic (Cd and Pb) elements in the maternal-placental-fetal functional unit and on essential elements (Cu, Fe, Se and Zn) transferred through the placenta (227).

6. Assessment of the effects of prenatal exposure to α -cypermethrin on epigenetic programming and endocrine disruption of reproduction and development in experimental rats

Animal experiments were performed, samples were collected and stored for planned analyses and parameters for assessing endocrine disruption of reproduction and development were recorded (214). Epigenetic, histopathological and immunohistochemical analyses at the Faculty of Medicine, University of Zagreb are in progress (210).

Other research activities

We published research results of the cyto- and genoprotective effects of strawberry tree honey and homogentisic acid against DNA damage induced by irinotecan in human peripheral blood lymphocytes *in vitro* (46, 212, 332). As part of a doctoral thesis, the phenolic profile and *in vitro* effects of strawberry tree honey on tumour cells and lymphocytes were investigated (176).

We investigated new authenticity markers in unifloral and multifloral honeys from Croatia taking into account the spatial, temporal and production practice variation (60). We compared metal(loid) contaminant and pesticide levels in Croatian chestnut honey from the Banovina (Banski med) and Ozalj regions (217). Differences in organic and inorganic contaminants were investigated in certified organic vs. conventional honeys (59).

We determined the concentrations of 7 polybrominated diphenyl ether (PBDE) congeners and 18 trace elements in dust samples from 68 Zagreb households. Based on the data of the dust analysis and the questionnaire on the characteristics of the house and the habits of the tenants, possible internal sources of PBDEs/elements and health risks associated with the intake of PBDEs/elements in the body were assessed (50, 256).

We continued to investigate the interaction of tetrahydrocannabinol and irinotecan by estimating tumor size and cholinesterase activity in the blood of mice (syngeneic model of colon tumors) after combined exposure (215, 235).

We published the results of the toxic effects of the neonicotinoid insecticide imidacloprid on cholinesterase activities, oxidative stress parameters and DNA damage in the blood and brain of male Wistar rats subchronically and orally exposed to low doses of imidacloprid (48, 307). We investigated the genotoxic effects of oral exposure to the pyrethroid insecticide α -cypermethrin in leukocytes and liver cells of dams and newborn offspring of Wistar rats exposed during the whole gestation to low doses of α -cypermethrin (223). We published the results of the genotoxic effects of the herbicide tembotrion in leukocytes and liver cells of dams and male and female offspring of Wistar rats at different stages of development until puberty, after oral exposure during gestation and/or lactation to low doses of tembotrion (76). We continued our investigation of sub-chronic toxicity of low-level exposure to terbutylazine on primary DNA damage and activity of antioxidant enzyme glutathione peroxidase in liver and kidneys of male Wistar rats orally exposed to the pesticide (159).

In collaboration with co-authors from the Ruđer Bošković Institute, we presented results on water quality and metal exposure in the upper part of the Krka River watercourse, which is under the influence of wastewater discharges (268, 346).

In collaboration with the Ministry of the Interior of the Republic of Croatia, we published a review on food crime and food defence (45).

RESEARCH PROJECTS FUNDED BY EXTERNAL SOURCES

National projects (Chapter 16.1.)

1. Assessment of daily exposure to metals and maternal individual susceptibility as factors of developmental origins of health and disease (METALORIGINS, HrZZ-IP)
2. Exposure to Pyrethroid and Organophosphate Insecticides in Children – Risk Assessment for Adverse Effects on Neuropsychological Development and Hormonal Status (PyrOPECh, HrZZ-IP)
3. Application of Nanobiotechnology for Nutritional Supplementation with Selenium (NutriTENSE, HrZZ-IP)

4. Role of blood-brain barrier, innate immunity, and tau protein oligomerization in the pathogenesis of Alzheimer's disease (ALZ-BBB-STOPINNATETAU, HrZZ-IP)
5. Integrated evaluation of aquatic organism responses to metal exposure: gene expression, bioavailability, toxicity and biomarker responses (BIOTOXMET, HrZZ-IP)
6. Indirect effect of global warming on mammals physiological parameters via high temperature-stressed plant diet (TEMPHYS, HrZZ-IP)
7. Development, validation and application of analytical methods for PBDE determination (DeValApp, HrZZ-UIP)
8. Biological effects of strawberry tree (*Arbutus unedo* L.) honey on tumour and healthy human cells (HAZU Foundation)
9. Biological monitoring of the effects of volatile aromatic hydrocarbons (BTEX) on the health of the Primorje-Gorski Kotar County population (UNIRI)
10. Opportunistic pathogens in the water supply system: a new challenge in water treatment (UNIRI)

International projects (Chapter 16.2.)

1. Development of functional beverage in sustainable packaging (JamINNO+, EFRR)
2. Science-based risk governance of nano-technology (RiskGONE, H2020)
3. Safe-by-Design Approach for Development of Nano-Enabled-Delivery Systems to Target the Brain (SENDER, HrZZ-PZS)
4. Cancer nanomedicine - from the bench to the bedside (Nano2Clinic, COST)
5. Pharmaceutical Open Innovation Test Bed for Enabling Nano-pharmaceutical Innovative Products (Phoenix, H2020)
6. Endocrine disrupting mechanism of typical environmental pollutants (EmergeTox, Bilateral CRO-CN)

PROFESSIONAL SERVICES

Professional analyses were carried out at the request of various institutions, companies, and individuals on metals and metalloids in samples of different origins (by ICP-MS and AAS) and drugs of abuse in hair and urine samples (by GC-MS).

A total of 248 analyses of specific indicators of exposure and effect to toxic metals/metalloids and essential trace element status in the human organism were performed. Most of the analyses were related to determining biological markers of Pb exposure [concentrations of Pb and erythrocyte protoporphyrin (EP) and activity of δ -aminolevulinic acid dehydratase (ALAD) in blood] during the assessment of professional exposure in workers at different workplaces ($n = 131$). Concentrations of Hg in urine, blood, and hair ($n = 23$) and a wide range of elements (Al, Ag, As, Cd, Co, Cr, Cu, Fe, I, Mn, Mo, Ni, Pb, Se and Zn) in those biological samples ($n = 145$) were also determined.

Drugs of abuse from the amphetamine and opiate groups, methadone, and cocaine were determined in 41 hair samples (64 analyses in total). THC-COOH (9 samples), buprenorphine (4 samples), opiates (3 samples) and methamphetamine (1 sample) were analysed in urine. A total of 52 queries were received regarding the analysis of drugs of abuse via the e-mail address infodroge@imi.hr.

Participation in intercomparison programmes (2)

ORGANISER	TEST	AREA	DATE
Society of Hair Testing, Strasbourg, France	Proficiency Test 2021	Analysis of drugs of abuse in hair	6/2021 and 12/2021 (two times per year, on three hair samples)
Frimley Health, NHS Foundation Trust, Guildford, Surrey, United Kingdom	UK NEQAS for Trace Elements	Analysis of elements in serum (Al, Co, Cr, Cu, Se i Zn), blood (As, Cd, Co, Cr, Hg, Mg, Mn, Pb, Se, Tl i Zn) and urine (As, Cd, Co, Cr, Fe Hg, Mg, Mn, Ni, Pb, Se, Tl i Zn)	1/2021–12/2021 (every month, on two serum, blood and urine samples)

PROFESSIONAL ACTIVITIES OF THE EMPLOYEES OUTSIDE THE INSTITUTE

I. Brčić Karačonji

Member of the Working Group on the Early Warning System on New Psychoactive Substances in the Republic of Croatia at the Croatian Institute for Public Health; member of the Presidency of the Croatian Society of Toxicology; member of the Strategic Board for Research Infrastructure at the Ministry of Science and Education of the Republic of Croatia; member of the Organization Committee of the CROTOX 2021.

J. Jurasović

Member of the Presidency of the Croatian Society of Toxicology; member of the Scientific Committee of the CROTOX 2021.

A. Jurič

Member of the Working Group on the Early Warning System on New Psychoactive Substances in the Republic of Croatia at the Croatian Institute for Public Health; member of the Organization Committee of the CROTOX 2021.

M. Lazarus

Secretary of the Croatian Laboratory Animal Science Association (CroLASA); secretary and member of the Organization Committee of the CROTOX 2021.

M. Piasek

Member of the Supervisory Board of the Croatian Society of Toxicology; member of the Scientific Committee of the CROTOX 2021.

A. Pizent

Guest editor of the Special Issue on Oxidative Stress Induced by Environmental and Lifestyle stressors: Impact on Reproductive Health and Development, Antioxidants (Vol 10 and 11, 2021/2022).

B. Tariša Lovaković

Member of the Organization Committee of the CROTOX 2021.

I. Vinković Vrček

Member of the Thematic Innovation Council for Health and Quality of Life, Ministry of Economy, Entrepreneurship and Crafts of the Republic of Croatia; member of the Working group for Regulations of Novel Food Ministry of Health of Republic of Croatia; Croatian representative in the European Food Safety Authority (EFSA) for Scientific Network on Risk Assessment of Nanotechnologies in Food and Feed.

SCIENTIFIC, TEACHING AND ACADEMIC ADVANCEMENT OF EMPLOYEES

Scientific-teaching degree of Assistant Professor was gained by *I. Brčić Karačonji*.

Scientific degree of senior scientific associate was gained by *T. Orct*.

PhD degree was gained by *R. Barbir*, *A. Jurič*, and *B. Pem*.



15.2. Biochemistry and Organic Analytical Chemistry Unit

EMPLOYEES OF THE UNIT

HEAD

Snježana Herceg Romanić, PhD, permanent scientific advisor

RESEARCHERS

Assoc Prof Zrinka Kovarik, PhD, permanent scientific advisor

Goran Šinko, PhD, scientific advisor

Anita Bosak, PhD, senior scientific associate

Sanja Fingler Nuskern, PhD, senior scientific associate

Maja Katalinić, PhD, senior scientific associate

Darija Klinčić, PhD, senior scientific associate since 19 May 2021

Gordana Mendaš Starčević, PhD, senior scientific associate

Assist Prof Sanja Stipičević, PhD, senior scientific associate

Marija Dvorščak, PhD, scientific associate since 29 Jan 2021

Nikolina Maček Hrvat, PhD, scientific associate

Nikola Maraković, PhD, scientific associate since 3 May 2021

Josip Madunić, PhD, postdoctoral researcher (HrZZ)

Antonio Zandona, PhD, postdoctoral researcher since 5 Dec 2021

Tamara Zorbaz, PhD, postdoctoral researcher

Marija Bartolić, MSc, PhD student-assistant (HrZZ) since 1 Oct 2021

Tena Čadež, MSc, PhD student-assistant (HrZZ)

Karla Jagić, MSc, PhD student-assistant (HrZZ)

Dora Kolić, MSc, PhD student-assistant (HrZZ)

Ana-Marija Lulić, MSc, PhD student-assistant (HrZZ)

Ana Matošević, MSc, PhD student-assistant

TECHNICAL STAFF

Nikolina Medved, technician (substitute: Petra Bajt, MSc, 9 Mar–31 Jul 2021 and since 1 Sep 2021)

Maja Meštović, technician

PARTICIPATING RETIRED RESEARCHER

Prof Vlasta Drevenkar, PhD, permanent scientific advisor

SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

Scientific collaborations

In collaboration with Vesna Pehar, we started studying selected commercially available herbicides as acetylcholinesterase (AChE) and butyrylcholinesterase (BChE) inhibitors to determine types of inhibition and the IC_{50} . As herbicides can cause different types of toxicity from reproductive toxicity, hepatotoxicity to neurotoxicity, cytotoxicity was examined on several selected cell lines. This research will be part of V. Pehar's doctoral thesis.

The atmospheric deposition was investigated in cooperation with the Environmental Hygiene Unit, and the performance of collectors on sampling efficiency was also examined (288). The first data on polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and nitro-aromatic compounds in atmospheric deposition samples at the coastal area of the central Adriatic were

evaluated (44). Concentrations of PAHs and PCBs and organochlorine pesticides (OCPs) present in the atmospheric bulk deposition samples in the colder period of the year at four locations in the Zagreb area and its surroundings south of the Sava River were estimated (287). The direct impact of the proximity of Zagreb on the environment of the Medvednica Nature Park was examined by determining PAHs in atmospheric bulk deposition samples (289).

In collaboration with colleagues from the Division for Marine and Environmental Research, Ruđer Bošković Institute, we monitored the products formed during the transformation of 2,4,4'-trichlorobiphenyl (PCB-28), 2,2',5,5'-tetrachlorobiphenyl (PCB-52) and 2,4,3'-trichlorobiphenyl (PCB-25) by previously characterized PCB-degrading rhodococci Z6, T6, R2, and Z57 isolates, with the aim to explore their metabolic pleiotropy in PCB transformations (88).

Environmental pollution was examined within the international program ICP Vegetation (The International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops in cooperation with scientific institutions in Serbia, specifically, with the Institute of Physics Belgrade and Faculty of Chemistry, University of Belgrade (66).

Sampling continued within the framework of the MONET project, active since 2009 under the auspices of RECETOX, the Regional Center for Environmental Chemistry and Toxicology, Masaryk University, Brno, Czech Republic).

As part of the last project of the Croatian Science Foundation "Organic pollutants in the environment – markers and biomarkers of toxicity" (OPENTOX, IP-2013-11-8366, 2014–2018), the seasonal distribution of pesticide residues (five herbicide classes and three insecticide classes) was evaluated in surface water samples collected in urban and agricultural areas of northwestern Croatia after pesticide application in 2015 (24). Within the same project, the toxicity of the insecticide imidacloprid to non-target species was evaluated. The effects of 28-day oral exposure to low doses of imidacloprid was determined considering the cholinesterase activity, responses to oxidative stress, and primary DNA damage in the blood and brain tissue of male Wistar rats (48).

In cooperation with the Department of Soil Amelioration, Faculty of Agriculture, University of Zagreb, hydraulic properties and preferential flows for the erosion prone vineyard soil were identified using Uni- and Bimodal Porosity Models (130).

In-house scientific projects (Chapter 16.1.A.3.)

1. *Persistent organic pollutants – Environmental impact assessment and stability of human genetic material*

The aim of the project was to investigate the exposure of marine organisms in the Adriatic Sea to persistent organic compounds under the Stockholm Convention, other anthropogenic pollutants and risk assessment for humans. Methods of numerical and statistical modeling, and algorithms of machine learning were applied for result interpretation. The overall research resulted in 4 publications in international journals (Q1), 3 master's theses, 2 book chapters and 2 international conference abstracts. The research was conducted in cooperation with the Institute of Physics Belgrade and Faculty of Chemistry University of Belgrade, Serbia, and the University of Zadar.

Two institutions from Belgrade, Serbia, were also involved during the project: the Institute of Hygiene and Meat Technology and Singidunum University. In the last year of the project, the health risk for small pelagic fish consumers was assessed by risk assessment information system models, and the benefit-risk ratio was estimated on the basis of results of the essential fatty acid analysis (36, 339, 340). As part of the project, Kristina Radušin defended her master's thesis "Human Health Risk Assessment with a Review of Correlations between Selected Organochlorine Pesticides and Fatty Acids in Pelagic Fish Species of the Adriatic Sea" at the Faculty of Chemistry, University of Belgrade, Serbia. The ratio of PCB-138, other persistent organic compounds and fatty acids was estimated by artificial intelligence methods (Extreme Gradient Boosting – XGBoost, Shapley Additive exPlanation – SHAP, Fuzzy clustering) (159).

2. Analysis of organic pollutants in biological systems and the environment

The effectiveness of herbicide terbuthylazine removal from surface water was tested by the addition of biomass fly ash, an industrial by-product from a cogeneration plant fuelled by deciduous hardwood chips (187, 270). Kinetics and mechanisms of terbuthylazine adsorption to fly ash particles were characterized with the aim of developing a new fly ash-based polymer formulations for the purification of aquatic ecosystems loaded with herbicides (79). Other reuse potentials of biomass fly ash in the circular economy and environmental services are also presented (78).

Measurement of indoor and outdoor air quality was performed in the university building in Belgrade (Serbia): O₃, CO, SO₂, NO_x, Rn, PM_{2.5}, trace metals (As, Cd, Cr, Mn, Ni and Pb), ions (Cl, Na⁺, Mg²⁺, Ca²⁺, K⁺, NO₃⁻, SO₄²⁻ and NH₄⁺) and 16 PAHs were measured. The levels in indoor and outdoor air were evaluated using Unmix, diagnostic ratios and XGBoost machine learning methods (104).

Investigations of the simulated gastrointestinal resorption of persistent organic compounds from breast milk was continued. We plan to investigate the total content of macro and micro elements and bioavailable fractions of elements in milk to assess the benefits and risks for infant health. At the Faculty of Chemistry, University of Belgrade, Serbia, Dragana Samardžić defended her master's thesis "Pesticides and polychlorinated biphenyls in breast milk". In this work, the distribution of persistent organic compounds in breast milk was evaluated and the Shapley Additive ExPlanations (SHAP) artificial intelligence method was used to investigate relationship between PCB-138 and other PCB congeners, maternal age and number of births (158).

Cooperation with the Public Institution AQUATIKA – freshwater aquarium Karlovac based on sediment pollution, chub from the Danube basin and from the Adriatic basin rivers was continued (259).

RESEARCH PROJECTS FUNDED BY EXTERNAL SOURCES

National projects (Chapter 16.1.)

1. Development of Bioactive Molecules for Neurodegenerative Diseases Treatment (BioMol4ND, HrZZ-IP)
2. Analysis of Butyrylcholinesterase Interactions with Novel Inhibitors and Reactivators (AnalyseBChE, HrZZ-IP)
3. Identification and functional characterization of (eco)toxicologically relevant polyspecific membrane transport proteins in zebrafish (*Danio rerio*) (DANIOTRANS, HrZZ-IP)
4. Molecular Mechanisms Underlying the Toxicity of Antidotes and Potential Drugs (CellToxTargets, HrZZ-UIP)
5. Development, validation and application of analytical methods for PBDE determination (DeValApp, HrZZ-UIP)
6. Development of analytical methods for the purpose of obtaining the first data on human exposure in Croatia to brominated compounds (HAZU Foundation)
7. Evaluation of kinetic parameters and cell effects of new antidotes based on vitamin B6 for the treatment of poisoning by highly toxic organophosphates (HAZU Foundation)

International projects (Chapter 16.2.)

1. CNS-active, Orally Bioavailable, Zwitterionic Oximes for Organophosphate (DTRA, USA)
2. Effects of selected pesticides on neuronal acetylcholinesterase expression (Bilateral CRO-CN)
3. Persistent organochlorine compounds in human milk and their potential effect on the level of primary DNA damage in human cells (Bilateral CRO-RS)
4. Effect of oxime analogues on skeletal muscle cell viability (Bilateral CRO-SI)

PROFESSIONAL ACTIVITIES OF THE EMPLOYEES OUTSIDE THE INSTITUTE

A. Bosak

Treasurer and member of the Executive Board of the Croatian Society of Natural Sciences; scientific staff representative at the Independent Trade Union of Science and Higher Education for the branch IMROH.

S. Fingler Nuskern

Member of the TO 147 Water Quality at the Croatian Standards Institute; member of the Working Group for monitoring EU Action Plan "Towards Zero Air, Water and Soil Pollution".

S. Herceg Romanić

Member of the Working Group for monitoring and meeting the requirements of the Third National Plan for the Implementation of the Stockholm Convention on Persistent Organic Pollutants.

M. Katalinić

Secretary and member of the Executive Committee of the Croatian Society of Biochemistry and Molecular Biology (HDBMB) (until 23 Apr 2021); member of the Court of Honour, Public Relations Committee, Collaboration and Development Committee and editor-in-chief of the website of HDBMB; President of the Organisation Committee of the 20 FEBS "Young Scientists' Forum"; member of the International Organisation Committee of the FEBS2021; member of the Organisation Committee of the HDBMB22 "From Science to Knowledge".

Z. Kovarik

President of the Croatian Society of Natural Sciences; member of the Executive Board of the Croatian Chemical Society; member of the Council of HDBMB and member of several committees; member of the Scientific Advisory Board of the Organization for the Prohibition of Chemical Weapons (SAB OPCW) and the SAB Technical Working Group on the Analysis of Biotoxins; member of the Board for Chemistry, Agency for Science and Higher Education; panelist and evaluator of the Croatian Science Foundation; member of the NATO working group "Translating Medical Chemical Defense Research into Operational Medical Capabilities against Chemical Warfare Threat Agents"; member of the International Advisory Board on Cholinesterases and International Advisory Board on Cholinergic Mechanisms; member of the Organising Committee of the FEBS2021; member of the Scientific Committee of the CBRNE Research & Innovation Conference 2022; Chair of the Organizing Committee of the 17th International Symposium on Cholinergic Mechanisms 2022; member of the Scientific Committee of the HDBMB22 "From Science to Knowledge"; associate editor of the *Periodicum biologorum*; member of expert committees for doctoral thesis, Faculty of Science, University of Zagreb; member of expert committees for scientific promotion, Ruđer Bošković Institute, Zagreb.

N. Maček Hrvat

Member of the Organizing Committee of the 17th International Symposium on Cholinergic Mechanisms 2022.

J. Madunić

Member of the HDBMB Public Relations Committee.

G. Mendaš Starčević

Member of the Working Group for monitoring and meeting the requirements of the Third National Plan for the Implementation of the Stockholm Convention on Persistent Organic Pollutants; member of the Working Group for Codex Alimentarius, Food Contaminants Committee; member of the Committee for Risk Assessment (RAC) at the European Chemicals Agency (ECHA).

M. Meštrović

Delegate representing the non-scientific staff at the Independent Trade Union of Science and Higher Education for the branch IMROH.

A. Zandona

Member of the HDBMB Young Scientists' Forum.

SCIENTIFIC, TEACHING AND ACADEMIC ADVANCEMENT OF EMPLOYEES

Scientific-teaching degree of Associate Professor was gained by *Z. Kovarik*.

Scientific-teaching degree of Assistant Professor was gained by *S. Stipičević*.

Scientific degree of scientific associate was gained by *T. Zorbaz*.

PhD degree was gained by *A. Zandona*.



15.3. Radiation Dosimetry and Radiobiology Unit

EMPLOYEES OF THE UNIT

HEAD

Ivica Prlić, PhD, professional advisor in science

RESEARCHERS

Ivan Pavičić, PhD, senior scientific associate

Ana Marija Marjanović Čermak, PhD, scientific associate

Marija Surić Mihić, PhD, scientific associate until 28 Feb 2021

Luka Pavelić, PhD, assistant

Krunoslav Ilić, MSc, PhD student-assistant

Ana Buinac, MSc, senior professional advisor in science (3h/week)

Tomislav Meštrović, MSc, senior professional associate in science

Jerko Šiško, MSc, senior professional associate in science since 3 May 2021

Branimir Zauner, PhD, professional associate in science

Mihovil Jurdana, professional associate in science

TECHNICAL STAFF

Selvije Sefić, BSc, senior technician

Silvija Kobeščak, BSc, technician

SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

Integrated hardware-software system for monitoring microlocation environmental parameters

IPPSO, RC.2.2.08-0027 (ERDF Project, 2014–2016 + 5 years of sustainability)

The measuring station at the location of the Šumbar research area successfully collected data from the environment and delivered them to the Unit wirelessly. A report was issued in 2021 after the fifth year of project implementation (31 Dec 2021), in which IMROH's commitment to continue investing in the scientific upgrade of this project regardless of the pandemic situation was emphasized. The visibility of all activities carried out by IMROH as an IPPSO project applicant in the field and in new project activities using equipment (infrastructure) or knowledge gained through the implementation of the IPPSO project continues to be systematically displayed in every public communication, written form and papers.

Field equipment as part of this project at the location of the Šumbar research site and equipment from IMROH sites (Ksaverska c. 2 and temporary location at Petrovaradinska 110) in Zagreb recorded the behaviour of measured parameters during the Zagreb earthquakes and earthquakes at locations in the Banija region. During 2021, an internal (not yet published) expert report was prepared, which is the basis for a more complex scientific contribution to the description of telecommunication behavior of the citizens of the City of Zagreb in situations of natural disasters.

Parts of IPPSO EM measuring equipment have been installed and measure the exposure of working spaces in private apartments, as well as in spaces where school children stay and follow online classes. A pilot project has been set up, a significant amount of experimental data has been collected, which have been classified and compared during 2021 to determine measurement methodologies that have not been published so far. These results will be the basis for the development of a new project on the exposure of humans and school children to EM fields during the pandemic period and in circumstances of natural incidence.

In-house scientific projects (Chapter 16.1.A.3.)

1. Thermometry, thermography and sensory evaluation of electromagnetic radiation in medicine (TTSem3)

Research within WP1 (TTSem2) continued. Due to the pandemic measures in hospitals, the planned clinical activities were postponed from 2020 to 2021, but even then they could not be implemented. Instead, work was done on improving the measuring equipment – the measuring temperature module was technologically improved in order to be upgraded with a possible wireless communication connection for the purpose of online monitoring of patients. Such monitoring of bone fracture healing has shown its great potential in pandemic conditions.

Research on the thermographic characteristics of the healing of fractures of the collarbone and upper arm bone in children (in cooperation with the University Hospital Center Zagreb and the Clinic for Children's Diseases, Zagreb) has continued and is still being carried out under pandemic conditions. Preliminary results of the work from the period from 2019 to 2021 are being prepared for publication. The preliminary study should be the doctoral thesis of dr Jurić, mentor Prof A. Antabak.

The plan is to continue the clinical mapping of temperature symmetry of skin regions in children and adults of both sexes. Measurements are to be performed during outpatient examinations in the polyclinic of the Clinic of Surgery of the University Hospital Center Zagreb. The aim of this research is to standardize physiological deviations in healthy populations and to measure the standard deviation for individual anatomical regions. Similar measurements have been made so far, but without a study of age differences. The clinical part of the research on the topic of skin thermometry below gypsum immobilization in thumb fractures has been prepared. IMROH's thermometers, designed by IMROH's partners, have been repeatedly tested, calibrated and are ready for use for contact measurement and storage of IT data on a given skin/tissue temperature throughout the time of wearing the immobilisation on the arm. Considering that during the clinical research it was established that thermometers should be shielded with a special anti-allergic, preferably plastic, material, the research was extended to a team of experts in the field of dermatology at the University Hospital Center Zagreb. Employees of the allergology clinic were involved in the dermatological effects study, together with the Occupational and Environmental Medicine Unit. After the development of an optimal number of thermometer sensors, it is planned to perform measurements in patients of the Clinic of Surgery of the University Hospital Center Zagreb who are in the standard procedure of fracture treatment. A protocol for the patient's consent to participate in the implementation of the measurement project was prepared and a plan for the training seminar of the Medical Faculty of the University of Zagreb at the University Hospital Center Zagreb was prepared.

2. Thermometry, thermography and sensory evaluation of electromagnetic radiation in medicine (TTSem4)

New scientific research topics on the TTSem3 project have been created (W1–W6):

W1 Thermometry of forearm fracture healing in children

Investigation of thermographic characteristics of exogenous plaster reaction in new gypsum material, product "Loman Raouscher" (LR). When plastering with materials that serve as immobilization, the manufacturer states caution due to possible thermal injuries. Children's skin is sensitive to elevated temperatures that occur during plastering. Thermography of gypsum immobilization seeks to investigate variations in maximum temperatures in the manufacturing of standard splints. A continuing education course is planned at the Faculty of Medicine in Zagreb (Feb 2022), where plastering will be performed on volunteers. Research material (plastic material LR, made by Austrian manufacturer) was provided. In this course, it is planned to install a sensor for measuring and storing temperature under immobilization material *in vivo*. Healthy volunteers would wear a plaster bandage and measuring instrument for three consecutive days. The research will use a possible IMROH patent – a sensor for heat produced by the bone healing process.

Measurement of daily variation in physiological temperature of hospitalized children measured in the frontal region of IR by non-contact measurement to compare day and night surface temperature, possibly related to operative stress and body mass index, is in progress.

A study comparing the thermographic and ultrasound characteristics of the testicles after descent surgery of 600 children is being prepared. We also plan to develop a protocol for monitoring the bone characteristics of the same children using new diagnostic equipment procured through the IMROH's infrastructure project (ReC-IMI, European Regional Development Fund).

W2 Thermometric monitoring of skin re-innervation after breast reconstruction with free flaps and implants

Fundraising for purchase of data collection equipment for thermographic and neurological characteristics of women's skin with breast implants was tasked during 2022. A new thermal camera with special features operating in the human temperature range will be purchased as part of the ReC IMI project. The documentation for this project has been prepared.

W3 Development of a human model of analgesic testing using axo-axon reflex and IR camera.

W4 Daily variations of frontal temperature in children.

W5 Frontal temperatures in obese children.

W6 Cooperation in the development of dosimetric methods and measurements during surgical procedures in the Clinic of Surgery and the Clinic of Interventional Neurology of the University Hospital Center Zagreb, where X-rays are used as standard for the diagnosis and implementation of surgical procedures.

A pilot project of comprehensive measurement of exposure of children and all operating staff during the implementation of surgical orthopedic procedures using diasopic X-ray diagnostics has been prepared. Measurements will be conducted during 2022.

3. Development of UV radiation sensors (SUVIndex)

Field measurements using developed prototypes of UV sensors, developed at IMROH in collaboration with external partners were postponed for a year due to the epidemiological situation. Data on UV behavior during the pandemic restrictions period are being collected.

Other research activities

The development and research of the architecture of the measuring system (dosimeter for measuring ambient dose equivalent H^* and velocities $H^*(10)$ in the pulse fields of X-ray devices) has been continued after the doctoral thesis defense of L. Pavelić and in cooperation with the Faculty of Electrical Engineering and Computing, University of Zagreb (Prof Igor Lacković). A part of the measurement in the field of a pulsed X-ray device was completed, which was used to analyze the characteristics of the developed detector system, such as time resolution, dynamic range and dose rate response. A new method of calculating the $H^*(10)$ dose and its speed for scintillation detectors has been developed, which has increased the dynamic range of the measuring system but the method should be further verified.

National Program for Screening and Early Detection of Lung Cancer 2020–2024

Lung cancer is one of the leading public health problems in the Republic of Croatia (close to three thousand patients and almost the same number of deaths per year). The adoption of the National Program for Screening and Early Detection of Lung Cancer in the Republic of Croatia aims to diagnose the early stages of the disease. This will increase the possibility of radical treatment and overall survival, and reduce mortality from lung cancer. This program is a new preventive measure in addition to the existing preventive programs for early detection of breast cancer, colon cancer and cervical cancer. An IT link has been provided between CEZIH (Central Health Information System of the Republic of Croatia), general medicine practices and hospitals. One of the relevant data in this association is the data on the patient's exposure to diagnostic radiation in order to participate in the screening program. Employees of the Unit also participate in this part of the implementation of the national program. The

program officially started in October at the Clinic for Lung Diseases Jordanovac, University Hospital Center Zagreb. More about the project: <https://zdravlje.gov.hr>.

Experimental development of TL dosimeter carriers for measuring eye lens exposure

The work on the design and development of our eye lens dosimeter was continued. The prototype of the eye lens dosimeter holder, printed using a 3D printer, is the first of its kind globally, and it was designed, manufactured and type-tested in the Unit. The research and testing has confirmed that our dosimeter with Panasonic's $\text{Li}_2\text{B}_4\text{O}_7$ detector meets the requirements of the IEC 62387:2012 standard and is suitable to use as a personal dosimeter for personal dose equivalent $H_p(3)$ measurements in interventional radiology and interventional cardiology. The measurement method for $H_p(3)$ photon measurement using our eye lens dosimeter prototype is in the process of validation by intercomparisons, the evaluation of the results and estimation of the correction factors is ongoing. The research activities on the investigation of the possibility to use different detectors in eye lens dosimeter holder were postponed due to COVID-19 pandemic restrictions.

RESEARCH PROJECTS FUNDED BY EXTERNAL SOURCES

National projects (Chapter 16.1.)

1. Significance of interaction of metal nanoparticles with sulphur biomolecules for nano-bio interface (NanoFaceS, HrZZ-IP)
2. Quantum-chemical design, preparation and biological properties of organometallic nucleobase derivatives (OrDeN, HrZZ-IP)
3. Application of Nanobiotechnology for Nutritional Supplementation with Selenium (NutriINTENSE, HrZZ-IP)

International projects (Chapter 16.2.)

1. European Concerted Programme on Radiation Protection Research (CONCERT, H2020)
2. Science-based risk governance of nano-technology (RiskGONE, H2020)
3. Safe-by-Design Approach for Development of Nano-Enabled-Delivery Systems to Target the Brain (SENDER, HrZZ-PZS)
4. Single layer gamma-ray polarimeter for medical imaging applications and fundamental physics research (SiLGaP, HrZZ-PZS)
5. Modified bacterial cellulose as artificial biomimetic membrane for biological blood-brain barrier (Bilateral CRO-SI)
6. e-Škole (e-Schools): Development of a digitally mature school system (Phase II) (ESF)

PROFESSIONAL SERVICES

Work of the Unit under the pandemic conditions

The implementation of field work, especially that performed by the Unit's associates within the Authorized Professional Technical Service for Radiological Safety (IMI STS), was difficult throughout 2021 for all users in Croatia. The pandemic measures in the Republic of Croatia, especially for healthcare institutions (hospitals), significantly prolonged the performance of quality control tasks and implementation of QA/QC procedures with ionizing radiation sources. Nevertheless, all of the contracted obligations of IMI STS have been successfully fulfilled. Employees who process personal dosimeters additionally collected and processed dosimeters that were used by professionals at the hospital, so-called COVID, departments and treated them according to a specially developed epidemiological protocol during their reading and further processing. For the health safety of its employees, the Unit introduced special protocols for the protection of employees and the disinfection and chemical treatment of dosimeter carriers.

Work of the Unit for the Ministry of the Interior of the Directorate of Civil Protection and monitoring of possible radiological accidents

As part of the IMI STS service, the staff of the Unit are obliged to participate in the supervision, remediation and monitoring of possible radiological accidents. This activities were on standby throughout the year due to the damage of IMROH's buildings and some hospital locations in the Republic of Croatia after the earthquake in Zagreb.

Professional work of the Authorized Expert Technical Service for Ionizing Radiation (IMI STS)

For the INA Group business members, related to the development of protocols for the implementation of business activities in oil and gas exploration in the Republic of Croatia, several new studies were contracted. One was designed specially for the STSI INA Group. The field surveys and monitoring of radiological works at the Molve gas production sites were performed as the second phase of joint activities. These activities comprise the manipulation of natural radioactive materials, preparation of an action plan in case of emergency containing radiological risks, recognizing the need for vocational training and implementation of safety measures related to ionizing radiation and the appearance of residues at INA Group production sites. The results of the cooperation with the INA Group will be visible in additional project research activities of the Unit, whose associates continue to develop and modernize the environmental model for monitoring residues in the gas and oil industry in the Republic of Croatia, with special concern on the residues impact on the biota at the location where these facilities are located.



Natural Radioactive Materials (NORM) – residues in oil and gas production in Croatia

Professional experimental work at the location of STSI in Strušac resulted in the development of an internal research project whose experimental development part was carried out on a trial basis in 2021 under the strictest pandemic restrictive measures in the field and in cooperation with external collaborators ALARA Instruments. The activities are linked to the sustainability of the IPPSO project, IMI_Ericsson Nikola Tesla (www.ippso.imi.hr), funded by the European Structural and Investment Fund.

The experimental measuring system nicknamed ALARA UAV (Unmanned Aerial Vehicle) was developed in the period 2019–2020 and is still being developed. Documentation is being prepared for the application of a pilot project for international funding and experimental technological development in full experimental form (research/technological development of measuring instrumentation).

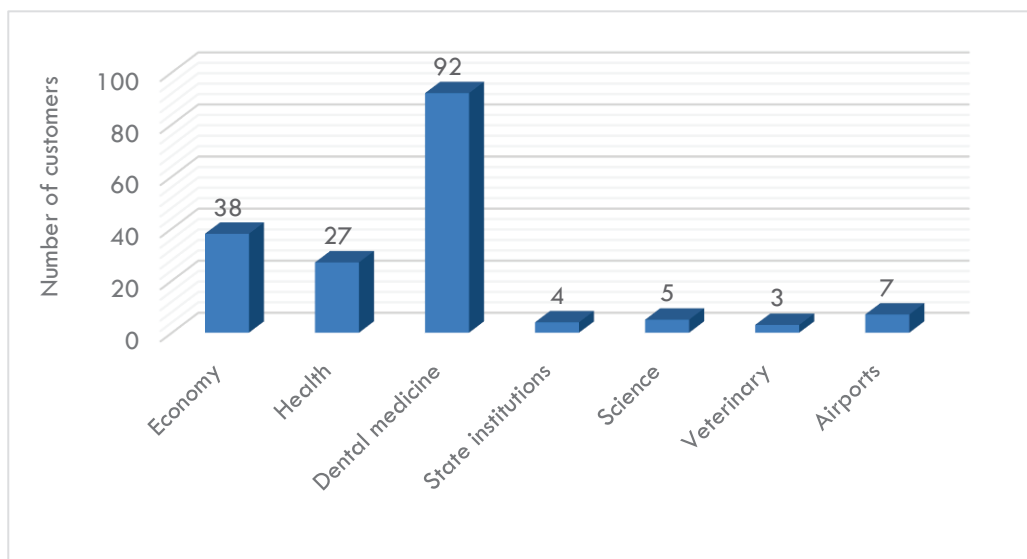
Professional risk assessment studies

10 risk assessment studies have been prepared for performing activities with ionizing radiation sources in medicine, dentistry, research and industry with various contractors. Several studies are in the process of being developed and refined.

CONTRACTOR	RAPORTEURS
Varaždin General Hospital	I. Prlić, B. Zauner
Teaching Institute of Public Health "Dr Andrija Štampar"	B. Zauner, I. Prlić
Office Cekić	T. Meštrović, B. Zauner
Dental office Dr Nika Kovačiček	T. Meštrović, B. Zauner
Končar – The electrical engineering Institute	T. Meštrović, B. Zauner
Zagreb Clinical Hospital Centre	I. Prlić
Siemens Healthcare	B. Zauner, T. Meštrović
2K Architectonic studio	I. Prlić, B. Zauner
ATS project engineering	M. Surić Mihić, B. Zauner
Studies in the process of revision and supplementation	I. Prlić

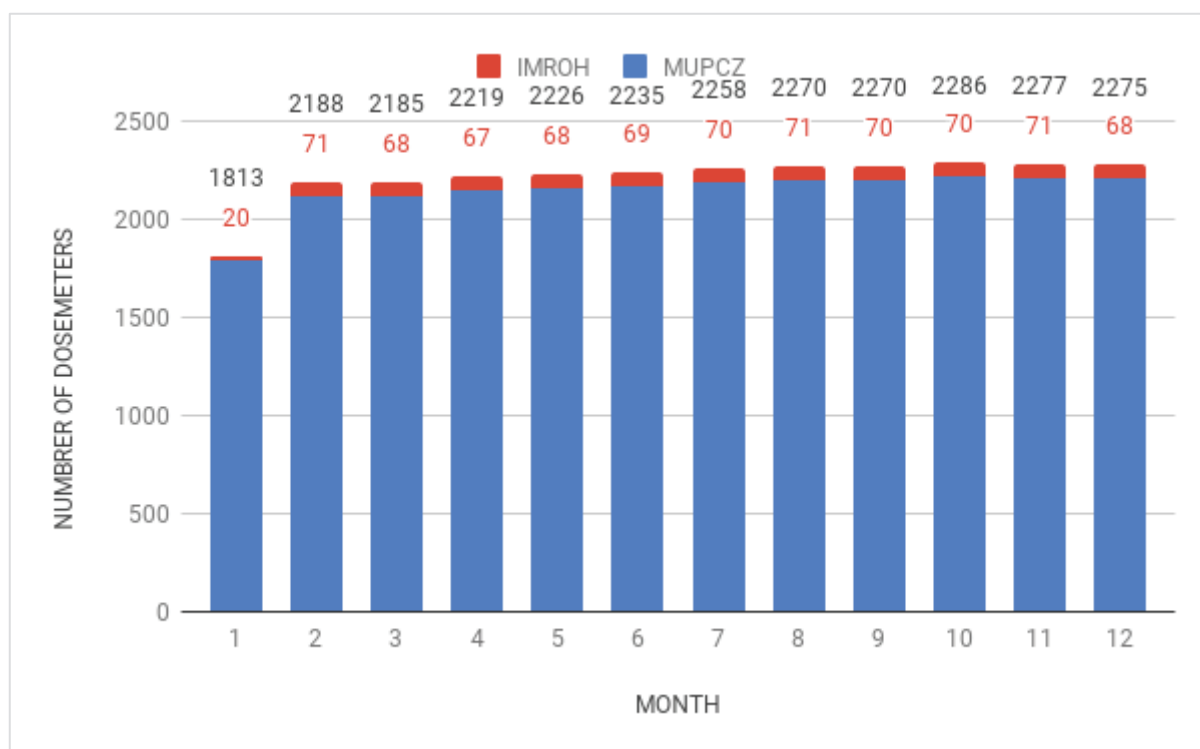
Professional reports of personal dosimetry and categorization of employees

The Unit conducted personal dosimetry monitoring, radiological monitoring of the workplace and testing of ionizing radiation sources for 188 contract users from various fields of activity in 2021, respecting the established epidemiological measures.



Number of contracting customers of the Unit in 2021 by field of activity

In 2021, about 2500 categorizations of exposed workers for contractual users of personal dosimetry supervision were made. More than 26,000 dosimetry measurements were performed, on the basis of which more than 3,000 dosimetry reports were prepared for contracted users of personal dosimetry monitoring.



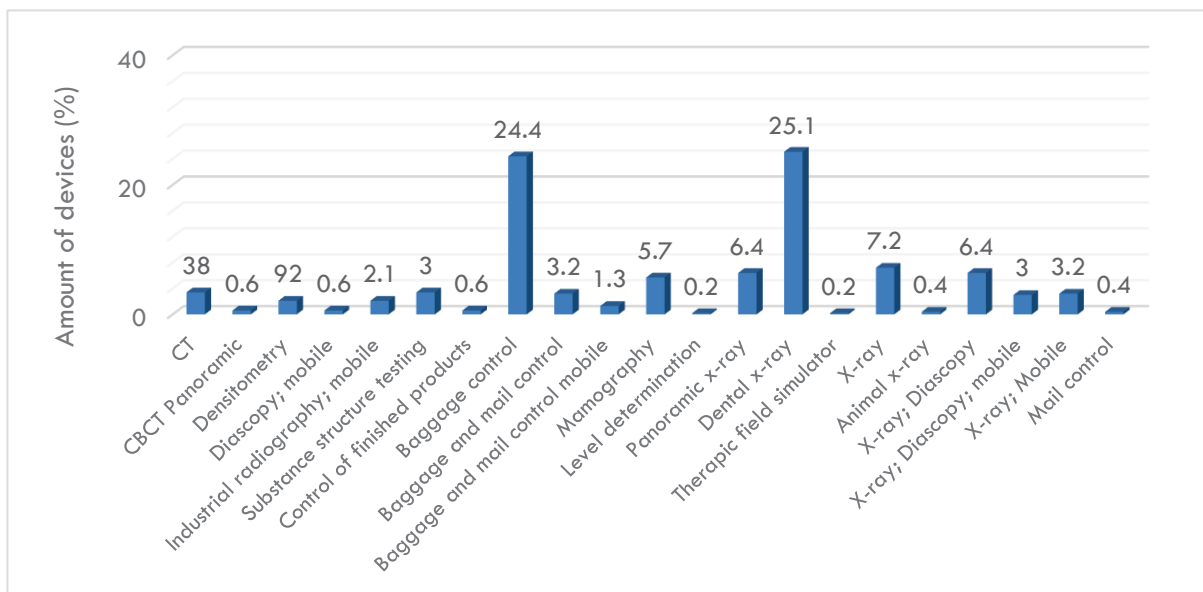
Number of tested dosimeters by month: blue are dosimeters whose results are reported to the national dose-register of exposed workers; red are dosimeters whose results are reported to users

The Unit is constantly updating its e-dosimetry protocol, which will be put into trial operation as soon as technically possible. This will modernize the communication between the users and IMI STS service enabling online submit of dosimetry reports. Further activities would entail the implementation of the e-dosimetry protocol to the Croatian e-Građani (*e-Citizens*) system. This protocol is still in its initial implementation phase and all relevant IT components and certificates for personal data protection of users have been tested during 2021.

I. PROTOCOL: e-dosimetry IMROH	RAPPORTEURS
Upgrading the TLD dosimetry system with programming and updating the HOLOGRAM IMROH® dosimetry according to the applicable regulations and maintaining the SQL database of all dosimetry data required for the preparation of online forms in the e-Građani system	J. Šiško (implementer) I. Prlić (advisor)

Professional reports on quality control of ionizing radiation sources

In 2021, more than 600 field tests were performed – quality control and measurements within radiological surveillance of about 550 electrical devices producing ionizing radiation (X-ray devices and linear accelerators) and close to 50 radioactive sources/isotopes used in medicine, industry and scientific institutions. Based on the conducted examinations, more than 1,200 expert reports and more than 1,300 expert opinions were made.



Percentage of tested devices by type

The Unit is working on completing the IMROH e-sources protocol, which will enable the transition to online delivery of reports on the implementation of QA/QC measurements to users of authorized IMROH STS and thus further modernize the business and relationship between the customers by submit electronically signed reports. This long-term professional project of the Unit will be in the test implementation phase for the next two years. We plan to test all of the relevant IT components and certificates for the protection of personal data of users, methods of receiving/storing and sending documentation and reporting to the regulatory body of the Ministry of the Interior of the Republic of Croatia of the Directorate of Civil Protection.

II. PROTOCOL: Control of ionizing radiation sources (e-sources)	RAPPORTEURS
Excel database for all ionizing radiation sources for which IMI STS implements QA/QC protocols. Excel sub-databases that serve as worksheets in which input data on devices and performed measurements are entered, and then an appropriate report (pdf) is generated, suitable for electronic signing and online delivery to users.	T. Meštrović J. Šiško

Professional work in the field of radiobiology

The immune response to specific allergens from the work and general environment in the serum of three individuals was examined. Identification of all types of asbestos in solid materials was carried out according to the model of the International Organization for Standardization (General requirements for the competence of testing and calibration laboratories International Standards Organization (ISO) Geneva: 1999). Eleven analyses of solid materials sent by interested companies were performed to determine the presence and type of asbestos. Material analysis was performed by the standardized method for stereomicroscopy and polarization microscopy MDHS 77-HSE (Document Method for the Determination of Hazardous Substances; series 77, Asbestos in bulk materials, in: HSG 248 Asbestos: The analyses' guide for sampling, analysis and clearance procedures Appendix 2: Asbestos in bulk materials: sampling and identification by polarized light microscopy).

Participation in international laboratory intercomparisons (1)

ORGANISER	TEST	AREA
Institut Jožef Stefan, Ljubljana, Slovenia	PRIMER 2021 Primerjalne meritve hitrosti doze in spektrometrije gama	Measurement of the ambient dose equivalent rate $H^*(10)/t$

List of accredited methods (2)

TEST METHOD	TYPE OF TEST, RANGE
ME-608-001 (In-house method)	Personal dosimetry of the photon radiation using TL dosimeters in the range 85 μSv –100 mSv and energy range 33 keV–1.3 MeV
ME-608-002 (In-house method)	Determination of ambient dose equivalent rate; $H^*(10)/t$, $H^*(10)/t$ range 100 nSv/h–100 mSv/h and energy range 36 keV–1.3 MeV

The Unit's quality manager: *J. Šiško*.

PROFESSIONAL ACTIVITIES OF THE EMPLOYEES OUTSIDE THE INSTITUTE

T. Meštrović

Radiation protection expert for the areas of personal dosimetric monitoring – assessment of external radiation, personal dosimetric monitoring – assessment of internal radiation, activities in medicine, dentistry and veterinary medicine with sources of ionizing radiation, activities in industry and science with radioactive and ionizing radiation sources.

L. Pavelić

Associate member of the European Radiation Dosimetry Group (EURADOS) Working Group WG3-S2; member of the of the Executive Board of the Croatian Nuclear Society.

I. Pavičić

Member of the Working Group for the development of the Croatian Position in the field of protection against electromagnetic fields.

I. Prlić – nominations

Member of the Reference Group of the Croatian Ministry of Health for cooperation with the EU EURATOM; member of the Scientific Expert Group ART 31 EURATOM, EC 2020–2025; member of the Scientific Expert Group ART 37 EURATOM, EC 2020–2025; member of IRPA (International Radiation Protection Association – Task Group on Radioactive Source Security, national nomination 2019-2024; EU ART31: member of the Working Group for Monitoring and Auditing of EU HORIZON projects.

I. Prlić – responsibilities

Expert-advisor of the Group for drafting the Position of the Republic of Croatia in the field of protection against non-ionizing radiation, Working Group for 5G technological solutions; member of the Commission of the Ministry of Health of the Republic of Croatia for the implementation of the Health Strategy of the Republic of Croatia – National Program for Screening and Detection of Lung Cancer 2020–2024; member of the Working Group of the State Institute for Standardization and the Ministry of Health of the Republic of Croatia for work on legal metrology in the field of medical equipment; member of the Board of Directors of the Croatian Society for Biomedical Engineering and Medical Physics; member of the Education and Training Committee of the European Federation of Organizations for Medical Physics (EFOMP); member of the International Atomic Energy Agency (IAEA); member of the EC Environmental Radiation-Effect Working Group: International Perspectives – part of the project for Croatia; member of the Commission of the Ministry of Health for review and evaluation of studies in the field of non-ionizing radiation sources; member and expert of the European ALARA Network for Naturally Occurring Radioactive Materials (EAN NORM); international expert for the International Road Transport Union and the International Labor Organization; member of the Board of

Directors of MELODI (Multidisciplinary European Low Dose Initiative); member of the Steering Committee of the international project CONCERT (H2020); member of the Steering Committee of ALLIANCE (The European Radioecology Alliance), Croatian member of the working group, Task Group on Radioactive Source Security, ICRP (International Committee for Radiation Protection); member of the Group for the preparation of scientific and professional EU regulatory documentation.

J. Šiško

Associate member of the European Radiation Dosimetry Group (EURADOS) Working Group WG3-S2; radiation protection expert.

SCIENTIFIC, TEACHING AND ACADEMIC ADVANCEMENT OF EMPLOYEES

PhD degree and scientific degree of scientific associate was gained by *L. Pavelić*.



15.4. Environmental Hygiene Unit

EMPLOYEES OF THE UNIT

HEAD

Assist Prof Gordana Pehnac, PhD, scientific advisor

RESEARCHERS

Ivan Bešlić, PhD, scientific advisor since 22 Jul 2021

Silvije Davila, PhD, scientific associate since 19 May 2021

Ranka Godec, PhD, scientific associate

Jasmina Rinkovec, PhD, scientific associate since 9 Jun 2021

Silva Žužul, PhD, scientific associate

Ivana Jakovljević, PhD, postdoctoral researcher

Iva Šimić, MSc, PhD student-assistant

Suzana Sopčić, PhD, professional associate in science

Valentina Gluščić, MSc, professional associate in science

Nikolina Račić, MSc, professional associate in science since 14 Jun 2021

Zdravka Sever Štrukil, MSc, professional associate in science

TECHNICAL STAFF

Ana Filipec, statistician, senior technician

Samuel Ljevar, senior technician

Magdalena Vincetić, MSc, senior technician

Marija Antolak, technician

Matea Kuzel, technician

Karmenka Leš Gruborović, technician

Martin Mihaljević, technician

Martina Šilović Hujić, MSc, technician

PARTICIPATING RETIRED RESEARCHERS

Krešimir Šega, PhD, permanent scientific advisor

Vladimira Vađić, PhD, permanent scientific advisor

Mirjana Čačković, PhD, senior scientific associate

SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

Long-term research activities

Investigation of metals in the PM₁₀ fraction of particulate matter and total deposited matter by inductively coupled plasma mass spectrometry (ICP-MS) continued at different locations with different pollution sources.

Mass concentrations of polycyclic aromatic hydrocarbons (PAHs) in PM₁₀ and PM₁ particle fraction were measured continuously at locations with different pollution sources and their spatial and seasonal variation as well as sources apportionment (239, 258, 283). An assessment of the human health impact of organic pollution was also determined at four major crossroads in Zagreb (33). At the same locations, concentrations of gaseous pollutants were also measured (33). Two methods of sample preparations for PAH analysis were compared: the accelerated solvent extraction method (ASE) and the ultrasonic method (UZV). The ASE method showed slightly better extraction efficiency

compared to the ultrasonic method, especially for PAHs with four aromatic rings. Both extraction methods were found suitable for preparation of particulate matter samples (257).

Measurements of air pollution with elemental (EC) and organic (OC) carbon in the PM_{2.5} fraction of particle matter continued at measuring stations for monitoring air quality of different characteristics (urban background, urban traffic and rural measuring stations) (33, 239, 252).

Carbohydrate analysis is performed in the PM₁₀ and PM₁ fraction of particulate matter at measuring stations of different characteristics; urban background, urban traffic, or rural measuring station. The results revealed the extent to which biomass burning contributes to the total concentration of suspended particles as well the presence of carbohydrates in individual fractions of suspended particles. Seasonal variations of twelve carbohydrates was monitored and their interrelationship as well as possible sources were studied. Since biomass burning is an organic type of air pollution, the results were compared against polycyclic aromatic hydrocarbons and organic carbon analysis results (253).

Measurements of ozone and its precursors nitrogen oxides and carbon monoxide were continued in order to study their trends and relationships. The ozone trend was studied at one location in Zagreb for the period 2003–2016. Using Fourier transformation analysis annual, weekly and daily periodicities were determined at the location (64). The influence of the lockdown due to the COVID-19 pandemic on the levels of ambient air pollutants was studied. Levels of nitrogen dioxide, ozone, PM₁₀, PM_{2.5} and PAHs in Zagreb during the lockdown period were compared with the average for the same period in 2017, 2018 and 2019 (274). The decrease in people's mobility, especially in the number of cars during the lockdown period led to a decrease of NO₂ concentrations and partly PM₁₀ concentrations, but at the same time concentrations of ozone increased (273). It was noticed that during the "lockdown" period at traffic measuring station in Zagreb the NO₂ concentration decreased by 35% compared with the same period in 2019 (43).

Measurements of the mass concentrations of water-soluble ions; anions (Cl⁻, NO₃⁻, SO₄²⁻) and cations (Na⁺, NH₄⁺, K⁺, Mg²⁺, Ca²⁺) in PM_{2.5} particle fraction continued. The investigation of the possible seasonality in their levels, relations and contribution to the total PM_{2.5} mass was examined in order to indicate its different air pollution sources or formation pathways present in air (250). Measurements of acidic components (Cl⁻, NO₃⁻, SO₄²⁻) in atmospheric bulk deposition (BD) continued at different locations. Furthermore, the measurements were extended to monitoring the levels of alkaline ions as well. The spatial and temporal distribution of ion levels in the BD were examined at monitoring stations in the city of Zagreb, distributed in the north-south and east-west directions (249, 250).

Scientific collaborations

In cooperation with the Biochemistry and Organic Analytical Chemistry Unit, the method for the determination of polybrominated diphenyl ethers (PBDEs) in breast milk samples was developed based on ASE and gas chromatography tandem mass spectrometry (GC-MS/MS). It was used to determine PBDEs in real samples (323). Also, the collection of monthly samples of atmospheric deposition in Zagreb and its surroundings was continued, in which 17 PCBs, seven organochlorine pesticides and 12 PAHs were determined (288, 290). Two different performances of a bulk collector were also compared (289). Research started within the institutional project "Analysis of organic pollutants in biological systems and the environment" (leader S. Herceg Romanić).

In collaboration with the Radiation Dosimetry and Radiobiology Unit and the Radiation Protection Unit, a study of radionuclide activity concentrations in soils all over Croatia was carried out, which resulted in radioactivity maps of Croatian soil (107, 108).

The cooperation with the Faculty of Science in Sarajevo, Bosnia and Herzegovina, and Katja Džepina, PhD (Multiphase Chemistry Department, Max Planck Institute for Chemistry, Germany; Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Switzerland, University of Nova Gorica, Slovenia) on data processing of PM₁₀ particle fraction at several measuring stations in the Sarajevo Canton, Bosnia and Herzegovina, continued with the aim of characterizing organic and inorganic atmospheric

pollutants. Within this collaboration, we also determined aerosol source apportionment and oxidative potential (297).

In the cooperation with the Faculty of Agriculture, University of Zagreb, an internal method for the determination of nitrogen dioxide in air was developed by using passive sampler and static chambers. The impact of mineral soil fertilization on the N-NO₂ flux during triticale vegetation was examined (122, 356).

Colaboration with the Andrija Štampar Teaching Institute of Public Health continued within the “Ecological Map of the City of Zagreb” programme. Air quality measurements are sent to the web portal <https://ekokartazagreb.stampar.hr/>, where the latest data on environmental measurements (soil, water, air, pollen, meteorological data) in Zagreb are continuously collected. At the beginning of 2021, measurements of particulate matter content were carried out at selected locations in Zagreb (Gornje Vrapče, Sesvete, Vrbani), including organic and elemental carbon, PAHs, water-soluble anions and cations and elemental PM content (252, 294).

In cooperation with the Faculty of Forestry, University of Zagreb, the effectiveness and applicability of the photometric method for determination of the mass concentration of inhalable dust from raw and dry hardwoods were investigated (16, 17, 244).

In-house scientific projects (Chapter 16.1.A.3.)

1. Levels of platinum group elements (PGE) near roads

The project in which samples of soil (depths from 0 to 5 cm and from 5 to 10 cm), vegetation (plantain, grass – at the early stage and near the end of vegetation) and PMs were collected at three differently polluted locations in Zagreb was completed. Studies were conducted to quantify the levels of platinum (Pt), palladium (Pd) and rhodium (Rh) in the above mentioned samples. Collected samples of PMs, soil and vegetation were prepared by microwave digestion in nitric acid under high pressure and temperature and analyzed by inductively coupled plasma mass spectrometry (ICP-MS). Soil was also characterized by basic agrochemical analyses important for understanding the mobility and bioavailability of PGE such as texture, pH, cation exchange capacity (CEC), exchangeable ions (Na⁺, K⁺, Ca²⁺ and Mg²⁺), water-soluble anions and cations, calcium carbonate, etc. At all three monitoring stations, the results showed significantly higher mass concentrations of Pd in air, soil and vegetation compared to the mass concentrations of Rh and Pt. In plantains (*Plantago Lanceolata* L.), higher mass concentrations of PGE were determined compared to those determined in grass (*Dactylis glomerata* L.) (295). Statistically significant seasonal variations of mass concentrations of Pt, Pd and Rh in PMs with the highest values measured during the colder part of the year (autumn–winter) were found at all of the measuring stations. Compared to previous research on these metals in the air of Zagreb (2015–2017), a decrease in mass concentrations was observed during the duration of this research (2018–2020). This research provided the first information on Pt, Pd and Rh levels in the environment (suspended particles, plants and soil) (280).

2. Organic content of PM₁ particle fraction

Collection of 24-hour PM₁ fractions of particulate matter continued during the year at IMROH as well as at a location in the centre of Zagreb. Organic and elemental carbon, water-soluble organic carbon, levoglucose and PAHs were analyzed in the collected samples. The collected data were processed and the obtained results were systematized. Data on PAHs, levoglucosane, organic and elemental carbon and water-soluble organic carbon in PM₁ particles were studied and presented at one national congress as a poster and oral presentation. For both locations, carcinogenic activity was determined (282). Concentration levels of organic pollutants were determined at one typical street canyon location (253). Furthermore, the level of air pollution during the “lockdown” period caused by the COVID-19 pandemic (15 Mar–15 May 2020) was compared with the same period a year earlier. During the “lockdown” period at the traffic measuring station, the concentrations of the sum of PAHs in the PM₁ fraction decreased by 26% (43).

3. Molecular markers of organic carbon – biomass burning indicators

This project is the first in Croatia to investigate the impact of biomass burning to the total level of particulate matter by analyzing different carbohydrates, primarily anhydrosugars as the mono-specific marker for air pollution caused by biomass burning. For proposed measurements, the method of high-performance anion exchange chromatography with pulsed amperometric detection was selected. Since such a method is novel in the analysis of carbohydrates in PMs, one of the project goals is to develop and validate a method for such analyses. Investigations are performed with the samples collected at the urban background station located at the IMROH. Sampling of three different PM fractions (PM₁₀, PM_{2.5} and PM₁) was carried out over a one-year period (1 Jan to 31 Dec 2020). Such results will ensure better insights into the carbohydrate presence in different PM fractions, which is very important from a health standpoint. Since the intensity of biomass burning is not constant throughout the year, the results will reveal the exact seasonal variations in the mass concentrations of individual analytes. The organic components in particulate matter are the result of several different sources of air pollution so the anhydrosugars mass concentrations results will be compared to the organic carbon and PAHs concentrations analyzed from the samples collected at the same measuring station.

The obtained results will be associated with the results that are systematically collected in the Unit and will be included in the Positive Matrix Factorization (PMF) analysis for pollution sources estimation.

So far, the performed analyses follow the work plan specified in the project. The validation of two methods using high-performance anion exchange chromatography with pulsed amperometric detection was performed and their suitability for routine analysis of carbohydrates in particulate matter was confirmed (285). Analyses of daily samples of PM₁₀ particulate matter collected on the urban background for 30 days in each season were conducted and results showed significant seasonal variation with levoglucosan as the most abundant anhydrosugar. The highest mass concentrations of anhydrosugars were detected in the colder part of the year, which is in accordance with the heating season in households (284, 285).

RESEARCH PROJECTS FUNDED BY EXTERNAL SOURCES

National projects (Chapter 16.1.)

1. Biochemical responses of the surface layer in the oligotrophic area of the Adriatic to atmospheric sedimentation (BiREADI, HrZZ-IP)
2. Air pollution and human biomarkers of effect (HUMNap, HrZZ-IP)
3. Ecological map of the City of Zagreb (City of Zagreb)

International projects (Chapter 16.2.)

1. Project of extension and modernisation of the national network for continuous air quality monitoring (AIRQ, ERDF)
2. Determining Long Term Time Trends of Air Pollution Source Tracers by Nuclear Techniques (IAEA)
3. Deployment of lower-cost ambient air quality sensor systems in urban environments (JRC)
4. Development of functional beverage in sustainable packaging (JamINNO+, ERDF)

PROFESSIONAL SERVICES

The monitoring of air pollution continued in Zagreb at six measuring stations of the local measuring network. At the Zagreb stations, the Unit measured different pollutants in the air: sulphur dioxide, black carbon, PM₁₀ fraction, metals arsenic (As), cadmium (Cd), nickel (Ni), lead (Pb), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), PAHs in PM₁₀ fraction, PM_{2.5} fraction, nitrogen dioxide (NO₂), ozone (O₃), carbon monoxide (CO), benzene, total deposited matter, and metals As, Cd, Ni, Pb, and Tl in the total deposited matter.

According to contracts with the Ministry of Economy and Sustainable Development and the Meteorological and Hydrological Service of Croatia, following the Air Protection Act (127/2019), the Unit as a reference laboratory performs the sampling of particulate matter (PM₁₀ and PM_{2.5}) and its physical and chemical analysis at measuring sites within the Croatian State Network for Air Quality Monitoring. The Unit also carries out equivalency of non-reference methods for the determination of particulate matter mass concentration (PM₁₀ and PM_{2.5}) in the air. In 2018, air pollutants were measured at the monitoring sites Zagreb-1, Zagreb-3, Sisak-1, Slavonski Brod-1, Slavonski Brod-2, National Park Plitvice Lakes, Ksaverska cesta, Velika Gorica, Kutina, and Rijeka-2, in Croatia.

Equivalence studies were performed for the non-reference measuring method of PM₁₀ at measuring sites Zajci and Čambarelići (contract with Rockwool Adriatic, Potpićan, Croatia).

The monitoring of air, water, soil, agricultural, and forest ecosystems and control of wild animals in the vicinity of the Central Gas Station (CGS) Molve continued. In 2018, in cooperation with the Institute of Public Health of the Koprivnica-Križevci County, the Institute performed measurements of hydrogen sulphide, mercaptans, and sulphur dioxide at five locations in the proximity of the CGS Molve.

The monitoring of air quality within the zone of influence of the Wastewater Treatment Plant in Zagreb was continued. The monitoring of levels of hydrogen sulphide, ammonium, and total mercaptans and meteorological parameters was carried out at five measuring stations. In 2021, the measurements of these pollutants were extended to two additional locations in the possible zone of influence (Resnik and Ivanja Reka, Croatia).

Near the Jakuševac landfill, the levels of PM₁₀ and mercaptans are continuously measured. During different seasons, levels of metals Pb, As, Ni, Cd and PAHs in PM₁₀ fraction were also measured as well.

Measurements of PM₁₀ fraction and PAHs in PM₁₀ fraction were carried out at a measuring site within Zagreb International Airport, Croatia.

Special purpose measurements were carried out in Zagreb at MO Kanal, in Ogulin, Varaždin and Novoselec (Municipality Sv. Križ, Croatia).

Measurements of total deposited matter were carried out at two locations at "Brezovi Rebar" sand excavation near Karlovac, in the area of the asphalt base in Našice and in the area of exploitation of construction sand and gravel in Severovci field, Đurđevac, Croatia.

List of intercomparisons (2)

ORGANISER	TEST	AREA	DATE
LGC	LGC – AIR PT Workplace Air, Ambient Air and Stack Emissions, Round 42 (AR042); 16 – Diesel Fume	Determination of mass concentration of elemental carbon in particles	Jan/Feb 2021
LGC	AIR PT Workplace Air, Ambient Air and Stack Emissions, Round 42 (AR042); 33 – Metals.	Determination of mass concentration of metals As, Cr, Cu, Pb, Se and Tl in deposited matter and the sample volume of deposited matter	Jan/Feb 2021

List of accredited methods (14)

During the accreditation supervision in 2020, accreditation area was expanded for a new method for determining the mass concentrations of anions and cations in PM_{2.5} as deposited on filters.

METHOD	TYPE OF TEST, RANGE
HRN EN 12341:2014 (EN 12341:2014)	Determination of mass concentration of PM ₁₀ and PM _{2.5} particle fractions
HRN EN 14212:2012 (EN 14212:2012), HRN EN 14212:2012/Amend. 1:2014 (EN 14212:2012/AC:2014)	Determination of the concentration of sulphur dioxide in the ambient air

HRN EN 14625:2012 (EN 14625:2012)	Determination of the concentration of ozone in the ambient air
HRN EN 14211:2012 (EN 14211:2012)	Determination of the concentration of nitrogen oxide in the ambient air
HRN EN 14626:2012 (EN 14626:2012)	Determination of the concentration of carbon monoxide in the ambient air
HRN EN 14902:2007 (EN 14902:2005), HRN EN 14902/AC:2007 (EN 14902:2005/AC:2006)	Determination of the concentration of Pb, Cd, As and Ni in the PM ₁₀ fraction of suspended particulate matter
HRN EN 16909:2017 (EN 16909:2017)	Determination of the mass concentration of elemental and organic carbon in the suspended particulate matter in the ambient air
HRN EN 15549:2008 (EN 15549:2008)	Determination of the concentration of benzo(a)pyrene in the ambient air
HRI CEN/TR 16269:2017 (CEN/TR 16269:2011)	Determination of the mass concentration of anions and cations in the suspended particulate matter
VDI 4320 Part 2: 2012 (VDI 4320 Part 2:2012)	Determination of the dust deposition according to the Bergerhoff method
HRS CEN/TS 16645:2016 (CEN/TS 16645:2014)	Determination of the concentrations of benz(a)anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene and benzo(ghi)perylene in ambient air
HRN EN 15841:2010 (EN 15841:2009)	Determination of arsenic, cadmium, lead, and nickel in atmospheric deposition
In-house method OP-610-UTT-TI Edition 01 2020-01-28	Determination of thallium in atmospheric deposition
HRN EN 16913:2017 EN 16913:2017)	Determination of the mass concentration of anions and cations in PM _{2.5} as deposited on filters

The Unit's quality manager: *R. Godec*.

PROFESSIONAL ACTIVITIES OF EMPLOYEES OUTSIDE THE INSTITUTE

I. Bešlić

Member of the Croatian Air Pollution Prevention Association's Presidency; member of the Working Group in charge of monitoring the activity plan for the national network for permanent air quality monitoring at the Ministry of Economy and Sustainable Development of the Republic of Croatia; member of the Commission for Reference Laboratory Work Monitoring at the Ministry of Economy and Sustainable Development of the Republic of Croatia; member of the Commission for the Selection of the Measuring Stations in the National Air Quality Monitoring Network; member of the Working Group for Air of the Croatian Accreditation Agency; member of the TO-146 Air Quality Committee of the Croatian Standards Institute; member of the Executive Editorial Board of the journal *Archives of Industrial Hygiene and Toxicology*; member of the "Air Protection 2021" conference Scientific Committee.

S. Davila

Member of the Croatian Air Pollution Prevention Association's Presidency; member of the "Air Protection 2021" conference Organizing Committee.

R. Godec

President of the Croatian Air Pollution Prevention Association; member of the TO-146 Air Quality Committee of the Croatian Standards Institute; president of the “Air Protection 2021” conference Organizing Committee.

I. Jakovljević

Member of the “Air Protection 2021” conference Organizing Committee.

G. Pehnec

International coordinator and member of the Croatian Air Pollution Prevention Association's Presidency; member of the Working Group in charge of monitoring the activity plan in the national network for permanent air quality monitoring at the Ministry of Economy and Sustainable Development of the Republic of Croatia; member of the Commission for Air Quality Improvement Monitoring in the area of Slavonski Brod; member of the Working Group for Air of the Croatian Accreditation Agency; President of the “Air Protection 2021” conference Scientific Committee; vice-president of European Federation of Clean Air and Environmental Protection Associations (EFCA).

J. Rinkovec

Member of the “Air Protection 2021” conference Organizing Committee.

Z. Sever Štrukil

Treasurer and member of the Croatian Air Pollution Prevention Association's Presidency; member of the “Air Protection 2021” conference Organizing Committee.

S. Žužul

Member of the Croatian Air Pollution Prevention Association's Presidency; member of the “Air Protection 2021” conference Scientific Committee.



15.5. Occupational Health and Environmental Medicine Unit

EMPLOYEES OF THE UNIT

HEAD

Prim Jelena Macan, MD, PhD, permanent scientific advisor
(90 % of working hours and 10 % in the Institute's company)

RESEARCHERS

Assoc Prof Selma Cvijetić Avdagić, PhD, MD, permanent scientific advisor
Veda Maria Varnai, PhD, MD, permanent scientific advisor
Željka Babić, PhD, scientific associate
Assist Prof Adrijana Bjelajac, PhD, scientific associate
Jelena Kovačić, PhD, scientific associate
Zrinka Franić, MD, PhD, assistant until 23 Oct 2021
Marija Macan, PhD student-assistant (HrZZ)
Patricija Tomac, PhD student-assistant (HrZZ) since 13 Sep 2021
Rajka Turk, MSc, professional advisor in science
Marija Kujundžić Brkulj, BSc, professional associate in science since 1 Feb 2021

TECHNICAL STAFF

Zrinka Benčak Gravara, senior technician until 1 Sep 2021
Franka Šakić, MSc, senior technician (90% of working hours)
Monika Vuletić, MSc, senior technician
Jagoda Mandić, nurse, technician

PARTICIPATING RETIRED RESEARCHERS

Prim Božica Kanceljak Macan, MD, PhD, permanent scientific advisor
Assist Prof Biserka Ross, PhD, permanent scientific advisor

SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

In-house scientific projects (Chapter 16.1.)

1. *Determination of body composition and chronic stress by the method of bioimpedance*

The project included additional 300 participants from nursing homes in Zagreb. Body composition was measured by a bio-impedance device and physical activity and nutrition were determined by questionnaire. The association of osteosarcopenic obesity with Covid was assessed (49).

2. *Relationship between chronic inflammation and osteopenia in patients on chronic hemodialysis*

The project was completed. It comprised 100 subjects of both sexes aged 26 to 90, who were on a chronic hemodialysis program. Sarcopenia was found in 28% of participants who also had a higher total number of lost teeth compared to patients without sarcopenia (54). The results of a study on bone density, determined by quantitative ultrasound (QUS) in 128 sawmill workers have been published. Physical workload was not significantly associated with bone density (139).

3. *Prevalence and predictors of occupational contact dermatitis in apprentice nurses/medical technicians (NurseSkin)*

The project was implemented according to the work plan from November 2020 to January 2022 as a cross-sectional study. The study included 240 nurse apprentices out of a total of 264 apprentices attending final (fifth) class in the three vocational schools in Zagreb (response rate 91%). Data collection was compromised by the COVID-19 pandemic and was performed under obligatory

epidemiological measures in schools in periods when apprentices attended practical training. The study protocol included data collection by questionnaire for all participants, clinical examination of the skin on hands/wrists, and measurement of the skin barrier function parameters (skin pH and TEWL-transepidermal water loss). Sixty participants with hand eczema that lasted for 3 or more months were invited to allergological skin testing with latex, a basic series of contact allergens, and common disinfectants. Forty-two of them agreed and were tested (response rate 70%). Results showed that 49% of apprentices had contact dermatitis of the hands during the COVID-19 pandemic, which was dominantly of irritative origin and related with the duration of practical training. This confirms the importance of cumulative effect of skin irritants on skin barrier. Latex allergy was not found and contact sensitization was found in 26% of apprentices, mostly to nickel (137). In the scope of this project, F. Šakić graduated with the master's thesis "Prevalence and predictors of occupational contact dermatitis in nurse apprentices" at the School of Medicine, University of Zagreb (180). An extension of a project work plan was requested with recruitment of new participants attending the last semester of vocational education in spring 2022. The completion of data collection and reports for vocational schools were planned in 2022, as well as further dissemination of study results.

4. Sleep quality in different age groups in Croatia before and during COVID-19 pandemic (CoV-Sleep)

The project started with implementation in 2021. The coronavirus pandemic and epidemiological measures introduced to control it have shown a number of adverse effects on human health and functioning. Research conducted in various countries around the world has shown an increase in sleep problems and disorders during the pandemic in all age groups. Data for our country are not known, so the aim of this study is to examine the differences in sleep quality before and during the COVID-19 pandemic in Croatia in the adult and elderly population. Data for adults will be collected as part of the ongoing ICOSS-2 international epidemiological study. Data for the elderly will be obtained by retrospective analysis of archive data collected in projects that began before the pandemic was declared. The results of this project will be among the first in our country to analyze the effects of the COVID-19 pandemic on sleep quality in the general adult population as well as in the particularly vulnerable group of the elderly. The results will provide epidemiological insight into the quality of sleep during the pandemic in Croatia, which is the starting point for planning further research and health and public health interventions for the primary prevention of sleep problems and drowsiness. Based on the results of the research, educational materials and recommendations will be developed and distributed electronically through various channels. Such action will increase the visibility of IMROH as a relevant applied-scientific expert base.

Scientific collaborations

Research entitled "**Implementation of Questionnaire for Diagnosing Occupational COVID-19 in Healthcare Workers**" was continued within the research cooperation between the Unit and School of Public Health A. Štampar, School of Medicine, University of Zagreb. Clinical data collected from 59 healthcare workers showed that work-related COVID-19 was most common in hospital nurses/laboratory technicians and takes a mild form, with symptoms clustering around three clinical phenotypes: general symptoms of acute infection, specific symptoms including neurological (anosmia, ageusia) and respiratory symptoms, and diarrhoea as a separate symptom (125). Additional analysis was done on data related to documentation that 100 healthcare workers submitted for registration of COVID-19 as an occupational disease. Findings confirm that the major risk of occupational COVID-19 in healthcare workers is close contact with patients and colleagues, and points to the need for better cooperation between occupational health physicians, occupational safety experts, employers, and diseased workers. More precisely, eighty participants did not enclose obligatory documents needed for registration of occupational COVID-19 (126). Data collection and analysis will continue in 2022.

Research cooperation with the Institute for Anthropological Research within the project "**The role of the mother and the experience of parental competence of mothers with impaired mental health** (MIMOZE, 2021–2025, leader: E. A. Delale; IMROH associate: A. Bjelajac)" started in 2021. The

objectives of the project are to investigate the experience of the parental role of women with mental health problems and to examine the representation of their parental role in the hospital archives and existing medical documentation. The research will be conducted with a mixed quantitative and qualitative research approach, respecting the dignity and well-being of participants, respecting their human rights, with professional and scientific responsibility of researchers, according to the highest ethical standards of the Helsinki Declaration, the Ethical Code of the Croatian Psychological Chamber and the General Data Protection Regulation. This is an internal project of the Institute of Anthropology, which will be conducted in cooperation with the Clinic of Psychiatry St. Ivan, without additional funding (leader E.A. Delale, IMROH's associate A. Bjelajac). The planned start of the project was in 2020, but due to the coronavirus pandemic, the research started at the end of 2021.

RESEARCH PROJECT FUNDED BY EXTERNAL SOURCES

National projects (Chapter 16.1.)

1. Exposure to pyrethroid and organophosphate insecticides in children – risk assessment for adverse effects on neuropsychological development and hormonal status (PyrOPECh, HrZZ-IP)
2. Assessment of daily exposure to metals and maternal individual susceptibility as factors of developmental origins of health and disease (METALORIGINS, HrZZ-IP)

International projects (Chapter 16.2.)

1. Network on the Coordination and Harmonisation of European Occupational Cohorts (OMEGA-NET, COST)
2. Genomics of MusculoSkeletal traits Translational Network (GEMSTONE, COST)
3. Chronic hand eczema in Europe: Patients' experiences and perspectives (CHEPEP, European Academy of Dermatology and Venereology)
4. Promoting the autonomous implementation of the European framework agreement on occupational health and safety in the hairdressing sector (EC: DG Employment, Social Affairs and Inclusion)

PROFESSIONAL SERVICES

Professional activities of the Unit included the organisation and implementation of teaching modules for medical doctors, residents in occupational and sport medicine, and clinical pharmacology and toxicology. A training in clinical pharmacology and toxicology of one week duration was conducted for two residents. J. Macan was appointed main supervisor by the Croatian Ministry of Health for 7 residents in occupational and sports medicine.

For teachers in vocational schools, lectures were delivered in the field of health and safety at work, and actual epidemiological investigations performed in this field within the Unit.

PROFESSIONAL ACTIVITIES OF THE EMPLOYEES OUTSIDE THE INSTITUTE

Ž. Babić

Member of the Committee for Safe Use of Medicines of the Agency for Medicinal Products and Medical Devices of Croatia; member of the Working group for the drafting of the proposal for an ordinance on the conditions of distribution and sale of pesticides; member of the Working group for the revision of the National Action Plan for Sustainable Use of Pesticides; member of the Editorial Board of the journal *Public Health Toxicology*.

A. Bjelajac

President of the Committee for evaluation of programs for propaedeutics in psychotherapy of the Association of Psychotherapy Societies of Croatia; member of the Ethical Committee of the Society of Gestalt and Integrative Psychotherapists of Croatia; member of the Supervisory Board of the Croatian

Chamber of Psychotherapists; member of the Executive Committee of the journal *Archives of Industrial Hygiene and Toxicology*.

J. Kovačić

Statistical editor and Executive Committee member of the journal *Archives of Industrial Hygiene and Toxicology*; external associate of the Agency for Medicinal Products and Medical Devices of Croatia.

J. Macan

Full member of the Croatian Academy of Medical Sciences, Collegium of Public Health; member of the Croatian Society of Occupational Health Management Committee; member of the Croatian Society of Medical Court Expertise; member of the European Initiative for Prevention of Occupational Skin Diseases at the European Academy for Dermatology and Venereology; member of the Committee for Medical Ecology, the Working Group for developing national positions in the field of protection from electromagnetic fields, and the Working Group for climate changes and health at the Ministry of Health of the Republic of Croatia; permanent court expert witness in occupational medicine; member of the Croatian Association of Court Expert Witnesses and Valuers; assistant editor and Executive Committee member of the journal *Archives of Industrial Hygiene and Toxicology*.

R. Turk

Member of the Biocidal Products Committee of the Ministry of Health of the Republic of Croatia and a substitute member of the Biocidal Products Committee of the European Chemicals Agency; member of the Committee for Safe Use of Medicines of the Agency for Medicinal Products and Medical Devices of Croatia; member of the Working group for the revision of the National Action Plan for Sustainable Use of Pesticides; substitute member of the Working group for the drafting of the proposal for an ordinance on the conditions of distribution and sale of pesticides.

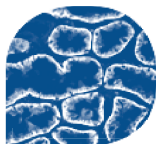
V. M. Varnai

Member of the Committee for Risk Assessment (RAC) at the European Chemicals Agency (ECHA).

SCIENTIFIC, TEACHING AND ACADEMIC ADVANCEMENT OF EMPLOYEES

PhD degree was gained by *Zr. Franić*.

Professional degree of Master of nursing was gained by *F. Šakić*.



15.6. Molecular Toxicology Unit

EMPLOYEES OF THE UNIT

HEAD

Davorka Breljak, PhD, scientific advisor

RESEARCHERS

Marija Ljubojević, PhD, senior scientific associate

Ivana Vrhovac Madunić, PhD, scientific associate

Dean Karaica, PhD, scientific associate since 9 Mar 2021

TECHNICAL STAFF

Ljiljana Babić, technician

PARTICIPATING RETIRED RESEARCHER

Ivan Sabolić, MD, PhD, permanent scientific advisor

SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

Long-term research activities

We continued our long-term study in the Unit covering the expression of various membrane transporters in the rat experimental model being started, but not completed in the given project period.

Within the frame of the research project funded by the Croatian Science Foundation that ended in 2020 (MycotoxA, IP-09-2014-5982), we studied the individual and combined effect of mycotoxins (ochratoxin A and/or citrinin) and antioxidant resveratrol on the expression of membrane transporters for organic cations (Oct1/Slc22a1 and Oct2/Slc22a2) in the rat kidney. The results of this study were summarized in the original scientific article being accepted for publication in 2022 (133). Furthermore, the results of these studies were presented at the congress CROTOX2021 and published in the Book of Abstract (213, 222). In addition, the Croatian Society and Toxicology awarded these studies with the Young Scientist Award (222) and Best Poster Presentation Award (213).

Within the frame of the research project funded by the Croatian Science Foundation that ended in 2019 (AGEMETAR, IP-2013-11-1481), we performed detailed statistical analysis of long-term effects of melatonin and resveratrol on oxidative parameters, sex hormones and DNA integrity in the rat blood, emphasizing the sex-related (male vs. female) as well as age-related (young vs. old) differences in the rat aging model. The results of this study were summarized in the original scientific article accepted for publication in 2022 (129). Within the frame of this project, some data were presented virtually at Greifswalders Transportage 2021: Annual meeting of scientists interested in physiology, pharmacology and structural biology of cell membrane channels and transporters. (<http://www.membrantransporter.de/program.html>).

Scientific collaborations

NATIONAL SCIENTIFIC COLLABORATIONS

As part of the cooperation with the University of Zagreb School of Medicine, one review article was published in a high-quality journal (119), summarizing the physiological importance of glucose transporters in the endometrium cells. Within the frame of collaborative research with the Analytical Toxicology and Mineral Metabolism Unit of IMROH, one original scientific article was published (18).

INTERNATIONAL SCIENTIFIC COLLABORATIONS

International collaboration with the research group led by prof. Dr I. Kalajzic (Department of Reconstructive Sciences, Center for Regenerative Medicine and Skeletal Development, Farmington, USA) led to the publication of one original scientific article (32).

Within the frame of international collaboration with the research group led by Prof T. Weide (University Hospital of Münster, Münster, Germany), we studied the impact of *Pals1* gene silencing on the expression of 'Solute carrier' membrane transporters as well as housekeeping proteins in the mouse kidney. The results of this study were summarized in the original scientific article accepted for publication in 2022 (127).

We continued collaboration with Prof M. V. Tzvetkov (Institute for Pharmacology, Center for Drug Absorption and Transport, University of Medicine, Greifswald, Germany), and established new collaborative research on identifying interactions of renal and hepatic organic cation transporters (OCTs) with oximes, antidotes in the treatment of organophosphate poisoning.

Furthermore, new scientific collaboration with a research group led by Prof B. Žegura (National Institute of Biology, Department of Genetic Toxicology, Ljubljana, Slovenia) has been established. The study visit of I. Vrhovac Madunić in the beginning of 2022 in her laboratory will result in learning and establishing the novel state-of-the art techniques of culturing *in vitro* 3D cell models (spheroids) in static and dynamic conditions.

Other research activities

Cooperation with the University of Zagreb constituents continued; teaching activities and student practice were carried out ($n = 2$) and two diploma theses were defended through joint efforts with the Faculty of Science (183, 187). Furthermore, numerous activities were carried out in order to popularize science (Chapter 11) and continue the mobility and training of researchers (Chapter 12).

RESEARCH PROJECT FUNDED BY EXTERNAL SOURCES

National projects (Chapter 16.1.)

1. Molecular mechanisms underlying the toxicity of antidotes and potential drugs (CellToxTargets, HrZZ-UIP)
2. Oximes as potential inhibitors of glucose transfer in prostate cancer cells (HAZU Foundation)
3. Understanding the (eco)toxicological role of selected SLC and MATE transport proteins in zebrafish (*Danio rerio*) using functional genomics tools (DANIOTRANS, HrZZ-IP)

International Projects (Chapter 16.2.)

1. Correlated Multimodal Imaging (COMULIS, COST)
2. Changes in the muscle cell viability under the influence of oxime analogues (Bilateral CRO-SI)
3. Generating new RGS5 mouse model for lineage tracing (University of Connecticut, Center for Regenerative Medicine and Skeletal Development, Farmington, USA)

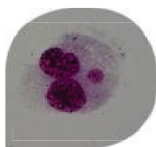
PROFESSIONAL ACTIVITIES OF THE EMPLOYEES OUTSIDE THE INSTITUTE

D. Karaica

Management Committee Member for the COST Action COMULIS; member of Board for Inclusiveness Target Countries (ITC) grants for the COST Action COMULIS.

I. Vrhovac Madunić

Member of the Executive Committee of the Croatian Society of Biochemistry and Molecular Biology (HDBMB); member of the Organizing Committee for organizing conference of the HDBMB "From Science to Knowledge"; Program Committee member of the workshop "Better skills for better jobs: Excellent lab book for an excellent career"; Management Committee member for the COST Action COMULIS; coordinator of Board for Inclusiveness Target Countries (ITC) grants for the COST Action COMULIS; Grant Awarding Coordinator of the COST Action COMULIS.



15.7. Mutagenesis Unit

EMPLOYEES OF THE UNIT

HEAD

Nevenka Kopjar, PhD, permanent scientific advisor

RESEARCHERS

Vilena Kašuba, PhD, permanent scientific advisor

Prof Davor Želježić, PhD, ERT, permanent scientific advisor

Mirta Milić, PhD, senior scientific associate

Goran Gajski, PhD, senior scientific associate since 22 Jul 2021

Marko Gerić, PhD, scientific associate

Katarina Matković, PhD student-assistant (HrZZ) since 13 Sep 2021

TECHNICAL STAFF

Maja Nikolić, senior technician

PARTICIPATING RETIRED RESEARCHER

Prof Vera Garaj Vrhovac, PhD, permanent scientific advisor

SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

Scientific research conducted with the aim of improving the methods in genetic toxicology

In the past year, our researchers participated in the development and improvement of methodological approaches for determining the levels of DNA damage. Guidelines important for the application of comet assay on sperm (29) and on the collection and storage of human white blood cells used in DNA damage/repair analyses in molecular epidemiology (74) have been published in papers resulting from the COST action CA15132 hCOMET.

Research on human populations (biomonitoring)

The hCOMET COST Action resulted in the establishment of a database comprising 19,320 individuals from 105 studies conducted in 44 laboratories from 26 different countries between 1999 and 2019. From these data, the baseline values of the three most important descriptors of the alkaline comet assay were derived. They originated from samples taken from healthy individuals, analysed manually or by software. It has been shown that values in controls and samples of healthy individuals statistically significantly differed from the exposed groups in terms of DNA damage, and that different exposures differed in the degree of damage as well. This proved once again, but now in a large number of samples, that the alkaline comet assay is a sensitive method for biomonitoring populations and detecting suspected subgroups prone to accumulation of damage, who can develop and accumulate genomic instability, and consequently certain diseases, and tumors (71).

Subsequent analysis of 2403 alkaline comet assay results obtained on blood samples, collected in 16 different international laboratories, compared with each country's registry of deaths and tumors showed a very high mortality rate in people who were considered healthy at the time of sampling and higher DNA damage at the time, placing them in the middle or third group of individuals with high DNA damage impairments. The third group with the highest recorded impairments in healthy age showed a higher risk of circulatory diseases and an increased mortality risk (13).

Research on the effect of low doses of ionising radiation on genome damage in occupationally exposed subjects continued. The obtained results were presented at scientific conferences (304, 327, 328).

The effects of ionising radiation on levels of genomic instability in children were investigated using a new, less invasive methodological approach – buccal micronucleus cytome test (302, 325, 326). The research aroused great interest, so in the comment – letter to the editor, we answered all the additional questions that were asked about the research (167).

Research regarding the impact of pesticide exposure on the human genome also continued. The micronucleus assay using whole blood and the buccal micronucleus cytome assay showed significantly greater genomic damage in 54 farm workers exposed to pesticide mixtures in the work environment compared to a control group of 26 subjects from a similar area in Mexico, but both groups did not differ in cholinesterase (AChE and BChE) inhibition in whole blood or in blood plasma samples (117).

A systematic and extensive review paper was published, which analysed the data regarding pesticide exposure research, collected from the *PubMed* and *Web of Science* databases. Studies involving genotoxicity tests: sister chromatid exchanges, chromosomal aberrations, cytochalasin-B blocked micronucleus assay, and alkaline comet assay were included (100).

We continued to collaborate with the Dental Medicine of the Faculty of the University of Zagreb and the Dental Medicine Department of the University of Split Faculty of Medicine. By applying the micronucleus assay on buccal epithelial cells of the gingiva of voluntary participants we aimed to establish differences in the level of biocompatibility between different materials used in sealing of fissures with regard to the monomer resin content and inorganic nanofillers. Sealing is an interceptive procedure in which the fissure system is sealed with a material that can adhere to the enamel. Three different fissure sealing materials have been tested. Thirty days following the placement of the sealant, only the sealing material that contains TiO₂ nanofillers and fluor led to a significant increase in the number of pyknotic and karyolytic gingival cells. The other two sealers, despite the differences in the content of resin monomers, did not affect any of the micronucleus assay parameters in gingival cells collected in the vicinity of their placement (30). The aim of the study published in (109) was to determine whether there was a difference in the status of the micronucleus assay parameters in oral epithelial cells between patients suffering general chronic periodontitis in the absence of other periodontal adverse health issues and voluntary examinees without any periodontal issues. In the buccal cells of periodontitis patients, no increase in the frequency of micronuclei was observed. Yet, compared to the healthy volunteers, a significant increase in the incidence of binuclear cells and cells with nucleoplasmic bridges was recorded. This finding indicates that in patients suffering chronic periodontitis, a significant disturbance of the cell cycle kinetics is present, which may act as the proliferating factor in oral epigenetic carcinogenesis.

The occurrence of certain skin features that could affect occupation health in the future as well as the development of various forms of skin allergies were investigated by analysing single nucleotide polymorphisms of inflammatory genes in buccal cell samples taken from high school students, future hairdressers (25).

A significant part of the research conducted in 2021 relates to the connection between diet and health, with special emphasis on processes at the cellular level. Levels of inflammatory parameters (IL-6, MDA) were found to decrease in patients with chronic obstructive pulmonary disease after three weeks of pulmonary hospital rehabilitation with moderate physical activity. Subjects ate more vegetables in their diet, their ratio of lymphocytes to monocytes increased, and the ratio of neutrophils and platelets to lymphocytes decreased. However, three weeks of therapy was still too short a time to achieve a statistically significant reduction in oxidative stress and DNA damage (37).

A three-week reduction diet of extremely low caloric value (567 kcal), in controlled hospital conditions in obese people with a body mass index over 35 kg/m², caused a decrease in body mass index by 3 to 5 units, statistically significant weight loss (an average of 9 kg). There were also changes in lipid profile parameters, glucose levels, insulin resistance, urea levels, levels of reduced glutathione, apoptotic cell frequency, and genomic instability, as measured by cytochalasin B-blocked micronucleus assay (82, 224).

The effects of vegetarian diet on genome stability and levels of inflammatory factors and oxidative damage were also investigated (131, 324, 382).

Animal studies

Animal studies included several experimental models. The effects of pesticide exposure were investigated on the Wistar rat model within the recently completed project Organic Pollutants in the Environment – Markers and Biomarkers of Toxicity (OPENTOX), funded by the Croatian Science Foundation, the results of which were published in several publications during 2021. The paper (76) communicates results of the alkaline comet assay on leukocytes and liver cells of the offspring of dams treated with low doses of tembotrione (acceptable daily intake – ADI, acceptable operator exposure level – AOEL, and 1/500 LD₅₀). The aim of the study was to determine possible transplacental or translactational genotoxicity or oxidative effect (TBARS as the measure of lipid peroxidation, level of reactive oxygen species, activity of superoxide dismutase, catalase and glutathione peroxidases). The dams were treated since the first gavage day. Alkaline comet assay and oxidative status were determined on the newborns, weaning offspring, pubertal rats, and dams after reestablishing the oestrus cycle. In the male offspring, no effect on alkaline comet assay determinants or oxidative stress parameters was recorded. However, in the female offspring the delayed effect of the oxidative stress was detected in the liver and plasma samples of pubertal females. The ground for such an observation was found in papers published by the authors testing other pesticides. The effect of low doses of imidacloprid on the level of primary DNA damage was assessed by alkaline comet assay in leukocytes and neurons of the frontal region of the brain cortex of mature male Wistar rats. The treatment lasted for 28 days, and the active substance solution was administered by gavage. Following the treatment, either in the leukocytes or neurons, a significant increase in the comet assay determinants was observed regardless of the dose. The level of DNA lesions positively correlated with the dose of imidacloprid administered to the animals. Results of genotoxicity testing were in line with those of the measuring the oxidative stress in plasma and neurons. The level of reactive oxygen species and lipid peroxidation significantly increased in the plasma of rats treated with imidacloprid at doses higher than 0.8 mg/kg b.w./day. Activity of glutathione peroxidase and superoxide dismutase increased both in erythrocytes and brain neurons (48).

Results regarding acetyl and butyryl cholinesterase activity, and biomarkers of oxidative stress in male Wistar rats following subacute 28-day treatment with the imidacloprid dose corresponding to ADI, AOEL, and 1/1000 LD₅₀ values were communicated in the form of the poster presentation (307). Already at such low dose as ADI, subacute treatment induced significant increase in the level of reactive oxygen species and lipid peroxidation in plasma and brain neurons. Though the imidacloprid treatment led to disturbance in the redox potential homeostasis, it did not affect the level of glutathione or activity of acetyl and butyryl cholinesterase.

The toxic effects of 28 days of repeated oral exposure to the herbicide terbuthylazine at doses of 0.004, 0.4 and 2.29 mg/kg b.w./day, were investigated. In the kidney cells of exposed rats, after administration of all doses of terbuthylazine, significantly elevated levels of comet tail intensity were measured, and two higher doses also caused a significant increase in GPx activity. All tested doses also caused a significant increase in comet tail length values in parenchymal and nonparenchymal liver cells (159).

Genotoxicity of α -cypermethrin in Wistar rats and their offspring during gestation was assessed. Adult female Wistar rats were treated with α -cypermethrin during the whole gestation period by gavage at doses representing acceptable daily intake (ADI), acceptable operator exposure level (AOEL) and 1/100 LD₅₀. The results showed significantly elevated tail length at 1/100 LD₅₀ and tail intensity at AOEL in dam leucocytes. No significant changes were observed in dam liver cells. In male F1 offspring, tail intensity was significantly increased at ADI in leucocytes, and at all doses in liver cells. No changes of comet assay parameters in female F1 offspring in leucocytes were observed. In liver cells, a significant damage in dams and their offspring were observed. Such a result could refer to a possibility of transplacental transfer (223).

The effects of anesthetics (isoflurane, halothane and sevoflurane) in combination with ionising radiation at doses of 1 and 2 Gy, which are usually used in radiotherapy treatment protocols, were investigated in a Swiss albino mice model. The genome stability in leukocytes, liver and brain cells of exposed mice was assessed using alkaline comet assay. The results suggest possible protective effects of isoflurane, and synergistic genotoxic effects of halothane and sevoflurane in combination with exposure to ionising radiation administered at 1 and 2 Gy (9, 147, 148, 319, 338, 353).

In the paper (81) the results of a study on the effect of caffeic acid on diabetes in mice are presented. Seven-day intraperitoneal administration of caffeic acid at a dose of 50 mg/kg b.w./day in diabetic mice acted as an effective antioxidant in reducing serum glucose, lipid profile and atherogenic indices, leading to extended lifespan in mice.

The effects of the cytostatic imanitib-mesylate were investigated in a model of zebrafish (*Danio rerio*). Exposure to 0.01, 1 and 100 g/L of the tested chemical started with adult individuals, continued after hatching and on the offspring for the next 7 months. No changes in fish survival and growth or histopathological changes were observed, but a marginal increase in chromosomal damage in blood cells was observed. Genome-wide transcriptome analysis showed an increase in the number of differently expressed genes, depending on the dose. Females had a significantly higher number of deregulated genes involved in response to DNA damage, cell cycle control, and circadian rhythm regulation compared to males. Current environmental levels of imanitib-mesylate exposure are considered to pose a low genotoxic risk to aquatic organisms (77).

Research on *in vitro* models

In the case of unwanted radiological incidents, there is need for networking between biodosimetric laboratories in order to quickly obtain homogeneous results regarding the frequency of chromosomal aberrations or estimated radiation doses. Interlaboratory comparisons play an important role in achieving this homogeneity. In 2017 and 2019, the EURADOS Working Group 10 and RENEB conducted international comparisons of the results of laboratories dealing with bio- or physical dosimetry in order to establish standard value ranges that could be used in retrospective dosimetry. Laboratories, including the Mutagenesis Unit, have shown that the results of the analyzed irradiated whole human blood samples irradiated *ex vivo* with a) 1.36 TBq ¹⁹²Ir radiation at different received doses (0.5–5 Gy) (year 2019) or b) 4-MV X-radiation (radiation rate 0.5 Gy/min) at doses of 0, 0.4 or 1.8 Gy (year 2017); representing partial radiation of the body, homogeneous and heterogeneous radiation of the whole body did not differ significantly between 17 (year 2019) or 38 (year 2017) laboratories in terms of biological dosimetry-bicentric chromosome analysis in chromosomal aberrations test and in terms of physical dosimetres that were analyzed after return to the initial irradiation laboratory (22, 34, 351).

Research regarding the toxic effects of mycotoxins *in vitro* also continued. Using HepG2 and A549 cell models, we investigated whether DNA damage induced by 24-hour exposure to noncytotoxic concentrations of single and combined mycotoxins sterigmatocystin (STC) and 5-methoxyterigmatocystin (5-M-STC) could alter phosphorylation of Chk2 and FANCD checkpoint proteins. Cytotoxic potential was assessed by MTT test and DNA damage by alkaline comet assay. Both mycotoxins were genotoxic and caused double and single breaks in the DNA chain that activate Chk2 (especially in HepG2 cells) but not the FANCD2 protein. STC showed a higher genotoxic potential than 5-M-STC in HepG2 and A549 cells when both toxins were administered individually at the same concentration (19). Studies of the cytotoxic and genotoxic effects of the mycotoxins deoxynivalenol and zearalenone produced by the genus *Fusarium* were also performed on the Hep G2 cell model (149, 204).

A review of research conducted within the recently completed HrZZ project MycotoxA (230) reports the results of the presence of moulds of the genus *Aspergillus*, isolated from air and dust in flood-affected homes in the Gunja area. Most isolates were found to produce sterigmatocystin, and some isolates also produced 5-methoxyterigmatocystin. The mycotoxin concentrations in dust samples in Gunja were STC 0.59 µg/g and 5-MET-STC: 7.70 µg/g. Further research within the project found that STC administered at a 10-fold lower dose than 5-MET-STC elicited similar effects at the DNA level.

In vitro studies of various natural compounds on a model of human peripheral blood leukocytes were performed. The protective effects of oleuropein and hydroxytyrosol on DNA damage caused by hydrogen peroxide were determined (124).

The effect of one-hour pre-treatment with arbutin (at concentrations in cell medium of 11.4 µg/mL, 57 µg/mL, 200 µg/mL and 400 µg/mL) on the ionising radiation exposure at a therapeutic dose of 2 Gy in human leukocyte samples was investigated (10, 221). The alkaline comet assay and cytochalasin B-blocked micronucleus assay showed that single arbutin had no genotoxic or cytotoxic effect, and pretreatment with arbutin showed a significant protective effect in both tests and at all concentrations. Pretreatment with the highest arbutin concentrations also showed the greatest protective effect against DNA damage caused by the well-established radioprotector amifostine.

The beneficial effect of chestnut honey in combination with UV radiation on reducing oxidative stress levels, increasing survival and protective effects at the genome level has been demonstrated on isolated human lymphocytes (315).

Research on the harmful effects of metals at the cellular level has also continued. The toxicity of cadmium in combination with decabrominated diphenylether (BDE-209) was investigated at the SW 480 colon cancer cell line and the relationship between applied concentrations and responses was modeled using the PROAST software (203).

Research of the selective genotoxicity of halogenated boroxin on the Ut-7 leukemia cell line and human peripheral blood mononuclear cells was also conducted (303)

Other research during 2021 focused on assessing the effects of newly developed probiotics for which beneficial effects and anti-inflammatory properties have been proven. The research results published in the paper (53) confirm the great probiotic potential of *Lactobacillus plantarum* M2 and *Lactobacillus plantarum* KO9 isolated from donkey and mare milk, and their good anti-inflammatory effect.

Research on wastewater treatment procedures continued with the aim of reducing their toxicity to the environment (209).

Furthermore, a review paper (99) was published in which a comprehensive overview of data obtained by searching *PubMed* and *Web of Science* databases on *in vitro* and *in vivo* exposure of human samples to inorganic, organic and elemental mercury was given. The focus was on genotoxicity tests: sister chromatid exchanges, chromosomal aberrations, cytochalasin-blocked micronucleus assay, and alkaline comet assay. In the case of inorganic exposure, mercury chloride and mercury nitrate were most present in accidental, occupational or iatrogenic exposure, while in the organic form of mercury the highest exposure was to methyl-mercury, thimerosal, methyl-mercury chloride, phenyl-mercury acetate and methylmercury hydroxide, and most studies have shown toxicity in exposure to mercury compounds. All of the techniques showed their sensitivity, with a great possibility of additional testing of various polymorphisms, oxidative damage and the use of miRNA in explaining the exposure results.

A detailed overview of current knowledge on the effects and fate of cytostatic drugs in the environment and in a professional settings was presented during a lecture held at the CROTOX 2021 congress (207).

In-house scientific projects

1. Investigation of interactions between irinotecan and tetrahydrocannabinols on laboratory rodents using integrated biochemical, molecular biology, pathohystologic and analytical methods

Data collected within the project resulted in several conference papers. A study (218) was conducted on male Wistar rats treated with Δ^9 -tetrahydrocannabinol (THC) per os for 1, 3 and 7 days at doses of 7 mg/kg b.w./day in order to determine the dynamics of DNA instability in liver cells, leukocytes and brain cells using alkaline comet assay. Exposure to THC had a negligible effect on total body weight as well as liver and brain mass compared to control rats. Repeated exposure to THC resulted in DNA instability in all cell types examined. While liver cells showed similar levels of primary DNA damage, leukocytes and brain cells tended to accumulate time-dependent accumulation of lesions in DNA. The pattern of DNA damage could also be related to repair, which created additional DNA damage that can be detected by alkaline comet assay. The obtained results indicate the induction of apoptosis in brain cells. Differences in cell susceptibility may also be associated with tissue-specific differences in repair

mechanisms. Interactions of THC (7 mg/kg b.w./day; *per os* over 7 days) and the cytostatic irinotecan (IRI, 60 mg/kg b.w./day, *i.p.*, 1st and 5th day of the experiment) were investigated in a male BALB/C mouse model with colorectal tumor. The parameters of body weight and tumor growth (215), and cholinesterase activity (235) were studied. There was a significant decrease in body weight of mice exposed to IRI and IRI + THC on the third day, as well as in mice exposed to IRI + THC on the seventh day compared to mice exposed to THC alone and tumor control mice. There were no significant changes in relative brain and liver masses between the experimental groups. Tumors grew steadily over time with significant differences in growth between days three and seven in all groups. No differences in tumor size were observed between the experimental groups (215). After the applied treatments, a time-dependent increase in total ChE and BChE activities was found in all experimental groups, including tumor mice. In contrast, AChE activities decreased, with less fluctuations in the group exposed to THC and IRI + THC. The time course of changes in the levels of AChE and BChE activity suggests that these esterases may be not only indicators of metabolic status, but also functionally important in the transformation of neoplastic cells (235).

2. Investigation of toxic effects of new psychoactive substances by biochemical and molecular-biological methods

Preliminary research on the SH-SY5Y cell model (human neuroblastoma cell line) was conducted. Levels of oxidative stress and cytotoxic and genotoxic effects of various new psychoactive substances were assessed. Amphetamine-like stimulants were found to reduce the survival of SH-SY5Y cells (306) and produce oxidative stress and DNA damage (354). Toxic effects of lysergic acid diethylamide (LSD) and phencyclidine (PCP) in the concentration range of 0.39–100 µmol/L for 24 hours were examined in the same cell model. Their effects on disturbing the oxidation-antioxidant balance in the cell and causing cytotoxic effects have been proven. At concentrations that reduce hourly survival by up to 30%, LSD had a higher potential for DNA damage and showed stronger oxidative activity than PCP (352).

Using a questionnaire on the population of Croatian students, the level of knowledge of the issue related to the consumption of products based on hemp oil was investigated, with emphasis on their nutritional value, health effects and possible risks. The results of the research show a low prevalence of consumption of hemp oil products in the population of surveyed students. Students of biomedicine and health, as well as biotechnical and natural sciences, were generally better informed about this issue than other students included in the survey (348).

3. Evaluation of reproductive toxicity of commonly used pesticides followed by chronic low-dose exposure in vivo

Research on the activity of antioxidant enzymes, DNA damage and measurement of concentrations of essential elements in the testes and epididymis of adult male Wistar rats exposed to imidacloprid was performed. The results are presented in (111). Animals were orally treated with doses comparable to currently proposed health-based reference values: 0.06 (ADI), 0.80 (10 × AOEL), or 2.25 (1/200 LD₅₀) mg/kg b.w./day for 28 consecutive days. Exposure to the highest applied dose of imidacloprid resulted in a significantly lower testis weight. Treatment with the lowest applied dose increased the level of reduced glutathione in the epididymis (73%), while the activities of epididymal glutathione peroxidase and superoxide dismutase significantly increased in all of the treated rats (74–92% and 26–39%, respectively). Exposure to imidacloprid resulted in a low but significant level of DNA damage in testicular sperm cells regardless of the concentration applied. Higher concentrations of Mo were measured in the testes of rats treated with 0.80 and 2.25 mg/kg b.w./day compared to the control animals. Higher concentrations of Na were measured in the testes of rats treated with 2.25 mg/kg b.w./day compared to controls. The fact that such low doses of imidacloprid were able to produce measurable biological effects calls for further evaluations of this widely used insecticide.

RESEARCH PROJECT FUNDED BY EXTERNAL SOURCES

National projects (Chapter 16.1.)

1. Air pollution and human biomarkers of effect (HUMNap, HrZZ-IP)
2. Interaction of metallic nanoparticles with sulphur-containing biomolecules – implications for nanobio interface (NanoFaceS, HrZZ-IP)
3. Domoic acid toxicity on non-target human cells (DomoTox, HAZU Foundation)
4. Evaluation of cytogenetic effects of air pollutants towards human cells *in vitro* (HAZU Foundation)
5. Biological effects of strawberry tree (*Arbutus unedo* L.) honey on tumour and healthy human cells (HAZU Foundation)
6. Toxicological profile of the phytoplankton *Ostreopsis* in the northern Adriatic Sea (Juraj Dobrila University of Pula)

International projects (Chapter 16.2)

1. European Venom Network (EUVEN, COST)
2. 'Good biomarker practice' to increase the number of clinically validated biomarkers (CliniMARK, COST)
3. Personalized Nutrition in Aging Society: Redox Control of Major Age-related Diseases (NutRedOx, COST)
4. Acetylcholinesterase Inhibitors as Potential Anti-Alzheimer Drugs: Prooxidative and Cytogenotoxic Properties (SafeAChE, Bilateral CRO-RS)
5. Toxicological profile and interactions of bisphenol A and its analogues (BPAnalogInteract, Bilateral CRO-SI)
6. Distribution of antibiotic resistance genes in waste water treatment plants and receiving environments of China and Croatia (Bilateral CRO-CN)

PROFESSIONAL SERVICES

The Unit performs five expert services for users: chromosomal aberration analysis, micronucleus assay, sister chromatid exchange analysis (SCE), comet assay and cell viability assay. Professional activities are realized through cooperation with occupational medicine specialists, clinics and polyclinics that conduct preliminary and/or periodic health examinations of employees of various professions occupationally exposed to physical mutagens (ionising and non-ionising radiation) and/or chemical mutagens (cytotoxic drugs and other genotoxic agents), and with other institutions that need professional services in the area of our expertise.

As part of professional services in 2021, toxicity testing of leather samples was performed using the alkaline comet assay on HepG2 cells for the Faculty of Textile Technology, University of Zagreb, research project funded by the Croatian Science Foundation: "Comfort and antimicrobial properties of textiles and footwear" (ComforMicrobTexFoot, IP-2016-06-5278).

PROFESSIONAL ACTIVITIES OF THE EMPLOYEES OUTSIDE THE INSTITUTE

G. Gajski

Chair of the International Comet Assay Working Group (ICAWG) as a specialist interest group of the European Environmental Mutagenesis & Genomics Society (EEMGS); member of the Supervisory Board of the Croatian Association for Cancer Research (HDIR); member of the Editorial board of the journal *Medicine*; member of the Working Group on Biotechnology of the Applied Genomics Committee of the Croatian Academy of Sciences and Arts (HAZU); member of the Working Groups (WG on Communications and WG on Sustainability) of International Society of Radiation Epidemiology and Dosimetry (ISoRED); member of the Scientific and Organising Committee 1st ICAWG Symposium; member of the Scientific and Organising Committee 1st International HUMNap Workshop & Kick off Meeting; Scientific Committee member of the congress CROTOX 2021; member of the Scientific Committee GENUBIH 2021; member of the Scientific Committee 7th Workshop "Specific methods for food safety and quality 2021."

M. Gerić

Chair of the New Investigators group within European Environmental Mutagenesis and Genomic Society (EEMGS); Work group member (Awards) at the International Society of Radiation Epidemiology and Dosimetry (ISoRED); member of the Organising Committee of the congress CROTOX 2021; member of the Organising Committee EEMGS Annual General Meeting 2021; member of the Scientific and Organising Committee 1st International HUMNap Workshop & Kick off Meeting.

N. Kopjar

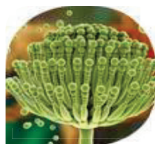
Member of the Presidency of the Croatian Toxicological Society; member of the Scientific Committee of the congress CROTOX 2021; member of the Governing Board of the Institute for Anthropological Research.

M. Milić

Member of the Advisory Board of journal *Helyion*; member of the Editorial Board of the journal *Mutation Research – Genetic Toxicology and Environmental Mutagenesis*; member of the Editorial and Advisory Board of journal *Toxics*; member of the Presidency of the Croatian Toxicological Society; member of the Scientific Committee of the congress CROTOX 2021; reviewer for journals: *Helyion*, *Toxicology Report*, *Toxicology Letters*, *Chemosphere*, *Food and Chemical Toxicology*, *Mutation Research*, *Archives of Industrial Hygiene and Toxicology*-*Archives of Industrial Hygiene and Toxicology*, *Acta Histochemica*, *Folia Biologica*, *Journal of Food Biochemistry*, *Medicine*.

D. Želježić

Member of the Editorial Board of the journal *BioMed Research International*; President of the Croatian branch of the Register of European Toxicologists EUROTOX; member of the Scientific Committee of the congress CROTOX 2021; Expert on biological methods of testing substances in the Member State Committee; member of the Risk Assessment Committee – European Chemicals Agency (ECHA); Expert in Toxicology and Clinical Research of the Food Committee of the Food Unit – European Food Safety Authority (EFSA).



15.8. Toxicology Unit

EMPLOYEES OF THE UNIT

HEAD

Maja Peraica, MD, PhD, ERT, permanent scientific advisor

RESEARCHERS

Prof Ana Lucić Vrdoljak, PhD, permanent scientific advisor (Director)

Ivana Novak Jovanović, PhD, senior scientific associate

Suzana Žunec, PhD, senior scientific associate

Dubravka Rašić, PhD, senior scientific associate since 22 Jul 2021

TECHNICAL STAFF

Jasna Mileković, senior technician

Lea Stančin, technician

SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

In-house scientific projects (Chapter 16.1.A.3.)

1. *Comparison of balanced anaesthesia and target controlled infusion on oxidative stress production*

In the Zagreb Children's Hospital, samples of blood of patients operated with hydronephrosis were collected. In samples of 30 patients divided randomly into two groups according to different anaesthesia the concentration of malondialdehyde (MDA), glutathione (GSH), protein carbonyls, levels of ROS, activity of superoxide dismutase (SOD) and antioxidative capacity of plasma were measured. The statistically evaluated results were presented in the PhD thesis "Comparison of the Effect of Balanced Anaesthesia and Anaesthesia with Target Controlled Infusion in Children with hydronephrosis Due to the Size of Oxidative Stress" which was defended at University of Zagreb, School of Medicine, mentor: M. Peraica (182, 226).

2. *A relationship of resveratrol administration in cardiac surgery patients with reduction of oxidative stress and systemic inflammatory response*

In cooperation with the Department of Cardiac and Transplant Surgery, Clinical Hospital Dubrava, blood samples of 34 patients undergoing heart valve surgery were collected. Patients received placebo or resveratrol two days before surgery. In plasma samples collected before, during and after surgery, parameters of oxidative stress were measured at the Toxicology Unit. GSH and protein carbonyl concentration and total antioxidant status in plasma were measured spectrophotometrically. MDA concentration was measured using HPLC. SOD activity was measured using a commercial kit and plate reader. The results were partly published in two master's theses (185, 190).

3. *Investigation of electrochemical properties and antioxidant activity of polyphenolic compounds and their complexes with essential elements*

As a continuation of our investigation into the dependence of the first electrochemical oxidation potential (E_a) on the electronic structures of flavonoids, the potentials of nine additional flavonoids (hesperetin, daidzein, kaempferol, acacetin, naringin, neohesperidin, quercitrin and gossypin) were assessed using square-wave voltammetry on a glassy-carbon electrode in aqueous buffer solutions with a pH of 3 and 7. The results of this study contribute to a better understanding of flavonoid electro-oxidation mechanisms and structure-activity relationships (68). In addition, we studied the scavenging activity of flavonoids against electrochemically generated superoxide radical anions.

4. Investigation of toxic effects of new psychoactive substances by biochemical and molecular-biological methods

The toxicity of new psychoactive substance (mephedrone) and so-called classical amphetamine-like stimulants (MDMA or ecstasy, methamphetamine and amphetamine) was tested on human neuroblastoma cells (SH-SY5Y). Parameters of oxidative stress were measured. Concentration of malondialdehyde was significantly increased compared to controls (354).

5. Evaluation of the effects of prenatal exposure to α -cypermethrin on epigenetic programming and endocrine disruption of reproduction and development of experimental rats

In order to assess the effects of prenatal exposure to the pesticide α -cypermethrin on epigenetic programming and endocrine disruption of reproduction and development of experimental rats, treatments were performed and samples from mothers and pups were excluded for further oxidative stress marker analyses to be performed at the Unit.

Other activities

Within the in-house project entitled “Investigations of the interaction of irinotecan and tetrahydrocannabinol (THC) on an experimental model of rats by integrating biochemical, molecular-biological, pathohistological and analytical methods”, led by A. Lucić Vrdoljak and ended in 2020, the problem of possible interactions between the cannabinoid THC and the cytostatic irinotecan was investigated. Analyses were performed in the target tissues of mice injected with tumor cells to induce a syngeneic intestinal tumor and then treated with irinotecan, THC, and their combination. The dissertation, defended in February 2021, summarizes the results on changes in the level of expression and activity of uridine diphosphate glucuronyltransferase (UGT), isoenzymes crucial for phase II metabolic reactions, in mouse liver samples after concomitant administration of high concentrations of THC and irinotecan. Comparison of the activity of pharmacologically important UGT isoenzymes between treatments showed that in the period of 7 days the activity of enzymes in samples treated with a combination of irinotecan and THC was the lowest, which suggests the existence of interactions at the level of metabolism of tested compounds (174). Using the described experimental model, effects of THC on the toxicity of irinotecan and its antitumor activity were determined. Exposure to irinotecan alone and in combination with THC affected the body weight of mice, but did not affect tumor growth (215). The results of the determination of cholinesterase activity in the blood of mice showed a time-dependent increase in total cholinesterase activity and butyrylcholinesterase activity (BChE) in all experimental groups, including the control group (individuals with tumor not exposed to treatment). In contrast, acetylcholinesterase (AChE) activities decreased. The time course of changes in AChE and BChE activity showed that these esterases can be indicators of metabolic status, but also functionally important in the transformation of neoplastic cells (235).

Results of an *in vitro* study on the antioxidant and cyto/genoprotective effect of chestnut honey from organic farming on human lymphocyte damage caused by UVB radiation were presented at the EUROTOX 2021 congress. Chestnut honey has shown good cytoprotective and gene-protective and antioxidant effects after exposure to lymphocytes and whole blood to UVB radiation. The beneficial effect of honey was more pronounced after the treatment of irradiated samples (315).

Previous knowledge about the effectiveness of honey (*Arbutus unedo* L.) has prompted an investigation on its possible cyto/genoprotective and antioxidant effects on UVB radiation damage in a human peripheral blood lymphocyte model. The study confirmed that the intake of plantain honey as a complex mixture of bioactive ingredients prior to exposure to a potentially cyto/genotoxic agent stimulated a wide range of protective mechanisms, including intracellular antioxidant defense and DNA repair systems that helped pre-treated cells respond more effectively to harmful exposure (132).

Research on the toxicity of the neonicotinoid pesticide imidacloprid was conducted. Oral 28-day exposure to low doses of imidacloprid in rats resulted in measurable levels of imidacloprid in plasma and brain tissue, indicating that imidacloprid directly induced DNA damage, particularly in brain tissue, with slight changes in plasma oxidative stress parameters (48).

During the HrZZ-MycotoxA project (finished in 2020) adverse effects of mycotoxins ochratoxin A (OTA), citrinin (CTN), sterigmatocystin (STC) and 5-methoxy-sterigmatocystin (5-M-STC) were studied

on cell cultures and experimental animals. Final results were presented at the CROTOX 2021 congress. Toxic effects of mycotoxins OTA and CTN and protective effects of resveratrol (RSV) on organic cation transporters in rats were studied. Protein expression of rOct1 was significantly downregulated by both OTA doses, the higher dose of OTA + CTN and OTA + CTN + RSV treatment. CTN treatment did not affect protein expression of rOct1 and rOct2 proteins (222). The common effects of these mycotoxins on the expression of renal water channels (rAqp) and sodium-glucose (rSglt) cotransporters in kidneys were investigated. OTA and CTN had a selective effect on the protein expression of the studied transporters in rat kidney while RSV did not show protective effect (213). Overall results of the project were presented as an invited lecture (230). Toxic effects of STC and 5-M-STC and their mixture were studied in male Wistar rats treated intratracheally with concentrations of these mycotoxins found in dust in damp indoor areas. In a bronchoalveolar lavage, the concentration of albumin and activity of lactate dehydrogenase were measured. The results were published in a master's thesis (189).

RESEARCH PROJECT FUNDED BY EXTERNAL SOURCES

National projects (Chapter 16.1.)

1. Analysis of Butyrylcholinesterase Interactions with Novel Inhibitors and Reactivators (AnalyseBChE, HrZZ-IP)
2. Exploring the antioxidative potential of benzazole scaffold in the design of novel antitumor agents (AntioxPot, HrZZ-IP)
3. Development of bioactive molecules for neurodegenerative diseases treatment (BioMol4ND, HrZZ-IP)

International projects (Chapter 16.2.)

1. CNS-active, Orally Bioavailable, Zwitterionic Oxime Antidote to Organophosphates (DTRA, USA)

PROFESSIONAL SERVICES

At the request of the Medical Center Krka, Novo Mesto, Slovenia, acetylcholinesterase (IU/g hemoglobin), activities were determined in whole blood samples of workers exposed to potential cholinesterase inhibitors.

PROFESSIONAL ACTIVITIES OF THE EMPLOYEES OUTSIDE THE INSTITUTE

A. Lucić Vrdoljak

Member of the Working Group in charge of monitoring the activity plan for the National Network for Permanent Air Quality Monitoring of the Meteorological and Hydrological Service at the Ministry of Economy and Sustainable Development of the Republic of Croatia.

M. Peraica

President and member of the Croatian Society of Toxicology's Presidency; President of the congress CROTOX 2021; associate member of the Medical Academy of Croatian Physicians.

D. Rašić

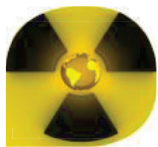
Secretary and member of the Croatian Society of Toxicology's Presidency; President of the Organising Committee of the congress CROTOX 2021.

S. Žunec

Member of the Court of Honour of the Croatian Society of Toxicology.

SCIENTIFIC, TEACHING AND ACADEMIC ADVANCEMENT OF EMPLOYEES

Scientific degree of senior scientific associate was gained by D. Rašić.



15.9. Radiation Protection Unit

EMPLOYEES OF THE UNIT

HEAD

Assoc Prof Branko Petrinc, PhD, senior scientific associate

RESEARCHERS

Assist Prof Dinko Babić, PhD, permanent scientific advisor since 22 Jul 2021

Zdenko Franić, PhD, permanent scientific advisor

Tomislav Bituh, PhD, senior scientific associate since 19 May 2021

Gina Branica Jurković, PhD, senior scientific associate

Davor Rašeta, PhD, postdoctoral researcher

Božena Skoko, PhD, postdoctoral researcher

Iva Franulović, MSc, senior professional associate in science since 1 Feb 2021

Milica Kovačić, MSc, professional associate in science

TECHNICAL STAFF

Mak Avdić, MSc, senior technician

Jasminka Senčar, senior technician

Ljerka Petroci, technician

SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

The Unit continuously carries out research on the radioactive contamination of the environment by naturally occurring and anthropogenic radionuclides.

We continued research on the radioecology of the aquatic component of the Plitvice Lakes which could be considered to be a natural freshwater ecosystem due to its status as a national park. This was fulfilled by measuring the content of radionuclides from the uranium and thorium decay chains, as well as of ^{40}K , in water, sediments, and fish. Due to the fact that the beginning of the project coincided with the Fukushima accident, anthropogenic ^{134}Cs and ^{137}Cs were also analysed (103).

In a review paper, an overview of a long-term investigation of naturally occurring radioactivity at a phosphogypsum disposal site was presented, together with an analysis of trends in potential uses of phosphogypsum (11).

We continued a comprehensive study on the radioactivity of soil in the Republic of Croatia, which resulted in a detailed map of naturally occurring and anthropogenic radioactivity in this medium. The largest absorbed rate was identified in the Istrian Peninsula and Croatian highlands (107, 108).

Research into the effects of fertilisation on the uptake of radionuclides by maize was carried out in collaboration with the Faculty of Agronomy of the University of Zagreb. Results of this investigation showed that an increase in fertiliser concentration did not enhance the concentrations of radionuclides in soil, whereas the concentration of some radionuclides in maize was reduced (123).

Special attention was given to the topic of *in-situ* measurements of radioactivity, with a focus on achieving better efficiency in the case of a nuclear or radiological accident, where the role of mobile laboratories is crucial. We carried out an investigation of a new calibration technique for *in-situ* gamma-ray spectrometry. Our conclusion was that a calibration performed using the InSiCal software led to relatively accurate results but that some improvements would have been welcome (91).

Radiochemical and measurement methods for monitoring radioactivity in various media are still being developed. Through monitoring, new knowledge in the field of radiation science and radiation protection, as well as in metrology and sampling, procedures, is standardized and methods

coordinated through the implementation of quality assurance procedures. Appropriate radiation protection measures are being developed in the event of a nuclear/radiological accident, with an emphasis on the role of mobile radiological measurement laboratories in order to achieve better and faster response to such situations by timely collecting data.

In-house scientific projects (Chapter 16.1.A.3.)

1. *Radiological characterization of Kopački rit*
2. *Chemical and radiological characterisation of strawberry tree (Arbutus unedo L.)*

RESEARCH PROJECT FUNDED BY EXTERNAL SOURCES

National projects (Chapter 16.1.)

1. Sediments between source and sink during a Late Quaternary eustatic cycle: The Krka and the Mid Adriatic Deep System (QMAD, HrZZ-IP)
2. Environmental risk assessment of materials with increased natural radioactivity – Transfer of ^{238}U sequence radionuclides to earthworms and consequent biological effects (HAZU Foundation)

International projects (Chapter 16.2.)

1. Ensuring Radiation Safety (INTERREG CRO-SI)
2. Science-based Risk Governance of Nano-technology (RiskGONE, H2020)

List of international intercomparisons (4)

ORGANISER	TEST	AREA	DATE
IAEA	IAEA-TEL-2021-04 Proficiency test on determination of anthropogenic and natural radionuclides in water, Japanese bamboo and simulated swipe samples	Determination of radioactivity in water, bamboo and swipe samples	7/2021 – 11/2021
IAEA	IAEA-RML-2021-01 Proficiency Test for Tritium, Strontium and Gamma emitters in Seawater	Determination of radioactivity in sea water	9/2021 on-going
EC JRC	REM PT on Naturally Occurring Radionuclides in Building Materials	Determination of radioactivity in NORM	11/2021 on-going
GIG	Identification and quantification of Naturally Occurring Radionuclides enclosed in Naturally Occurring Radioactive Material	Determination of radioactivity in NORM	12/2021 on-going

Special attention in the Unit was given to quality control. Accreditation in accordance with the international General Requirements for the Competence of Testing and Calibration Laboratories (HRN EN ISO/IEC 17025 standard) has become a widely accepted method of quality management and objective evidence of technical competence, knowledge, and skills of testing and calibration laboratories. This year's audit was performed by the Croatian Accreditation Agency on November 23rd 2021. The Radiation Protection Unit did not have any nonconformities.

List of accredited methods (3)

TEST METHOD	TYPE OF TEST, RANGE
RU-602-5.4-1 (In-house method)	Determination of radionuclides by high-resolution gamma spectrometry in energy range 40–2000 keV
RU-602-5.4-4 (In-house method)	Determination of ^{90}Sr activity concentration

RU-602-5.4-5
(In-house method)

Determination of ^{226}Ra activity concentration

The Unit's quality manager: *T. Bituh*.

● PROFESSIONAL ACTIVITIES OF THE EMPLOYEES OUTSIDE THE INSTITUTE

D. Babić

Member of the Radon Action Plan 2019–2024 Committee (Ministry of the Interior of the Republic of Croatia, The Civil Protection Directorate, Zagreb).

T. Bituh

Partner (Deputy Representative of the Republic of Croatia) on the IAEA project RER7014; member of the Management Board of the Croatian Radiation Protection Association since 6 Oct 2021.

Z. Franić

Member of the National Scientific Council; member of Management Board of the Croatian Radiation Protection Association until 6 Oct 2021; member of the TO-45 (Nuclear Instrumentation) of the Croatian Standards Institute; member of the Board of Governors of Joint Research Centre European Commission, JRC EC; member of Ethics Committee in Dental Polyclinic Zagreb; Chairperson of Zrinska gora NGO; Lead auditor of Croatian Accreditation Agency for accreditation schemes HRN EN ISO/IEC 17025:2017 (General requirements for the competence of testing and calibration laboratories) and HRN EN ISO 14065 (Greenhouse gases-Requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition).

I. Franulović

Member of the Management Board and treasurer of the Croatian Radiation Protection Association since 6 Oct 2021.

B. Petrinec

Member of the Education, Science and Culture Committee of the Croatian Parliament; Vice-president of the City Council of the Town of Ivanić-Grad; Vice-president (since 6 Oct 2021) and member of the Management Board of the Croatian Radiation Protection Association; member of the TO-45 (Nuclear instrumentation) of the Croatian Standards Institute; member of the Management Board of Ivanić-Grad Junior College; member of the Editorial Board of the journal *Vatrogastvo i upravljanje požarima*; Quality manager of the Firefighters Community of the Town of Ivanić-Grad; Senior firefighting officer 1st class; firefighter with special authorisations and responsibilities.

D. Rašeta

Member of the Croatian Nuclear Society; member of the IAEA Nuclear Safety Standards Committee IAEA NUSSC.

J. Senčar

Member of the Management Board and treasurer of the Croatian Radiation Protection Association (until 6 Oct 2021).

15.10. Independent researchers



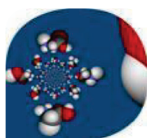
Aleksandra Fučić, PhD
permanent scientific advisor

SCIENTIFIC RESEARCH

RESEARCH PROJECTS FUNDED BY EXTERNAL SOURCES

International projects (Chapter 16.2.)

1. Scientific Centre of Excellence for Reproductive and Regenerative Medicine: Reproductive and Regenerative Medicine – Exploring New Platforms and Potentials (CERRM, ERDF)
2. European Human Biomonitoring Initiative (HBM4EU, H2020)
3. Relationship of the respiratory microflora composition with the human genome activity and integrity in the residents of coal industrial region (Kemerovo State University, Russia)



Jasmina Sabolović, PhD
scientific advisor

RESEARCHER

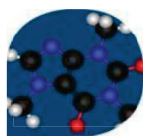
Jelena Pejić, MSc, PhD student-assistant (HrZZ)

SCIENTIFIC RESEARCH

RESEARCH PROJECTS FUNDED BY EXTERNAL SOURCES

National project (Chapter 16.1.A.1.)

1. Combined molecular modelling and experimental studies of physiologically and stereochemically important copper(II) amino acid complexes (CopperAminoAcidates, HrZZ-IP)



■ SCIENTIFIC RESEARCH

RESEARCH ACTIVITIES WITH INSTITUTIONAL FINANCING

In-house scientific project (Chapter 16.1.A.3.)

1. *Investigation of electrochemical properties and antioxidant activity of polyphenolic compounds and their complexes with essential elements*

In continuation of our work in 2021 we published a paper on 29 flavonoids in which we showed the validity of our model for the estimation of oxidation potentials of flavonoids based on the spin density of the radical molecule (68). In the same paper we developed one more, equally valid, model based on the difference of atom charges between a cation and neutral form of a flavonoid, and resolved the impact of the *O*-glycosyl, galloyl and methoxy substituents on oxidation potentials.

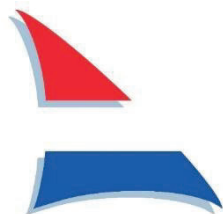
Furthermore, two more papers were submitted to journals. In one paper we measured the potentials of six more flavonoids and antioxidant activities of 17 flavonoids toward superoxide anion radical, $O_2^{\bullet-}$. In the other paper, beside the model for the estimation of oxidation potentials based on the difference of atom charges between cation and the neutral form of a flavonoid, we developed models based on the difference of atom charges between a radical and an anion, and a radical and neutral form of a flavonoid. These three models were derived from three possible mechanisms of flavonoid oxidation: single electron transfer-proton transfer (SET-PT), sequential proton loss electron transfer (SPLET) and hydrogen atom transfer (HAT).

■ PROFESSIONAL ACTIVITIES OUTSIDE THE INSTITUTE

A. Miličević

The chief shop steward at the Independent Trade Union of Science and Higher Education for the branch IMROH until 1 Sep 2021.

16. PROJECTS



16.1. NATIONAL PROJECTS

16.1.A. RESEARCH PROJECTS LED BY IMROH RESEARCHERS

16.1.A.1. CROATIAN SCIENCE FOUNDATION PROJECTS

Research projects (7 projects)



LEADER (IMROH)	PROJECT	DURATION
Anita Bosak	Development of bioactive molecules for neurodegenerative diseases treatment (BioMOI4ND, IP-2020-02-9343)	2021–2024
IMROH ASSOCIATES: S. Žunec, A. Matošević, A. Zandona, M. Bartolić (since 1 Oct 2021), Z. Kovarik EXTERNAL ASSOCIATES: D. Opsenica, K. Komatović, S. Šegan (Institute of Chemistry, Technology and Metallurgy, University of Belgrade, Serbia)		
<p>Twenty-four 4-aminoquinoline derivatives with structurally different side chains as linkers between 4-aminoquinoline and adamantyl parts of the molecule were synthesized and their inhibitory potential against human cholinesterases and inhibition selectivity were evaluated. The lipophilicity of compounds and their ability to pass through the blood-brain barrier by passive transport was performed accompanied by QSAR analysis of the relationship between structural descriptors and inhibitory potential of compounds (272, 300, 308). The 3rd generation of biscarbamates with carbamate groups in the meta-position was designed and 8 biscarbamates with different nitrogen substituents of the carbamate group and amine substituents in the side chain were synthesized and structurally described. The ability of the newly synthesised biscarbamates to inhibit native human cholinesterases was determined (267, 337). Six carbamates with propargylamine in the side chain were also synthesized (265). Quinuclidinium carbamates have been shown to be promising candidates for the further development of drugs that act in the central nervous system, especially for the treatment of Alzheimer's disease. Analysis of inhibition of human cholinesterases by carbamates, structurally based on quinuclidine, has shown that such quinuclidine carbamates inhibit human cholinesterase activity with total inhibition rate constants ranging from $10^3 \text{ M}^{-1} \text{ min}^{-1}$, with no pronounced selectivity for any of the cholinesterases. <i>In silico</i> analysis showed that six quinuclidine carbamates could cross the blood-brain barrier by passive transport, and none of the compounds showed toxicity to cells that represented the major models of individual organs. Also, the most optimal regression models for predicting the bioactivity of compounds of similar structure have been established and confirmed by the machine learning method (65). The PhD student Marija Bartolić was employed in Oct 2021. Members of the project team held three public lectures at which the objectives and the results of research of the project were presented; one lecture for the scientific public at the scientific conference (272), one lecture for the highschool teachers and one lecture for the scientific community (266).</p>		
LEADER (IMROH)	PROJECT	DURATION
Goran Gajski	Air pollution and human biomarkers of effect (HUMNap, IP-2020-02-1192)	2021–2025
IMROH ASSOCIATES: M. Gerić, M. Milić, V. Kašuba, K. Matković (since 13 Sep 2021), G. Pehnek, S. Davila, I. Jakovljević EXTERNAL ASSOCIATES: A. Cvitković, M. Sanković, A. Šumanovac, A-M. Domijan, I. Guseva Canu, P. Wild, N. Hopf		
<p>Clean air is crucial to our health and the environment. Rising industrial and energy productions, the burning of fossil fuels and biomass, as well as the rise in road traffic contribute to air pollution in our cities. Hence, air pollution leads to serious health and environmental problems. Urban air is a complex and variable mixture of</p>		

many different chemicals whose exact mechanisms of action is not known, although oxidative stress and inflammation are suspected. Human biomonitoring is an essential tool for assessing whether and to what extent environmental substances affect the human population and as such can provide valuable data on environmental exposure and to help identify potential health risks. HUMNap will determine possible associations between the air pollutants and biomarkers of exposure and early biological effect. The project will start with investigations at multiple locations with different air pollution levels and origin followed by measurement of various environmental airborne pollutants. The next step will be a detailed assessment of different biomarkers of exposure and early biological effects (genomic instability and oxidative stress) in human populations living in those locations. HUMNap will promote state-of-art techniques and research approaches to develop risk assessments of human exposure to airborne pollutants. The results from HUMNap will demonstrate how airborne pollutants affect early molecular events important for disease development in different human cells. It will also provide an assessment of cancer risk among human populations affected by polluted urban areas. Moreover, HUMNap aims to draw the attention of many stakeholders such as leading scientists, policy makers, industry, and the public in order to raise awareness regarding air pollution and to develop monitoring regimes. Finally, HUMNap will provide new datasets necessary for scientifically based risk assessments of human populations exposed to urban air pollution. Planned and implemented project activities during 2021 were presented at two scientific conferences (208, 248).

LEADER (IMROH)	PROJECT	DURATION
Jasna Jurasović (since 1 Jan 2021)	Assessment of Daily Exposure to Metals and Maternal Individual Susceptibility as Factors of Developmental Origins of Health and Disease (METALORIGINS, IP-2016-06-1998)	2017–2022

IMROH ASSOCIATES: M. Piasek (leader until 31 Dec 2020), T. Orct, A. Pizent, M. Lazarus, I. Brčić Karačonji, N. Brajenović, A. Katić, B. Tariba Lovaković, A. Sekovanić, A. Sulimanec Grgec, Z. Kljaković-Gašpić, J. Kovačić
EXTERNAL ASSOCIATES: D. Pašalić (School of Medicine, University of Zagreb), S. Stasenko (Merkur University Hospital, Zagreb), K. Branović Čakanić (Croatian Veterinary Institute, Zagreb), L. Škratić, I. Miškulin (University Hospital Centre, Zagreb)

We continued research activities planned for the last period of the project, which assesses health risks postnatally to adulthood in connection to prenatal exposure to major toxic metals in the environment, maternal intake of essential elements and specific maternal genetic polymorphisms. Mechanisms of the consequent disorders in the offspring involve epigenetic regulation changes and oxidative stress during early period of life *in utero*. The development of a suitable method for determining circulating non-coding micro-RNA (miRNA) in maternal and umbilical cord blood plasma was reported in the research paper (101) and the preliminary results of the association between candidate miRNAs and cigarette smoking as the main source of exposure to toxic metal Cd were presented at an international scientific conference (312). The review paper was published on the toxicity of chemicals and their harmful effects as endocrine disruptors during development (142). In the scientific work related to the research on this and previous research project (001-0013077-0532, "Biodiversity and sustainable management of pelagic and demersal resources of the Adriatic"; leader: Dr Gorenka Sinovčić, IZOR, Split) were reported data on the content of total mercury (THg) and Se in archive samples of wild bluefin tuna caught in open waters of the middle Adriatic Sea (51). The results of research related to the project activities have been presented at two national congresses with international participation (199, 225, 227, 228, 281). Data on the exposure and intake of toxic and essential elements from the diet that includes marine fish were presented during the activities of popularization of scientific work at the Institute (Chapter 11). All of the published results are regularly presented on the project website (<http://metalorigins.imi.hr/>).

LEADER (IMROH)	PROJECT	DURATION
Zrinka Kovarik	Analysis of Butyrylcholinesterase Interactions with Novel Inhibitors and Reactivators (AnalyseBChE, IP-2018-01-7683)	2018–2022

IMROH ASSOCIATES: A. Bosak, T. Čadež, M. Katalinić, N. Maček Hrvat, A. Matošević, G. Šinko, T. Zorbaz, S. Žunec

EXTERNAL ASSOCIATES: V. Gabelica Marković (Faculty of Chemical Engineering and Technology, University of Zagreb), A. Knežević (Ruđer Bošković Institute, Zagreb), Z. Radić (University of California, La Jolla, USA)

In our studies of the interaction mechanisms of butyrylcholinesterase (BChE), we included the pesticides ethoprophos, fenamiphos, metamidophos and phozalon, and described the interactions and kinetics of inhibition other than BChE and acetylcholinesterase (AChE) using *in silico* and *in vitro* methods. For both

enzymes, ethoprophos and fenamiphos have been shown to be the strongest inhibitors. For reactivation experiments, we focused on phosphoroamidates metamidophos and fenamiphos, analogs of tabun. Molecular modelling allowed the assessment of the interaction important for the specificity and selectivity of both cholinesterase inhibition and reactivation. We concluded that two newly developed reactivators – bispyridinium triazole oxime 14A and zwitterionic oxime RS194B have remarkable potential for further development of antidotes when exposed to these pesticides and related phosphoramidates, such as nerve agent tabun or Novichoks (15, 200). Reactivation of BChE inhibited by nerve agents – tabun, VX, sarin and cyclosarin was tested with fluorinated pyridinium oximes, K-oxime analogues, which despite favourable physicochemical properties were not more efficient than their chlorinated analogues (314). In collaboration with Prof Irena Škorić, Faculty of Chemical Engineering and Technology, University of Zagreb, we studied a new class of neutral thiostilbene oximes as reactivators of AChE and BChE inhibited by nerve agents. Four derivatives reactivated cyclosarin-inhibited BChE by up to 70% in two hours of reactivation, and molecular modelling confirmed their productive interactions with the cyclosarin-inhibited BChE. Based on the moderate binding affinity of both AChE and BChE for all of the selected oximes and *in silico*-evaluated ADME properties in terms of lipophilicity and CNS activity, these compounds have the potential for further development of CNS-active therapeutics in organophosphate poisoning. Preparation of new carbamates as BChE inhibitors and potential therapeutics continued, and new biscarbamates were tested as inhibitors of several natural variants of human BChE (310).

LEADER (IMROH)	PROJECT	DURATION
Jasmina Sabolović	Combined molecular modelling and experimental studies of physiologically and stereochemically important copper(II) amino acid complexes (CopperAminoAcidates, IP-2014-09-3500)	2015–2021

IMROH ASSOCIATE: J. Pejić

EXTERNAL ASSOCIATES: D. Vušak (Faculty of Science, University of Zagreb), M. Ramek (Technische Universität Graz, Graz, Austria), G. Szalontai (NMR laboratórium, Pannon Egyetem, Veszprém, Hungary)

In collaboration with Michael Ramek, we published the scientific paper on the theoretical study of structural and electronic properties of the copper(II) compounds with L-cysteine (Cys) and L-histidine (His) (90, 278). Since there are no experimental data in the literature about the geometries that physiological species of electrically neutral bis(L-cysteinato)copper(II) $[\text{Cu}(\text{Cys})_2]$ and (L-histidinato)(L-cysteinato)copper(II) $[\text{Cu}(\text{His})(\text{Cys})]$ could form in solutions (because of specific reactivity of the Cys thiol S–H group with the copper ions), we examined the possible conformations that the two compounds could form with the Cys ligand using the density functional theory method with two density functionals and two basis sets. These two amino acids can bind copper(II) in a tridentate fashion and thus form many possible coordination patterns. Density functional calculations were performed for the conformational analyses in the gas phase and in implicitly modeled aqueous solution using a polarizable continuum model. Additionally, we examined which coordination mode, with a thiol or thiolate group, was more stable. The metal-ion affinity calculations for the lower-energy aqueous conformers suggested as follows: the Cys coordination via the amino N and carboxylate O atoms was obtained as the most stable one in aqueous $\text{Cu}(\text{Cys})_2$, and also in $\text{Cu}(\text{His})(\text{Cys})$ when the His glycinate or histaminato mode combined with the intact thiol group; while the conformers with N and thiol S as the copper(II) donor atoms were predicted to be the least stable, those with the Cu–N and Cu–S(thiolate) bonding (and protonated carboxylate group) were the most stable. The differences were explained by different covalent and ionic contributions of Cu–S(thiol) vs. Cu–S(thiolate). This theoretical study can contribute to the insight into the formation and reactivity of the copper(II) cysteinato complexes in solution. Although the project was officially completed on January 2021, after that date we continued with experimental and computational studies of copper(II) coordination compounds with amino acids outlined with the project. The continuation has been done within the Project for career development of young researchers – training of new doctors of science, DOK-2015-10-4185 (funded by the Croatian Science Foundation) whose main result should be a dissertation on the research topics of the project IP-2014-09-3500. PhD student J. Pejić (employed on the project DOK-2015-10-4185 for the period 2 Dec 2016–6 Mar 2023) together with D. Vušak examined the conditions for obtaining single crystals of the ternary Cu(II)-His compounds with L-glutamine Gln) and Cys. She also made preliminary calculations of the metal-ion binding affinities of His and Gln with Cu(II) in $\text{Cu}(\text{Gln})_2$ and $\text{Cu}(\text{His})(\text{Gln})$ as well as of the magnetic parameters for their conformers with one or two explicit water molecules in aqueous solution. A new crystal structure of the copper(II) compounds with stereoisomers of isoleucine in a *trans*-configuration was obtained.

LEADER (IMROH)	PROJECT	DURATION
Veda Marija Varnai	Exposure to Pyrethroid and Organophosphate Insecticides in Children – Risk Assessment for Adverse Effects on Neuropsychological Development and Hormonal Status (PyrOPECh, IP-2019-04-7193)	2020–2024
IMROH ASSOCIATES: J. Kovačić, A. Bjelajac, S. Cvijetić Avdagić, J. Macan, R. Turk, Ž. Babić, A. Jurič, A. Sulimanec Grgec, P. Tomac (since 13 Sep 2021) EXTERNAL ASSOCIATES: J. Garvey, M. Posavec, V. Musil, B. Krnić, M. Matek Sarić, I. Keser, S. Kralik Oguić, I. Bebek, G. Jurak, T. Petričević-Vidović, A. Nugent, M. Jergović (born Grgić), R. Gjergja Juraški, S. Sekušak-Galešev, B. McNulty, K. Dumić Kubat, B. Murray <p>The main objective of the project is to assess inadequately explored risks of pyrethroid (PYR) and organophosphate (OP) insecticide exposure to neuropsychological development and hormonal status in prepubertal and pubertal boys in a 2-year cohort study, while controlling for potential confounders, and using only non-invasive methods. In the first project period, a greater part of the Total Diet Study was accomplished, in which pesticide residues in food samples collected during spring, summer, and autumn seasons, as well as in part of the samples from the duplicate diets collected in 30 respondents, were measured in the Backweston Laboratory Campus, Celbridge; Department of Agriculture, Food and the Marine). The Croatian Science Foundation approved the funding of one PhD student (P. Tomac; DOK-2021-02) who will, as part of her dissertation research, participate in an epidemiological cohort study. Preparations for epidemiological research in primary schools have begun, including the development of questionnaires and the recruitment of teams of school medicine specialists. The research is expected to increase the knowledge on possible risks of PYR and OP insecticides' exposure for neurodevelopment and hormonal status in pubertal boys; help to recognise deficiencies and assess available methodology for evaluation of developmental neurotoxicity and endocrine disruption within the framework of regulatory toxicology; improve insufficient methodology for exposure assessment of non-bioaccumulative pesticides; and contribute to the better characterisation of pesticide exposure in the Croatian population.</p>		
LEADER (IMROH)	PROJECT	DURATION
Ivana Vinković Vrček	Interaction of metallic nanoparticles with sulphurcontaining biomolecules – implications for nano-bio interface (NanoFaceS, IP-2016-06-2436)	2017–2021
IMROH ASSOCIATES: M. Milić, G. Šinko, I. Pavičić, A. Miličević, K. Ilić, B. Pem, R. Barbir EXTERNAL ASSOCIATES: I. Capjak, S. Šupraha Gopreta, M. Milić, B. Vuković, V. Šerić, W. Goessler, D. Horak <p>As a result of the project activities in 2021, five scientific papers were published (5–7, 38, 85).</p>		

Installation research projects (2 projects)



LEADER (IMROH)	PROJECT	DURATION
Maja Katalinić	Molecular mechanisms underlying the toxicity of antidotes and potential drugs (CellToxTargets, UIP-2017-05-7260)	2018–2023
IMROH ASSOCIATES: A.-M. Lulić, J. Madunić, N. Maraković, I. Vrhovac Madunić, A. Zandona EXTERNAL ASSOCIATE: S. Pirkmajer (Institute for Pathophysiology, Ljubljana, Slovenia) <p>The research included in the project work plan was continued, as well as the analysis of how compounds, tested as antidotes and potential drugs, work at the cellular level. These effects were examined in a time- and concentration-dependant manner by specific methods to determine possible toxic effect, mechanism of cell death (apoptosis and/or necrosis), induction of reactive oxygen species, activation of antioxidant defence, and activation of specific caspases. Summarizing the results so far, the mechanism of toxic action of selected bispyridinium and imidazolium oximes at the cellular level was assumed and recommendations were given to improve their structure (121). Furthermore, the effects of newly synthesized carbamates, potential drugs for the treatment of neurodegenerative diseases (65), as well as the effects of new synthetic drugs (47) were</p>		

investigated on a cellular level. In addition, research continued the effects of a group of nicotinamides, vitamin B3 analogues, tested in the previous project year. The research continued the second subject of this project, where the NRE enzyme was successfully expressed and purified, and *in vitro* kinetic studies of the enzyme's interaction with various substrates/inhibitors were started. In addition, we detected the NRE enzyme in liver cells and tested the ability to measure its activity and inhibition by certain inhibitors *in vitro*. During the fourth year of the project, the cytotoxic effects of four newly synthesized imidazole compounds on PC-3 prostate cancer cells were investigated. These results were presented and defended in the diploma thesis entitled "Cytotoxic effect of imidazole compounds on prostate cancer cells" under the mentorship of I. Vrhovac Madunić (187) and 2 manuscripts are in preparation. The doctoral dissertation "Relationship between the structure and cytotoxicity of oxime reactivators of phosphorylated acetylcholinesterase" (181) was also defended. The topic and the importance of this project, as well as the results of the project's fourth year were presented through published scientific articles and a scientific lecture, and several abstracts at scientific congresses (205, 234, 306, 313).

LEADER (IMROH)	PROJECT	DURATION
Darija Klinčić	Development, validation and application of analytical methods for PBDE determination (DeValApp, UIP-2017-05-6713)	2018–2023

IMROH ASSOCIATES: M. Dvorščak, K. Jagić, A. Jurič

An optimized and validated method for the analysis of selected polybrominated diphenyl ether (PBDE) congeners in dust samples (40) was applied to obtain first insight into the presence of PBDE compounds in households in Croatia (255). These preliminary studies also included Estimated Daily Intake (EDI) calculations via dust ingestion for young children (12 to ≤35 months) and adults (18 to ≤65 years) (41, 211). Further research was extended to a higher number of households, and additionally, 18 trace elements were analyzed in dust samples. According to the obtained mass fractions of compounds of interest and collected data on households (age of the property, year of last renovation, frequency of ventilation, number of household members etc.), the possible indoor sources that contribute statistically significant to increased levels of PBDEs/elements were assessed, and their daily intake for the two mentioned age groups was assessed via the dust ingestion, and via the dermal dust absorption (50, 256). The dust samples from various other indoor places besides the household (kindergartens, working places, cars) were included in the research, and the time fraction that people spend in each indoor place was considered to calculate the total daily intake of PBDE compounds in their body by dust ingestion (305, 331). Research on the application of the microwave extraction technique for the analysis of PBDEs in human milk samples was continued (254). Accelerated solvent extraction (ASE) was used to extract PBDEs from human milk samples collected in 2010 and 2020 to get an insight into the time distribution of compounds of interest, and to assess the infant health risk (323). *In vitro* toxicity studies of PBDEs were also performed (205). A review paper has been published summarizing data on methods used to analyze different groups of brominated flame retardants to obtain information on levels and distribution of PBDEs, polybrominated biphenyls (PBBs), tetrabromobisphenol A (TBBPA), tetrabromobisphenol S (TBBPS), an analogue of TBBPA and hexabromocyclododecane (HBCD) in the aquatic environment (42). Apart from scientific congresses, the significance and results of the project so far were presented during the third year through several popularization activities.

16.1.A.2. CROATIAN ACADEMY OF SCIENCE AND ART FOUNDATION (7 projects)



LEADER (IMROH)	PROJECT	DURATION
Irena Brčić Karačonji	Biological effects of strawberry tree (<i>Arbutus unedo</i> L.) honey on tumour and healthy human cells	2020–2022

IMROH ASSOCIATES: A. Jurič, A. Katić, N. Kopjar, S. Žunec

EXTERNAL ASSOCIATES: K. Durgo, A. Hušek (Faculty of Food Technology and Biotechnology, University of Zagreb)

High biocompatibility of strawberry tree honey and homogentisic acid with lymphocytes from human peripheral blood and their protective effect at the cytogenetic level against damage caused by irinotecan were determined using micronucleus test and analysis of chromosomal aberrations (46, 212, 332).

LEADER (IMROH)	PROJECT	DURATION
Marija Dvorščak	Development of analytical methods for the purpose of obtaining the first data on human exposure in Croatia to brominated compounds	2020–2021
IMROH ASSOCIATES: D. Klinčić, K. Jagić		
According to the available literature, accelerated solvent extraction (ASE) is the most used technique for extracting PBDEs from the human milk samples. A comparative study of efficiency of microwave-assisted extraction technique and ASE showed that both techniques can be used for efficient extraction of seven PBDE congeners from human milk samples. The results of the analysis of milk samples collected from breastfeeding mothers in the Zagreb area indicate that the levels of target compounds in human milk in Croatia are very low, and an additional decreasing trend in their mass fractions over a ten-year period has been observed (323).		
LEADER (IMROH)	PROJECT	DURATION
Goran Gajski	Domoic acid toxicity on non-target human cells (DomoTox)	2020–2021
IMROH ASSOCIATE: M. Gerić EXTERNAL ASSOCIATE: A.-M. Domijan		
The aim of the project is to investigate the genotoxic and oxidative effects of domoic acid, a known neurotoxin produced by diatoms and accumulates in marine animals that serve as potential food source on non target cells in order to give broader picture of mechanistic activity of the toxin. Project activities in 2021 have resulted in the publication of a scientific paper (151), which reports the results of research on the toxicological profile of domoic acid on human blood cells.		
LEADER (IMROH)	PROJECT	DURATION
Marko Gerić	Evaluation of cytogenetic effects of air pollutants towards human cells <i>in vitro</i>	2021–2022
IMROH ASSOCIATES: G. Gajski, I. Jakovljević, G. Pehnc, J. Rinkovec EXTERNAL ASSOCIATE: A.-M. Domijan		
Air pollution is a growing environmental and public health problem. Leading world organizations associate polluted outdoor air with the occurrence of numerous diseases and premature mortality. This project will evaluate of the modal solutions that represent air pollution for winter and summer on human cells <i>in vitro</i> for their toxic effects and mechanisms of action. The results of this project will contribute to the understanding of the mechanisms of harmful effects of compounds that pollute the air and the development of scientific research abilities of scientists at an early stage of their scientific careers.		
LEADER (IMROH)	PROJECT	DURATION
Božena Skoko	Environmental risk assessment of materials with increased natural radioactivity – Transfer of ²³⁸ U sequence radionuclides to earthworms and consequent biological effects	2020–2021
IMROH ASSOCIATES: T. Bituh, I. Prlić, D. Rašeta, B. Petrinc EXTERNAL ASSOCIATES: G. Klobučar, D. Hackenberger Kutuzović, M. Jukić, O. Malev		
The aim of the project is to examine the impact of coal ash and slag with elevated concentrations of the radionuclide ²³⁸ U radioactive series on organisms that are in close contact with such a medium. The experimental results will be used for further analysis of the ERICA Tool (Environmental Risk from Ionizing Contaminants: Assessment and Management) program in the context of NORM (Naturally Occurring Radioactive Material) issues.		

LEADER (IMROH)	PROJECT	DURATION
Ivana Vrhovac Madunić	Oximes as potential inhibitors glucose transfer in prostate cancer cells	2021–2022
IMROH ASSOCIATES: D. Karaica, A.-M. Lulić, M. Katalinić, J. Madunić, A. Zandona		
The aim of this project is to determine whether newly synthesized oxime compounds inhibit glucose uptake and thus the growth of human prostate cancer cells and as such can be considered as candidates for antitumor drugs. Most of the newly synthesized oximes that will be examined are either constantly positively charged quaternary amines, or contain amino groups that could be strongly protonated under physiological conditions.		
LEADER (IMROH)	PROJECT	DURATION
Antonio Zandona	Evaluation of kinetic parameters and cell effects of new antidotes based on vitamin B6 for the treatment of poisoning by highly toxic organophosphates	2020–2021
IMROH ASSOCIATES: M. Katalinić, Z. Kovarik EXTERNAL ASSOCIATES: D. Gašo Sokač and V. Bušić (Faculty of Food Technology, University J. J. Strossmayer Osijek, Osijek)		
Eight pyridoxal dioximes, analogs of vitamin B6, were successfully synthesized. Their effect on inhibition and reactivation of cholinesterases inhibited by various organophosphates was investigated. In addition, the toxicity of new compounds on nerve cells (SH-SY5Y) was tested. The analysis of the results highlighted candidates who could be modified and used as cholinesterase inhibitors or reactivators. Finally, selected candidates may represent a starting point as a basic structure for the modification and synthesis of new series of pyridoxal dioxime analogs with the aim of finding more effective inhibitors or reactivators for the treatment in case of organophosphorus poisoning.		

16.1.A.3. IN-HOUSE SCIENTIFIC PROJECTS (22 projects)



LEADER (IMROH)	PROJECT	DURATION
Adrijana Bjelajac	Sleep quality in different age groups in Croatia before and during COVID-19 pandemic (CoV-Sleep)	2021–2023
IMROH associates: J. Macan, S. Cvijetić Avdagić, P. Tomac, J. Mandić, B. Ross External associates: E. A. Delale (Institute for Anthropological Research), D. Lučanin (University of Applied Health Sciences)		
Irena Brčić Karačonji	Investigation of toxic effects of new psychoactive substances by biochemical and molecular-biological methods	2020–2023
IMROH associates: N. Brajenović, A. Jurić, M. Katalinić, N. Kopjar, A. Lucić Vrdoljak, J. Madunić, K. Nekić, M. Nikolić, A. Pizent, D. Rašić, L. Stančin, B. Tariba Lovaković, V. Triva, A. Zandona External associates: I. Canjuga, G. Kozina, M. Neuberg (University North, Koprivnica), N. Benco, I. Hižar, J. Leniček Krleža, J. Obuljen, A. Rešić, M. Zrilić (Children's Hospital Zagreb), M. R. Meyer (Saarland University, Homburg, Saar, Germany)		
Irena Brčić Karačonji	Chemical and radiological characterisation of strawberry tree (<i>Arbutus unedo</i> L.)	2020–2021
IMROH associates: N. Brajenović, A. Jurić, M. Lazarus, B. Petrinc, A. Pizent, D. Rašeta, B. Tariba Lovaković, T. Živković Semren External associates: K. Jurica (Ministry of the Interior of the Republic of Croatia, Zagreb), D. Milojković Opsenica (Faculty of Chemistry, University of Belgrade, Serbia)		
Selma Cvijetić Avdagić	Determination of body composition and chronic stress by bioimpedance method	2018–2022
IMROH associates: A. Bjelajac, J. Macan, Ž. Babić, J. Jurasović, Zr. Franić, T. Orct, R. Luzar, F. Šakić External associates: I. Colić Barić, I. Keser (Faculty of Food Technology and Biotechnology, Zagreb), J. Ilich Ernst (Florida State University, Tallahassee, SAD)		

Selma Cvijetić Avdagić	Relationship between chronic inflammation and osteopenia in patients on chronic hemodialysis	2019–2021
IMROH associates: J. Macan, V. M. Varnai, Ž. Babić, J. Kovačić, M. Kujundžić Brkulj, R. Luzar		
Ranka Godec	Organic content of PM ₁ particle fraction	2018–2023
IMROH associates: G. Pehnek, I. Bešlić, I. Jakovljević, Z. Sever Štrukil, I. Šimić, S. Sopčić		
Snježana Herceg Romanić	Persistent organic pollutants – environmental impact assessment and stability of human genetic material	2018–2021
IMROH associates: G. Mendaš Starčević, S. Fingler Nuskern, S. Stipičević, D. Klinčić, M. Dvorščak, D. Želježić, V. Mužinić External associates: B. Mustać (University of Zadar Department of Ecology, Agronomy and Aquaculture), G. Jovanović i A. Stojić (Institute of Physics Belgrade, Serbia)		
Snježana Herceg Romanić	Analysis of organic pollutants in biological systems and the environment	2021–2024
IMROH associates: G. Mendaš Starčević, S. Fingler Nuskern, S. Stipičević, D. Klinčić, M. Dvorščak, N. Medved, G. Pehnek, I. Jakovljević, I. Šimić External associates: M. Matek Sarić (University of Zadar Department of Health Studies), G. Jakšić (AQUATIKA, Karlovac), G. Jovanović i T. Miličević (Institute of Physics Belgrade, Serbia), A. Popović (University of Belgrade Faculty of Chemistry, Serbia), D. Stanković (Vinča Institute of Nuclear Sciences, Serbia)		
Anja Katić	Assessment of the effects of prenatal exposure to α -cypermethrin on epigenetic programming and endocrine disruption of reproduction and development in experimental rats	2020–2023
IMROH associates: A. Lucić Vrdoljak, V. Micek, A. Sulimanec Grgec, S. Žunec External associates: M. Himelreich Perić, A. Katušić Bojanac, D. Krsnik (School of Medicine, Zagreb), I. Canjuga, G. Kozina, M. Neuberg, R. Ribić (University North, Koprivnica)		
M. Lazarus	Bioactive potential, metal and nicotine content in edible boletes regarding the toxic metal burden of soil	2021–2022
IMROH associates: I. Brčić Karačonji, A. Jurić, S. Mataušić, B. Petrinc, D. Rašeta, A. Sekovanić, J. Senčar External associates: D. Šamec (University North, Koprivnica), I. Širić and N. Šprem (Faculty of Agriculture, University of Zagreb)		
Jelena Macan	Implementation of questionnaire for diagnosing occupational COVID-19 in healthcare workers	2020–2021
External associates: M. Milošević and R. Žaja (School of Public Health A. Štampar, School of Medicine, Zagreb), I. Kerner (Bonifarm, Zagreb)		
Jelena Macan	Prevalence and predictors of occupational contact dermatitis in apprentice nurses/medical technicians (NurseSkin)	2021–2022
IMROH associates: S. Cvijetić Avdagić, Zr. Franić, Ž. Babić, A. Bjelajac, J. Kovačić, F. Šakić, J. Mandić		
Ante Miličević	Investigation of electrochemical properties and antioxidant activity of polyphenolic compounds and their complexes with essential elements	2017–2021
IMROH associates: I. Novak Jovanović, I. Pavičić External associates: N. Bregović (Faculty of Science, Zagreb), G. I. Miletić (Ruđer Bošković Institute, Zagreb)		
Branko Petrinc	Radiological characterization of Kopački rit	2016– 2021
IMROH associates: D. Babić, T. Meštrović PARTNER: Physics Department of J. J. Strossmayer University, Osijek		
Ivica Prlić	Thermometry, thermography and sensory evaluation of electromagnetic radiation in medicine (TTSem3)	2014–2023
IMROH associates: L. Pavelić, I. Bešlić, J. Šiško, S. Kobeščak, M. Jurdana PARTNERS: KBC Zagreb, Children's Hospital Zagreb (A. Antabak), OB Karlovac, M. Hajdinjak (Haj-kom), Z. Cerovac (ALARA)		

Ivica Prlić	Development of UV radiation sensors	2015–2023
IMROH associates: J. Macan, L. Pavelić, J. Šiško, M. Jurdana PARTNERS: M. Hajdinjak (Haj-kom), Z. Cerovac (ALARA), KBC Zagreb, Lj. Orešić		
Dubravka Rašić	Comparison of balanced anaesthesia and target controlled infusion on oxidative stress production	2019–2021
IMROH associate: M. Peraica PARTNER: Children's Hospital Zagreb		
Dubravka Rašić	A relationship of resveratrol administration in cardiac surgery patients with reduction of oxidative stress and systemic inflammatory response	2021
IMROH associate: M. Peraica PARTNER: KB Dubrava, Zagreb (M. Planinc)		
Jasmina Rinkovec	Levels of platinum group elements (PGE) near roads	2018–2021
IMROH associates: G. Pehnek, S. Žužul, I. Bešlić, S. Davila, M. Vincetić External associate: Ž. Zgorelec (Faculty of Agriculture, Zagreb)		
Ankica Sekovanić	Assessment of the effects of MT2A + 838 G/C and MT2A –209 A/G gene polymorphisms on the levels of toxic and essential elements at childbirth	2021–2022
IMROH associates: J. Jurasović, T. Orct, M. Piasek External associate: D. Pašalić (School of Medicine, University of Zagreb)		
Suzana Sopčić	Molecular markers of organic carbon – biomass burning indicators	2021–2023
IMROH associates: G. Pehnek, I. Jakovljević, R. Godec		
Blanka Tariba Lovaković	Evaluation of reproductive toxicity of commonly used pesticides followed by chronic low-dose exposure <i>in vivo</i>	2019–2021
IMROH associates: A. Pizent, Z. Kljaković-Gašpić, A. Sekovanić, T. Orct, V. Kašuba		

16.1.B. COLLABORATION ON RESEARCH PROJECTS OUTSIDE THE INSTITUTE

16.1.B.1. CROATIAN SCIENCE FOUNDATION

Research projects (9 projects)



LEADER	PROJECT	DURATION
V. Filipović-Marijić, Ruđer Bošković Institute, Zagreb	Integrated evaluation of aquatic organism responses to metal exposure: gene expression, bioavailability, toxicity and biomarker responses (BIOTOXMET, IP- 2020-02)	2020–2024
IMROH ASSOCIATE: Z. Kljaković-Gašpić		
<p>The objectives of the project are to determine the concentration of metals in the water and sediment of the Krka River and its tributaries, assess seasonal trends and long-term exposure to metals, study biological responses of organisms to metal exposure, assess the bioavailability and toxicity of food metals, and determine binding mechanisms and efficiency of accumulation of metals in intestinal parasites of fish. All the activities planned for the first year were carried out according to the schedule and all of the planned goals have been achieved. Associates from IMROH determined the concentrations of total mercury in water and sediment samples from eight locations of different levels of pollution in the upper Krka River course. In combination with the results of other project participants, the water status in the upper course of the Krka River, which is partly influenced by the city of Knin wastewater and industrial wastewater from the adjacent factory was assessed (268, 346).</p>		

LEADER	PROJECT	DURATION
S. Frka Milosavljević, Ruđer Bošković Institute, Zagreb	Biochemical responses of oligotrophic Adriatic surface ecosystems to atmospheric deposition Inputs (BiREADI, IP-2018-01-3109)	2018–2022
IMROH ASSOCIATES: I. Bešlić, R. Godec, S. Žužul, I. Šimić, G. Pehnec (advisor)		
<p>The aim of the project was to assess the impact of atmospheric deposition on complex biochemical responses of oligotrophic systems, considering the importance of promotion and inhibition effects on phytoplankton, and the consequent altering of the surface water chemistry, including the sea surface microlayer at the air-water interface. In the first phase of the project, the concentrations, sources and deposition fluxes of atmospheric constituents have been evaluated as well as the nature of enrichments of macro-nutrients, trace metals and organic pollutants within the sea surface layers. All activities were carried out according to schedule and all of the planned goals have been achieved. Associates from IMROH analysed the results of measurements of airborne particulate matter and atmospheric deposition, collected at the location of Martinska near Šibenik in 2019. Atmospheric deposition of nitrogen and phosphorus in the central Adriatic and biogeochemical consequences (268) were analyzed. Seasonal changes, variability and origin of polycyclic aromatic hydrocarbons (PAHs) and nitro-aromatic compounds (NACs) in particulate matter, as well as PAHs, NACs and polychlorinated biphenyls (PCBs) in bulk and wet deposition were determined, which is the first such study for the Adriatic (44). The impact of atmospheric deposition of biologically relevant heavy metals on the sea surface microlayer was assessed, as well as the influence of open fire biomass burning and Saharan dust intrusion (87).</p>		
LEADER	PROJECT	DURATION
M. Hranjec, Faculty of Chemical Engineering and Technology, Zagreb	Exploring the antioxidative potential of benzazole scaffold in the design of novel antitumor agents (AntioxPot, IP-2018-01-4379)	2018–2022
IMROH ASSOCIATE: I. Novak Jovanović		
<p>The antioxidative potential of novel unsubstituted and <i>N</i>-substituted imidazo[4,5-<i>b</i>]pyridine derived acrylonitriles was studied using spectroscopic DPPH and ABTS assays, FRAP method and square-wave voltammetry. In voltammetry, the main parameter used for evaluation of the antioxidant potential of a specific compound is the electrochemical oxidation potential. It is expected that compounds with lower (more negative) oxidation potentials possess higher antioxidant activity. In line with this, a reasonably good linear correlation was found between electrochemical oxidation potentials and FRAP activities ($r = 0.91$). In addition, we studied the structure-electrooxidation potential relationship. The lowest (least positive) oxidation potential was found for compounds bearing a <i>p</i>-<i>N</i>(Et)₂ substituent on the distant phenyl moiety and lacking one at the N atom of imidazo[4,5-<i>b</i>]pyridine nuclei. The <i>N</i>-substitution of the imidazo[4,5-<i>b</i>]pyridine ring shifted the oxidation potential towards more positive values. When comparing compounds with identical substitution on the phenyl moiety but different substituent on the imidazo[4,5-<i>b</i>]pyridine nuclei, one can see that the latter did not influence the oxidation potential significantly. Replacement of <i>p</i>-<i>N</i>(Et)₂ with <i>p</i>-<i>N</i>(Me)₂ group had negligible effects on oxidation potential. However, methoxy substitution on the phenyl moiety shifted the oxidation peak potentials to high positive values. The results of this study were published in a scientific article (12) and presented as a poster at the International Symposium on Medicinal Chemistry, Basel, Switzerland 2021 (320).</p>		
LEADER	PROJECT	DURATION
S. Miko, Croatian Geological Institute, Zagreb	Sediments between source and sink during a Late Quaternary eustatic cycle: The Krka and the Mid Adriatic Deep System (QMAD, IP-04-2019-8505)	2019–2023
IMROH ASSOCIATE: B. Petrinc		
<p>The proposed project aims to improve the knowledge of the thus far poorly explored submerged landscapes of the eastern Adriatic shelf, as well as late Quaternary sediments deposited along the eastern part of the Central Adriatic Basin (MAD). The study of the Pleistocene floodplain of the Krka River will provide insight into the stratigraphic sequence of sediments with the development of the delta system and estuaries, which were formed by the interaction of eustatic sea level changes and local factors such as sediment yield and tectonic activity. Continuous marine sedimentation during the late Quaternary and the yield of material from the Krka River Basin will be investigated in the eastern part of the MAD. By applying high-resolution geophysical methods and sedimentological, petrophysical, geochemical, micropaleontological and aDNA methods on samples from</p>		

sediment cores, it will for the first time be possible to monitor paleoenvironmental evolution from rivers/lakes to deep-sea environments on a profile shorter than 100 km. Appropriate climatic and environmental indicators will be identified and insight will be gained into the migration and environmental adaptation of hunters and gatherers who lived on the eastern Adriatic coast during the late Palaeolithic, where the Krka River floodplain probably existed. The obtained results on sea level and landscape changes will enable an understanding of the possible interaction among people from the wider study area during the time of systemic tracts of falling, low and rising sea levels. This will explore the possible role of the Krka River as a land/floodplain “bridge” for human migration. Special attention will be paid to the assessment of the new sedimentation rate, the recognition of the characteristics of submerged landscapes and the calculation of the rate of accumulation of organic carbon and terrestrial components of sediments, as well as potentially toxic elements.

LEADER	PROJECT	DURATION
T. Smital, Ruđer Bošković Institute, Zagreb	Identification and functional characterization of (eco)toxicologically relevant polyspecific membrane transport proteins in zebrafish (<i>Danio rerio</i>) (DANIOTRANS, IP-2019-04-1147)	2020–2024

IMROH ASSOCIATES: D. Karaica, N. Maraković (until 22 Sep 2021)

We completed the optimization of techniques for preparation of tissue samples and protocols for antigen retrieval in zebrafish tissues/organs for the purpose of (immuno)histochemical analyses. A detailed immunocytochemical characterization of designed antibodies for various zebrafish transporters was conducted. Three-dimensional homologous models for selected membrane carriers (Oatp2b1 and Oatp1d1) were developed by computer method of homologous modelling (20, 61). One graduation thesis was completed and defended (183) and two laboratory practices were provided under the mentorship of D. Karaica.

LEADER	PROJECT	DURATION
G. Šimić, Croatian Institute for Brain Research, Zagreb	Role of blood-brain barrier, innate immunity, and tau protein oligomerization in the pathogenesis of Alzheimer's disease (ALZ-BBB-STOPINNATETAU, IP-2019-04-3584)	2020–2024

IMROH ASSOCIATE: A. Sekovanić

Element concentrations were determined in plasma and cerebrospinal fluid and levels compared between groups of patients with Alzheimer's disease, mild cognitive impairment patients, and healthy controls with different APOE genotype (4, 237).

LEADER	PROJECT	DURATION
I. Šola, Faculty of Science, University of Zagreb	Indirect effect of global warming on mammals physiological parameters via high temperature-stressed plant diet (TEMPHYS, IP-2020-02-7585)	2021–2025

IMROH ASSOCIATE: M. Lazarus

In this project the chain interactions between temperature shift, plant biochemical traits and mammal (fed with those plants) physiology will be assessed employing targeted specific metabolomics approach for plant analyses, biosafety and bioactivity tests on mammals, and statistical data analyses and modelling in order to construct a model showing a tentative pattern of environment temperature indirect (through plant diet) effect on mammal physiology. Our strategy is to identify metabolites of plants that have been altered by HT, to quantify the intensity of changes, and to correlate those with changes in the physiological parameters of mice fed by these plants. As a plant representative we will use *Brassica oleracea botrytis* var. *cymosa* (broccoli) seedlings and mature plants, and as a mammal representative Swiss Webster mice (CFW, Coat Color White (albino), Strain Code: 024 by Charles River). Additionally, for *in vitro* biosafety analyses, the cell culture of human hepatocellular carcinoma (HepG2) and mouse embryonal fibroblasts (MEF) will be used. The results of the project will clarify whether the phytochemical ability of plants to adapt to HT (simulating global warming) will be crucial for its nutritional value and biological effects in mammals, i.e. mammal health status. Given the ubiquitous effect of global warming, the results will contribute to predictions on diet-mediated indirect effects of global warming on animal physiology.

LEADER	PROJECT	DURATION
T. Vinković, Faculty of Agriculture, Osijek	Application of Nanobiotechnology for Nutritional Supplementation with Selenium (NutriNtense, IP-2018-01-8119)	2019–2022
IMROH ASSOCIATES: A. M. Marjanović Čermak, B. Tariba Lovaković, I. Vinković Vrček (advisor)		
The green synthesis of nanoselenium was investigated using the raw and purified pectins extracted from mandarin peel, tomato peel, and olive pomace extract rich in polyphenols. The influence of different synthesis conditions on the size distribution, zeta potential, and gastrointestinal stability of the obtained nanoparticles were examined. <i>In vitro</i> studies of chemically and biologically synthesized selenium nanoparticles were performed.		
LEADER	PROJECT	DURATION
V. Vrček, Faculty of Pharmacy and Biochemistry, Zagreb	Quantum-chemical design, preparation and biological properties of organometallic nucleobase derivatives (OrDeN, IP-2016-06-1137)	2017–2021
IMROH ASSOCIATES: A. M. Marjanović Čermak, I. Pavičić, I. Vinković Vrček		
A series of different ferrocene-substituted purines, overall 29 compounds, were synthesized during the course of this project. A compound's electrochemical activity as well as ability to generate acellular reactive oxygen species were studied. Cyclic voltammetry showed that all of the measured compounds followed a reversible one-electron oxidation in the range of 300-450 mV with N7 isomers being better oxidants than N9. While nucleobases coupled with ferrocene generated ROS in acellular media, ferrocene and nucleobases were not active. The cytotoxic effect of newly synthesized compounds was examined by determining IC ₅₀ values in mouse fibroblast cells (L929), human cell lines of hepatocellular carcinoma (HepG2), pancreatic (PANC-1), breast (MCF7), and lung (A549) cancer cell lines (291, 292). Based on the conducted research, the most active compounds with IC ₅₀ values <50 µM were selected and their ability to generate ROS as a possible mechanism of cytotoxic action in the cell were further assessed.		

16.1.B.2. UNIVERSITY PROJECTS (4 projects)

LEADER	PROJECT	DURATION
A. Bulog, Faculty of Medicine, Rijeka	Biological monitoring of the effects of volatile aromatic hydrocarbons (BTEX) on the health of the Primorje-Gorski Kotar County population	2019–2021
IMROH ASSOCIATE: I. Brčić Karačonji		
We developed and validated a method for determining the mass concentration of S-phenylmercapturic acid in urine (biomarker of benzene exposure) using gas chromatography-mass spectrometry (GC-MS) (184).		
LEADER	PROJECT	DURATION
I. Gobin, Faculty of Medicine, Rijeka	Opportunistic pathogens in the water supply system: A new challenge in water treatment	2019–2021
IMROH ASSOCIATE: I. Brčić Karačonji		
Studies on the antimicrobial potential of natural substances (essential oils and hydrolates), active metabolites of bacteria of the genus <i>Bacillus</i> and selected synthesized photodynamically active compounds against resistant bacteria that colonize part of the water distribution system are underway.		

LEADER	PROJECT	DURATION
M. Knežević, Department of Psychology, Catholic University of Croatia	Family dynamics, health and well-being of Croatian families in the light of war and post-war experiences	2019–2021
IMROH ASSOCIATE: P. Tomac		
<p>The main goal of the project was to investigate the relationship between active participation in the Homeland War and the physical, mental, and social well-being of veterans and their families through a series of qualitative and quantitative research methods and to compare them with families whose members did not participate in the war. The aim was to find answers to three important questions: 1) Do these families differ in terms of physical, mental, and social well-being; 2) Is there a relationship between the war experience and marital adjustment, how is this related to the psychosocial development of children and the possible intergenerational transmission of trauma; 3) What are the risk and protective factors associated with possible differences between those families. Due to epidemiological circumstances, the duration of the field research was extended. In December 2021, the first results of the quantitative data analyses were orally presented within the symposium “Family Functioning in the Light of Posttraumatic Recovery” at the 3rd International Scientific Conference of the Department of Psychology of the Catholic University of Croatia “Coping with Crisis–Pathways Towards Resilience” (238, 242, 262, 287, 293).</p>		
LEADER	PROJECT	DURATION
G. Millotti (Juraj Dobrila University of Pula)	Toxicological profile of the phytoplankton <i>Ostreopsis</i> in the northern Adriatic Sea	2021–2022
IMROH ASSOCIATE: G. Gajski		
<p>The aim of the project is the isolation of Adriatic phytoplankton species and their cultivation for the purpose of further research. As part of the project, morphological and genetic identification of the species and the isolation of associated toxins and their characterization will be carried out. Furthermore, the project will examine the effect of toxins on nasal epithelial cells and how the toxin affects their permeability. Also, a detailed toxicological characterization will be performed on human peripheral blood lymphocytes as sensitive biomarkers of exposure in this type of research.</p>		

16.1.C. PROFESSIONAL PROJECTS

PROJECT	CONTRACTOR	LEADER
Service provider: Environmental Hygiene Unit		
Monitoring air pollution in the City of Zagreb (from 1963)	City of Zagreb, City Office for Energy, Environmental Protection and Sustainable Development	G. Pehnec
Monitoring of the Total Effects of CPS Molve on the Ecosystem (from 1998)	INA-Naftaplin and Institute for Public Health of the Koprivnica-Križevci County	G. Pehnec
Monitoring Air Quality at the CWWTP Construction Site in Zagreb (from 2003)	Zagrebačke otpadne vode	G. Pehnec
Monitoring Air Pollution at National Network Stations for the Purpose of Continued Air Quality Monitoring (from 2015)	Ministry of Economy and Sustainable Development and Meteorological and Hydrological Service of Croatia	G. Pehnec
Drafting Equivalency Studies at Measurement Stations of the National Network for Continued Air Pollution Monitoring (from 2015)	Ministry of Economy and Sustainable Development and Meteorological and Hydrological Service of Croatia	I. Bešlić
Ecological Map of the City of Zagreb	City of Zagreb	G. Pehnec, S. Davila

Service provider: Radiation Protection Unit		
Background Radioactivity Monitoring in the Republic of Croatia, IMI-CRZ-96 (since 1959)	Civil protection directorate of the Republic of Croatia Ministry of the Interior	B. Petrinec
Radioactivity measurements of zero state at the location of the Center for Radioactive Waste Disposal and in the area of the Dvor municipality	Decommissioning and Disposal of Radioactive Waste and Spent Nuclear Fuel of the Krško Nuclear Power Plant Fund	B. Petrinec
Results of Monitoring of Environmental Radioactivity in Vicinity of Plomin Coal-Fired Power Plant, IMI-P-383	HEP proizvodnja, Thermal power plant Plomin I, Plomin	B. Petrinec
Results of Radioactivity Measurements at Gas Field Molve, IMI-P-384	Koprivnica-Križevci County, Koprivnica	B. Petrinec
Service provider: Radiation Dosimetry and Radiobiology Unit		
Determination of the radiological status of the working environment in IPNP (Phase II)	INA Group	I. Prlić
Determining of the radiological status of production tubing during maintenance processing (Phase III)	INA Group and STSI	I. Prlić



16.2. INTERNATIONAL PROJECTS

16.2.A. SCIENTIFIC RESEARCH PROJECTS

16.2.A.1. EUROPEAN UNION PROGRAMS

EUROPEAN REGIONAL DEVELOPMENT FUND
Operational Program Competitiveness and Cohesion (4 projects)



European Union
 European Regional
 Development Fund

INSTITUTION (Leader)	PROJECT	DURATION
School of Medicine, Zagreb (D. Ježek)	Scientific Center of Excellence for Reproductive and Regenerative Medicine, Reproductive and Regenerative Medicine – Exploring New Platforms and Potentials (CERRM, KK.01.1.1.01.0008)	2014–2022
IMROH ASSOCIATE: A. Fučić		
<p>Men with pathological semen diagnoses were studied and compared with healthy men. DNA Damage and N-glycans in seminal plasma have been found to be associated with pathological sperm parameters. Specific N-glycans are associated with sperm chromatin maturity and have potential in future fertility research and clinical diagnosis (63). An association between environmental and occupational exposure to pesticides and male infertility has been established (26, 62). The study of preterm infants provided for the first time reference values for CYP19A1 gene methylation levels that differed significantly from those in preterm infants. Differences in testosterone levels and testosterone to estrogen ratios between preterm infants and preterm infants were also found (56). It is proposed to develop and use OneHealth Medical Record to enable the collection of medical data from a variety of sources, with high value-added integration for prevention and therapy including environmental exposure data, occupational exposure data, allergies and drugs from birth through lifetime (27). In the study of head and neck cancer, the results showed for the first time the interaction between the androgen receptor, VEGF, MMP9, HIF1beta and Ki67, which may contribute to better diagnosis and choice of therapy (8).</p>		

A new method of acridine orange sperm staining has been developed that provides an innovative approach to sperm pathology analysis, enables RNA localization and quantification in residual cytoplasm, opens new options for automating sperm quality assessment and improves personalized approach in *in vitro* fertilization protocol selection (28). In a book on toxic chemical compounds that affect the endocrine system, a systematic overview of the type of endocrine-active compounds was given, their mechanisms of action and legislation (153).

INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (A. Lucić Vrdoljak)	Research and Educational Centre of Environmental Health and Radiation Protection – Reconstruction and Expansion of the IMROH (ReC-IMI, KK.01.1.1.02.0007)	2017–2022

IMROH ASSOCIATES: S. Barbarić, M. Herman, B. Roić, S. Stankić

The project grant of HRK 232.6 million is intended for the implementation of the project during whose implementation the Institute will be expanded with a new building of 6,785.15 m², while its existing building of 2,067.41 m² will be renovated and the Institute will also increase its capacities with modern research and IT equipment for all of its units. During 2020, the first and larger phase of construction, which covers the expansion of the Institute, was completed and the renovation of the older building began. Apart from construction works, the Institute also finished nearly all public procurement procedures to acquire the funded research and IT equipment. Due to delays caused by the earthquakes in Zagreb and Petrinja, as well as the pandemic of the SARS-CoV-2 virus, the implementation period was extended to 31 Dec 2022.

INSTITUTION (Leader)	PROJECT	DURATION
Meteorological and Hydrological Service of Croatia (J. Škevin Sović)	Project of extension and modernisation of the national network for continuous air quality monitoring (AIRQ, KK.06.2.1.02.0001.)	2017–2022

IMROH ASSOCIATES: G. Pehnc (coordinator), R. Godec, I. Bešlić, S. Žužul, S. Stankić, B. Roić, S. Barbarić, M. Herman

The purpose of the project is to improve and optimize the system for managing and monitoring air quality in urban areas, zones, and agglomerations. The project aims to support the implementation of the legislative framework for air quality and environmental protection. This entails developing integrated strategies and projects which enable the evaluation, planning and implementation of adequate procedures for controlling air quality by means of measuring relevant parameters. Ultimately, the project aims to improve the monitoring programme for short-lived climate forcers (SCLF) and introduce climate-sensitive measures against air pollution. The lead beneficiary is the Croatian Meteorological and Hydrological Service (DHMZ) and the partner institution is IMROH. The project will receive a grant in the amount of HRK 125.1 million (85% funded by the ERDF OP Competitiveness and Cohesion, 15% by the Environmental Protection and Energy Efficiency Fund). The project will result in: 5 new and 19 modernized measuring stations at full functionality; a developed and functional model for the assessment of ground level concentrations of pollutants; additional equipment for DHMZ and IMROH chemical laboratories for measurements in accordance with the National Programme for measuring the level of air pollution in the national network for continuous air quality monitoring; with additional equipment for a laboratory for calibrating air quality measures and related measurement sizes. In 2019 and 2020 IMROH finished in full all planned procurements. All equipment have been put into operation. After the trial work, development of methods was carried out and the analytical methods for determining the chemical composition of particles were introduced on the AIRQ equipment. In 2021, employee training was performed for the particulate matter sampling equipment. Two advanced trainings planned in the laboratory of equipment manufacturers abroad were postponed due to the COVID-19 pandemic for the first possible date. Due to delays in the implementation and completion of certain public procurement procedures, the extension of the whole project until the end of 2022 has been approved.

INSTITUTION (Leader)	PROJECT	DURATION
Jamnica plus, Zagreb (S. Lovković)	Development of functional beverage in sustainable packaging (JamiNNO+, KK.01.2.1.02.0305)	2020–2023
IMROH ASSOCIATES: J. Jurasović (coordinator), I. Bešlić, N. Brajenović, I. Brčić Karačonji, S. Davila, G. Pehnc, I. Jakovljević, A. Jurić, Z. Kljaković-Gašpić, T. Orct, A. Sekovanić, A. Sulimanec Grgec, I. Šimić, B. Tariba Lovaković, S. Žužul PARTNERS: Faculty of Pharmacy and Biochemistry University of Zagreb, IMROH and Ruđer Bošković Institute		
<p>The key stakeholder of this project, Jamnica plus, is the largest Croatian producer of mineral and spring waters and soft drinks. The project's goal is to develop a new functional low-energy beverage with bioactive components that will be packed in new, lightweight, and sustainable packaging made of recycled PET, with tethered closures and without microplastics. Additionally, in line with the guidelines of the EU Strategy for Plastics in the Circular Economy, activities to introduce such a sustainable packaging for all of the company's beverage products will be simultaneously carried out. During the first year of the project's experimental activities, we started the testing air sampling system for the collection of microplastic particles in the air on the beverage bottling line and analysis of currently used and new sustainable PET packaging. In the Jamnica natural mineral water bottling plant in Pisarovina and the Jana natural spring water and soft drinks bottling plant in Sveta Jana, samples of mineral and spring water in different types of packaging ("virgin" PET, 100% recycled PET, coloured and clear glass bottles) were collected for analysis of metals, phthalates and polycyclic aromatic hydrocarbons as well as samples of suspected particles for microplastic analysis. The active pumped sampler systems for airborne microplastics sampling were constructed and installed in bottling plants near bottle filling zone. We collected test samples of airborne microplastic particles using different filter types (silver, quartz, polycarbonate, membrane). Procurement and installation of equipment for microplastic analysis, laser direct infrared (LDIR) chemical imaging system 8700 LDIR (Agilent Technologies Inc, USA), were carried out. Following the onsite and online education and training regarding the use of equipment, we started the work on airborne microplastic particle analysis method optimization.</p>		

EUROPEAN UNION SOLIDARITY FUND (2 projects)



INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (M. Herman)	Strengthening and Renovation of the Earthquake-damaged Central Building of the Institute for Medical Research and Occupational Health (FSEU.2021.MZO.038)	2021–2022
IMROH ASSOCIATES: S. Barbarić, A. Lucić Vrdoljak, B. Roić, S. Stankić		
<p>Following the earthquake that took place in Zagreb on 22 Mar 2020, the Croatian Ministry of Science and Education opened a call to fund the strengthening and renovation of infrastructure damaged by the earthquake. Within this call, the Institute submitted a project to fully strengthen and renovate its central building. The project grant of HRK 13.2 million will go toward repairing and strengthening the central building, built in 1947, for the purpose of increasing its resilience against earthquakes. During 2021, the Institute prepared all the necessary documentation for construction and laid the legal foundation for initiating construction works.</p>		
INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (M. Herman)	Strengthening and Renovation of the Northern Building of the Institute for Medical Research and Occupational Health (FSEU.2021.MZO.071)	2021–2023
IMROH ASSOCIATES: S. Barbarić, A. Lucić Vrdoljak, B. Roić, S. Stankić		
<p>Following the earthquake that took place in Zagreb on 22 Mar 2020, the Croatian Ministry of Science and Education opened a call to fund the strengthening and renovation of infrastructure damaged by the earthquake. Within this call, the Institute also submitted a project to fully strengthen and renovate its northern building. The project grant of nearly HRK 6.7 million will go toward repairing and strengthening the northern building, built in 1961, for the purpose of increasing its resilience against earthquakes. The project grant was officially awarded on 5 Nov 2021 and during 2021, the Institute prepared the initial construction documentation, as well</p>		

as made preparations for all of the upcoming public procurement procedures that will take place within the project's activities.

EUROPEAN REGIONAL DEVELOPMENT FUND Operational Program INTERREG V-A Slovenia-Croatia



INSTITUTION (Leader)	PROJECT	DURATION
Jožef Stefan Institute, Ljubljana, Slovenia	ENSuring RAdiation Safety (ENRAS)	2018–2021
<p>IMROH ASSOCIATES: B. Petrinc (coordinator), T. Meštrović, T. Bituh, D. Babić, Z. Franić, M. Kovačić, M. Avdić PARTNERS: Slovenian Fire Association, Croatian Fire Association, Civil protection directorate of the Republic of Croatia Ministry of the Interior, Slovenian Nuclear Safety Administration, Administration of the Republic of Slovenia for Protection and Rescue</p> <p>The ENRAS project will help develop cross-border services in the field of ensuring safety (civil protection) in cases of nuclear or radiological accidents. The shared challenge within the project is to enable harmonised and safe joint interventions in cases of such accidents.</p>		

EUROPEAN RESEARCH AND INNOVATION PROGRAMME HORIZON 2020 (4 projects)



INSTITUTION (Leader)	PROJECT	DURATION
Federal Office for Radiation Protection, Salzgitter, Germany (T. Jung)	European Concerted Programme on Radiation Protection Research (CONCERT, 662287 COFOUND EJP-Topic: NFRP-2014-2015)	2015–2020 + 1 year of sustainability
<p>IMROH ASSOCIATES: I. Prlić (coordinator for Croatia and POM Contact point, Program Manager, member of the project consortium management), I. Brčić Karačonji, A. Lucić Vrdoljak, J. Macan, M. Surić Mihić Consortium: 28 national POM Institutions from 22 EU Member States and Norway</p> <p>CONCERT is a co-fund action with the policy of the European Atomic Energy Community (EUROATOM) that aims to attract and pool national research efforts with European ones in order to make better use of public R&D resources and to tackle common European challenges in radiation protection more effectively by joint research efforts in key areas. CONCERT is open to new national Programme Owners and Programme Managers at any time. The achievements of the project so far can be seen on the website: http://www.concert-h2020.eu/en/Publications</p>		
INSTITUTION (Leader)	PROJECT	DURATION
German Environmental Agency, Dessau-Roßlau, Germany (M. Gehring-Kolossa)	European Human Biomonitoring Initiative (HBM4EU, Grant Agreement No 733032)	2017–2021
<p>IMROH ASSOCIATE: A. Fučić Consortium: 24 EU Member States and Norway, Israel, Switzerland, European Environment Agency and European Commission</p> <p>An analysis of the international cohort of workers exposed to chromates by the micronucleus method has been performed and the publication is in preparation.</p>		

INSTITUTION (Leader)	PROJECT	DURATION
Norwegian Institute for Air Research (NILU), Kjeller, Norway (M. Dusinska)	Science-Based Risk Governance of Nanotechnology (RiskGONE, Grant Agreement No 814425)	2019–2023
IMROH ASSOCIATES: I. Vinković Vrček (coordinator), I. Pavičić, Z. Franić, B. Pem, K. Ilić, L. Božičević Consortium: 15 EU Member States and USA, and Iran		
The aim of the project is to establish a pan-European council for risk management in the field of nanotechnology, i.e. a solid framework for risk assessment and risk management procedures for consistent management of manufactured nanomaterials. All project work plans have been fulfilled through the synergy and joint work of all project partners. More about project activities: https://riskgone.wp.nilu.no/ .		
INSTITUTION (Leader)	PROJECT	DURATION
MyBiotech (N. Günday-Türel) and Luxembourg Institute for Science and Technology (T. Serchi)	Pharmaceutical Open Innovation Test Bed for Enabling Nano-pharmaceutical Innovative Products (Phoenix, Grant Agreement No 953110)	2021–2025
IMROH ASSOCIATES: I. Vinković Vrček (coordinator), I. Pavičić, I. Capjak, N. Peranić, Ž. Babić Consortium: 12 EU Member States		
PHOENIX-OITB develops a consolidated network of facilities, technologies, services and expertise for all the technology transfer aspects from characterisation, testing, verification up to scale up, GMP-compliant manufacturing and regulatory guidance. PHOENIX-OITB will develop and establish new facilities and upgrade existing ones to make them available to SMEs, start-ups and research laboratories for scale-up, GMP production and testing of nano-pharmaceuticals. The services and expertise provided by the OITB will include production and characterisation under GMP conditions, safety evaluation, regulatory compliance and commercialisation boost.		

EUROPEAN SOCIAL FUND

Operational Programme Efficient Human Resources

Croatian Science Foundation – Scientific Cooperation Programme (2 projects)



HRZZ
Hrvatska zaklada
za znanost



INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (I. Vinković Vrček)	Safe-by-Design Approach for Development of Nano-Enabled-Delivery Systems to Target the Brain (SENDER, HrZZ-PZS-2019-02-4323)	2019–2023
IMROH ASSOCIATES: I. Pavičić, B. Pem, K. Ilić, N. Kalčec, M. Beus, R. Barbir, N. Peranić PARTNER: University of Melbourne, Victoria, Australia		
<p>Project activities included regular meetings of the research team, analysis of all results obtained for the interaction of BRaiND systems with proteins, preparation of scientific publications, establishment of artificial biological membrane systems (PAMPA system) to determine blood-brain barrier permeability for different BRaiND, DFT dopamine interaction studies and L-dopa and their oxidized forms with Au gold nanoclusters ($n = 2,4,6$), simulations of molecular dynamics of binding of DOPA, dopamine and derivatives to gold nanosurfaces, NMR study of AuNP interaction with l-dopa and dopamine, planning and conducting preliminary experiments on determining the permeability parameters of artificial biological membranes for different BRaiND systems, writing manuscripts on dopamine and L-dopa interaction and their oxidized forms with different BRaiND systems, writing manuscripts on NMR study of AuNP interactions with l-dopa and dopamine. All key implementation indicators planned for the first year of the project have been achieved:</p> <ul style="list-style-type: none"> - 1 standard operating procedure (SOP) was prepared to assess the interaction of the BRaiND system with proteins, 1 SOP for protein synthesis, 1 SOP for biomembrane preparation, 1 SOP for PAMPA method - a total of 50 different BRaiND samples of well-defined properties were prepared, 7 of which were selected for further research - all planned experiments related to activities were conducted - scientific publications are in preparation. 		

The achieved results even exceeded the plan because the project team not only published the planned conference presentations, but in the second project period also presented a total of 9 conference presentations at 6 international scientific conferences (260, 261, 316, 329, 330, 333–336), so far published 4 scientific manuscripts, one submitted for review, and an additional two papers are in preparation. In addition, part of the project team is dedicated to the development of methodology for *in vitro* and *in vivo* experiments, and significant results have been achieved in this area, whereas scientific publications from this part of the project activities are being prepared.

INSTITUTION (Leader)	PROJECT	DURATION
Department of Physics, Faculty of Science, Zagreb (M. Makek)	Single layer gamma-ray polarimeter for medical imaging applications and fundamental physics research (SiLGaP, HrZZ-PZS-2019-02-5829)	2019–2023

IMROH ASSOCIATE: L. Pavelić, M. Surić Mihić (until 28 Feb 2021)

PARTNER: University of Sydney, New South Wales, Australia

The plan of this project is to develop a new modular gamma-photon polarization measurement system based on single-layer detectors for measuring Compton scattering. The individual modules will consist of a matrix of scintillation detectors read by silicon photomultipliers. Compared to two-layer systems, this concept offers the possibility of constructing cost-effective compact and multi-purpose devices. The project will set up a system of sixteen modules, which will then be applied in two studies. The first study will experimentally examine for the first time the possibility of using gamma-ray polarization information in positron emission tomography (PET) as an important step towards a new generation of efficient medical imaging devices. The second study will analyze the azimuthal correlations of three gamma photons from the decay of ortho-positrons to investigate quantum coupling as a fundamental physical concept.

EUROPEAN COMMISSION, DG EMPLOYMENT, SOCIAL AFFAIRS AND INCLUSION



INSTITUTION (Leader)	PROJECT	DURATION
University of Osnabrück, Germany (S. Malte John)	Promoting the autonomous implementation of the European framework agreement on occupational health and safety in the hairdressing sector (VS/2019/0440)	2021–2022

IMROH ASSOCIATES: J. Macan, Ž. Babić, R. Turk, Zr. Franić, M. Macan

Project is implemented by the research consortium from Germany, Denmark, the Netherlands, and Croatia. The specific aims of the project are to: 1) identify and prioritize hazardous and harmful substances contained in cosmetic products used by hairdressers by means of a systematic review; 2) adopt two Medical Reference Documents, which identify and prioritize different substances and ingredients (including reprotoxic substances); 3) draft a Methodological Note showcasing the difference in exposure between a consumer and a professional hairdresser; 4) participate in the Technical Working Group at the level of the CEN on the hairdressing glove standardisation process. In 2021 protocols for systematic reviews were published (116, 172), and literature searches were performed. Systematic reviews about health effects of the most common hairdressing chemicals and exposure in hairdressers through skin and respiratory system have been submitted to the journals.

INSTITUTION (Leader)	PROJECT	DURATION
VITO, Flemish Institute for Technological Research, Belgium (M. Van Poppel)	Deployment of lower-cost ambient air quality sensor systems in urban environments (ENV.C3/SER/2019/0010)	2020–2022
IMROH ASSOCIATES: S. Davila (coordinator for Croatia), I. Bešlić, M. Mihaljević		
<p>This project aims to help evaluate the performance and potential of low-cost sensor systems for air quality and make comparisons with conventional measurement methods. To achieve this, the sensors are used under different environmental and meteorological conditions in three different European cities, Antwerp, Oslo and Zagreb. In May 2020, measurements of pollutants began in Zagreb using 17 sensor boxes owned by the JRC. In the first phase of the project, from early June to early July, all 17 instruments were placed at IMROH for calibration. At the beginning of July 2020, the second phase of measurement began, in which the devices were installed at an additional 16 locations in the city of Zagreb. The devices were installed at all air quality monitoring stations in the city of Zagreb, as well as at locations where air quality measurements have not yet been carried out. The locations have been proposed by IMROH and approved by the JRC. The location of the automatic measuring station at the Institute was selected as the reference location for monitoring the air quality of the city of Zagreb, and two sensor measuring devices were installed at the automatic station. In February 2021, sensor measurements were completed at assigned locations in the city of Zagreb. During March 2021, all sensors were returned to IMROH and the calibration of the sensors was checked with the reference station for measuring air quality at the Institute. In the summer of 2021, the second phase of the project was completed, and 7 sensor sets were returned to the JRC, while the other sensor sets were left to IMROH for further research for a year, after which they will be returned to the JRC. At the end of 2021, the research group started working on three publications. The first publication will be published by the JRC in the form of a technical report, while the other two will be in a form of scientific articles. Publications of articles are expected in 2022. During 2021, 12 online meetings were held (every month) at which the dynamics of the project, scientific publications and problems in project management were agreed upon. Also, 5 reports related to the project itself were written and sent to the European Commission. The reports covered each phase of the project and described in detail all the procedures of all institutions involved in the project. The project was presented at two conferences as oral presentations (245, 246).</p>		

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY COST ACTION Programme (7 projects)



INSTITUTION (Leader)	PROJECT	DURATION
University of Burgundy, Dijon, France (M. C. Malki)	Personalized nutrition in aging society: Redox control of major age-related diseases (NutRedOx, CA16112)	2017–2021
IMROH ASSOCIATE: M. Gerić (Management Committee member)		
Partners: 110 partners from 33 European countries and associated: Armenia, Georgia, Algeria, Morocco, Ukraine, Albania		
<p>The importance of a healthy ageing process becomes apparent when considering that (a) the Generation 50+ (G50+) already has a share in population of around one third across Europe, with obvious regional variations, (b) this share is likely to increase further in the future, and (c) vitality at older age is not only an important measure of quality of life but also key to participation and productivity. The theme “nutrition and ageing” has many different aspects and poses numerous challenges, which provide a fertile ground for many research themes and networks. Among them, the NutRedOx network will focus on the impact of redox active compounds in food on healthy ageing, chemoprevention and redox control in the context of major age-related diseases. The main aim of the NutRedOx network is the gathering of experts from across Europe, including other Mediterranean countries, and from different disciplines that are involved in the study of biological redox active food components and are relevant to the ageing organism, its health, function and vulnerability to disease. Together, these experts will form a major and sustainable EU-wide cluster in form of the “NutRedOx Centre of</p>		

Excellence“ able to address the topic from different perspectives, with the long-term aim to provide a scientific basis for (improved) nutritional and lifestyle habits, to train the next generation of multidisciplinary researches in this field, to raise awareness of such habits among the wider population, and also to engage with Industry to develop age-adequate foods and medicines. As result of the project collaboration, a scientific paper (52) was published in 2021. It reports results on the effectiveness of natural products in reducing cardiotoxic effects during chemotherapy.

INSTITUTION (Leader)	PROJECT	DURATION
Erasmus University Medical Center, Rotterdam, Netherlands (T. M. Luider)	“Good biomarker practice” to increase the number of clinically validated biomarkers (CliniMARK, CA16113)	2017–2021

IMROH ASSOCIATE: G. Gajski (Management Committee member)

Thousands of circulating proteins have been shown to be hallmarks of emerging disease, response to treatment, or a patients’ prognosis. The identification of these small molecule biomarkers holds a great promise for significant improvement of personalized medicine based on simple blood tests. For instance, diagnosis and prognosis with biomarkers (e.g. carcinoembryonic antigen) has significantly improved patient survival and decreased healthcare costs in colorectal cancer patients. Unfortunately, despite significant investments to increase the number of biomarker studies, only ~150 out of thousands of identified biomarkers have currently been implemented in clinical practice. This is mainly caused by the time-consuming process of reliably detecting biomarkers, the irreproducibility of studies that determine a biomarkers’ clinical value, and by a mismatch in studies that are performed by academia and what is required for regulatory and market approval. To increase the number of clinically validated biomarkers, rather than further increasing the number of biomarker discovery studies, CliniMARK will improve the quality and reproducibility of studies and establish a coherent biomarker development pipeline from discovery to market introduction.

INSTITUTION (Leader)	PROJECT	DURATION
National Institute of Occupational Health, Oslo, Norway (I. S. Mehlum)	Network on the coordination and harmonisation of European occupational cohorts (OMEGA-NET, CA16216)	2017–2022

IMROH ASSOCIATES: J. Macan and A. Bjelajac (Management Committee members), Zr. Franić

The main aim is to establish a network to optimize the usage of cohort from the working and general population in Europe. The aims of the OMEGA-NET projects are the promotion of collaboration between existing cohort researches, gathering the information on employment and occupational exposure, coordination and harmonization researches on exposure assessment in working population, and the promotion of integrative strategies for the research studies of workers’ health in Europe. The promotion of evidence-based preventive strategies directed to health at work are expected. Associates of this Unit are involved in working groups focused on prevention of occupational skin diseases and mental disorders related to work. Working Group and Management Committee Meeting was held in October 2021. Working groups of the Action have been complemented COVID-19 Task Group dealing with COVID-19 questionnaires, COVID-19 JEMS, and COVID-19 as an occupational disease. In 2021 Jelena Macan became a member of an expert group for the creation of job-exposure matrix for occupational exposure to UV radiation in south Europe.

INSTITUTION (Leader)	PROJECT	DURATION
University of Lodz, Poljska (B. Klajnert-Maculewicz)	Cancer Nanomedicine – from the bench to the bedside (Nano2Clinic, CA17140)	2018–2022

IMROH ASSOCIATE: I. Vinković Vrček (Management Committee member, WP2 leader)

The following activities were conducted:

- preparation of consensus protocols for full physicochemical characterization of new/existing chemical entities and/or nanomaterials
- preparation of roadmap and consensus protocols for controlling of selected new/existing chemical entities and/or nanomaterials
- organization of the WG2 Virtual Conference held on 22–23 July 2021

- several members of the research team used the Short Term Scientific Mission to improve their research skills and knowledge.

INSTITUTION (Leader)	PROJECT	DURATION
Vienna BioCenter Core Facilities, Vienna, Austria (A. Walter)	Correlated Multimodal Imaging in Life Sciences (COMULIS, CA 17121)	2018–2022
IMROH ASSOCIATES: D. Karaica (Management Committee Member, Member of Board for ITC grants) and I. Vrhovac Madunić (Management Committee Member, Coordinator of Board for ITC grants, Grant Awarding Coordinator)		
Due to the sudden epidemiological situation caused by COVID-19, the Management committee meeting was held on 21 Oct 2021 and many planned activities which require travelling were postponed or cancelled. During 2021, six virtual mobility and one Short-Term Scientific Mission were approved. The results of project activities in the past year are presented in a book chapter (162).		
INSTITUTION (Leader)	PROJECT	DURATION
Erasmus University Medical Center, Rotterdam, Netherlands (F. Rivadeneira)	Genomics of MusculoSkeletal traits Translational Network (GEMSTONE, CA18139)	2019–2023
IMROH ASSOCIATE: S. Cvijetić Avdagić		
The project work continued in the area of the major membrane trafficking pathways in osteoclasts, bone phenotyping approaches in humans and monogenic forms of low and high rare bone mass disorders.		
INSTITUTION (Leader)	PROJECT	DURATION
Stazione Zoologica Anton Dohrn, Napoli, Italy (M. V. Modica)	European Venom Network (EUVEN, CA 19144)	2020–2024
IMROH ASSOCIATE: G. Gajski (Management Committee member substitute) Partners: 27 European countries, Tunisia, Armenia, Belarus, Russia, and Morocco		
The overarching aim of this Action is to foster venom investigation at European level. The Action will identify priority targets and promising innovative approaches, develop best practice pipelines ensuring consistency across Europe and providing international standards in venom research. Furthermore, it provides a novel platform to promote synergistic interactions between academia, industry and society, and to nurture a new generation of venom researchers with a multidisciplinary expertise. Building a gender, age, and geographically balanced network involving all the relevant stakeholders will be the fundamental prerequisite to leverage the extraordinary biochemical warfare enclosed in animal venoms, with an enduring scientific, technological, and socioeconomic impact.		

16.2.A.2. Other european and international collaborations

EUROPEAN ACADEMY OF DERMATOLOGY AND VENEREOLOGY



INSTITUTION (Leader)	PROJECT	DURATION
Universitätsklinikum Carl Gustav Carus, Dresden, Germany (A. Bauer)	Chronic hand eczema in Europe: Patients' experiences and perspectives (CHEPEP)	2020–2021
IMROH ASSOCIATES: J. Macan, A. Bjelajac, F. Šakić, M. Herman		
<p>Projects goals are: 1) to inform physicians about the problems, needs and goals of chronic hand eczema patients by answering how patients from northern, southeastern, southwestern, and central Europe experience their chronic hand eczema, why they adhere or do not adhere to the proposed treatment, why they are satisfied or unsatisfied with the available medical services; 2) the project shall inform the HECOS (Hand Eczema Core Outcome Set) initiative about outcome domains considered important by chronic hand eczema patients to ensure that future study outcomes are meaningful and relevant for patients. A list of efficacy outcome domains, safety outcome domains, and suitable time frames relevant to patients from North, South-East, South-West, and Central Europe will be created and compared to previously measured trial outcome domains. This is a multicentric qualitative epidemiological study based on the analysis of transcripts of interviews with patients having chronic hand eczema. According to the study protocol, twelve interviews were conducted in Croatia during 2020, which have been recorded, transcribed, and translated in English. Coding of transcripts collected from institutions from the EU included in the project was finished in 2021.</p>		

EUROPEAN SLEEP RESEARCH SOCIETY

International collaboration without founding



INSTITUTION (Leader)	PROJECT	DURATION
International COVID-19 Sleep Study Collaboration Group (ICOSS-2): 31 coordinators from 19 states worldwide; leader from Croatia: A. Bjelajac (IMROH)	ICOSS 2 nd Survey: Sleep disorders related to coronavirus infection and confinement during COVID-19 Pandemic (ICOSS-2)	2021–2022
IMROH ASSOCIATES: J. Macan, S. Cvijetić Avdagić, P. Tomac, J. Mandić, B. Ross Partner: EA Delale (Institute for Anthropological Research)		
<p>The research represents the inclusion of Croatia in the international collaborative project International COVID-19 Sleep Study (ICOSS), which began in 2020 at the initiative of members of the European Sleep Research Society. The purpose of launching the ICOSS research collaboration was to harmonize the instruments and methods of gathering knowledge on various aspects of sleep and adult health during the COVID-19 pandemic, to allow a valid comparison of results collected in different countries. The first ICOSS survey included over 26,000 participants from 14 countries around the world. The goal of the ICOSS-2 study is to recruit a representative number of adults from 18 countries worldwide to determine the prevalence and incidence of sleep disorders and coronavirus-related symptoms and to analyze the effects of infection independently of other effects of the COVID-19 pandemic (67). Data were collected through online survey presented through various media from May to November 2021. Systematization and analysis of collected data is in progress. The study is being conducted by all members of the ICOSS-2 collaboration without additional financial support.</p>		

16.2.A.3. UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP) International Atomic Energy Agency (IAEA)



INSTITUTION (Leader)	PROJECT	DURATION
Environmental Radioactivity Monitoring Department Greek Atomic Energy Commission, Atena, Grčka (K. Karfopoulos)	Enhancing Regulatory and Metrological Infrastructures Needed to Ensure Radiation Safety in Naturally Occurring Radioactive Materials Industry (RER/9/155)	2019–2022
IMROH ASSOCIATE: I. Prlić		
The aim of the project is to improve the regulatory and metrological infrastructure and to include the industry that works with NORM types of materials in order to protect workers and the general population from radiation.		
INSTITUTION (Leader)	PROJECT	DURATION
Department of Nuclear Sciences and Applications, IAEA Laboratories Seibersdorf, Austria (R. Padilla Alvarez)	Determining Long Term Time Trends of Air Pollution Source Tracers by Nuclear Techniques (RER/7/012)	2020–2022
IMROH ASSOCIATES: I. Bešlić, S. Davila, R. Godec		
The three-year project “Enhancing the Inventory of Aerosol Source Profiles Characterized by Nuclear Analytic Techniques in Support of Air Quality Management” (RER/7/011) organized by the IAEA was officially completed in 2019. In accordance with the plan of the mentioned project, a MABI aethalometer for the determination of black carbon from air samples and a multi-element reference material for 28 elements were delivered to IMROH during 2020. Samples of PM _{2.5} fraction of suspended particles sampled at the IMROH air quality monitoring station within the RER/7/011 project are analysed with the MABI. Multi-element reference material is used to check the performance characteristics of the ED-XRF. An elemental analysis of samples on ED-XRF collected under RER/7/011 was provided at IMROH during 2020. Samples from Bosnia and Herzegovina, Montenegro, Serbia, Slovenia, Lithuania, and Bulgaria were analysed. During 2021, additional samples from Slovenia, Serbia, BIH, Bulgaria, and Portugal were analyzed. Sampling for the new IAEA project RER/7/012: “Determining Long Term Time Trends of Air Pollution Source Tracers by Nuclear Techniques” began on 1 April at the IMROH air quality monitoring station. Daily samples of PM _{2.5} fraction of suspended particles are collected on Teflon filters every third day. Distribution of filters and Petri dishes was taken over by IMROH, as was the case in previous projects. Also, an elemental analysis of samples at IMROH has been agreed. During 2021, the campaign of collecting samples continued with the third day dynamics.		

16.2.A.4. NATIONAL GOVERNMENT PROJECTS

US Department of Defense, US Defense Threat Reduction Agency (DTRA)



INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (Z. Kovarik)	CNS-active, Orally Bioavailable, Zwitterionic Oximes for Organophosphate	2019–2022
IMROH ASSOCIATES: D. Kolić, N. Maček Hrvat, S. Žunec EXTERNAL ASSOCIATES: P. Taylor (PI), Z. Radić (University of California at San Diego, La Jolla, SAD), K. Barry Sharpless (The Scripps Institute of Science) et al.		
Our research included a detailed pharmacokinetic and pharmacodynamic characterization of aldoxime RS194B which due to its zwitter properties crosses the blood-brain barrier and thus may be a CNS-active reactivator of acetylcholinesterase inhibited by nerve agents (113). In cooperation with the Croatian Institute for Brain Research, the study was directed towards its neuroprotective activity, i. e. the prevention of the development of neuroinflammation caused by exposure of mice to sarin. In collaboration with colleagues from the Faculty of Food Technology and Biotechnology, University of Zagreb the solubility of RS194B was tested in various natural solvents (NADES). Furthermore, it was found that solvents affect AChE kinetics (309).		

Ministry of Science and Education, Republic of Croatia
Scientific and Research Bilateral Cooperation in Science and Technology
(9 projects)



MINISTARSTVO ZNANOSTI
I OBRAZOVANJA
REPUBLIKE HRVATSKE

INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (S. Herceg Romanić) Institute of Physics, University of Belgrade, Serbia (G. Jovanović)	Persistent organochlorine compounds in human milk and their potential effect on the level of primary DNA damage in human cells (Bilateral CRO-RS)	2019–2022
IMROH ASSOCIATES: D. Želježić, D. Klinčić, G. Mendaš Starčević		
Investigations of simulation gastrointestinal resorption of persistent organic compounds from breast milk was continued. We plan to investigate the total content of macro and micro elements and bioavailable fractions of elements in milk to assess the benefits and risks for infant health. At the Faculty of Chemistry, University of Belgrade, Serbia, Dragana Samardžić defended her master thesis "Pesticides and polychlorinated biphenyls in breast milk". In this paper, the distribution of persistent organic compounds in breast milk was evaluated. Shapley Additive Explanations (SHAP) artificial intelligence method was used to investigate relationship between PCB-138 and other PCB congeners, maternal age, and number of births (158).		
INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (G. Gajski) Vinča Institute of Nuclear Science, University of Belgrade, Serbia (M. Čolović)	Acetylcholinesterase Inhibitors as Potential Anti- Alzheimer Drugs: Prooxidative and Cytogenotoxic Properties (SafeAChE, Bilateral CRO-RS)	2019–2022
IMROH ASSOCIATES: M. Gerić, M. Milić		
SafeAChE will evaluate pro-oxidative and toxic effect of newly synthesized polyoxometalate compounds exhibiting an inhibitory effect on AChE; a targeted enzyme of drugs used as symptomatic therapy in patients with Alzheimer's disease. As a result of the project activities during 2021, a scientific paper was published that presents the results of research on selected polyoxopalladates that show promising properties for the development of anticancer drugs (39). The toxicity of polyoxopalladates as potential antitumor drugs has been investigated <i>in vitro</i> (201). Studies of the cyto/genotoxic effects of palladium-based drugs have also been performed (202).		
INSTITUTION (Leader)	PROJECT	DURATION
Ruđer Bošković Institute, Zagreb (S. Orlić) Chinese Academy of Sciences (A. Hu)	Distribution of antibiotic resistance genes in waste water treatment plants and receiving environments of China and Croatia (Bilateral CRO-CN)	2019–2022
IMROH ASSOCIATE: G. Gajski		
The project goal is to evaluate the types and concentrations of typical new organic pollutants in the coastal cities and the receiving environment and their temporal and spatial distribution characteristics, migration patterns and country differences. The abundance and community composition of typical antibiotic resistance genes in sewage plants and receiving environments in the two countries and their temporal and spatial distribution characteristics, migration patterns and country differences. Besides, the project will clarify the coupling relationship between new organic pollutants and antibiotic resistance genes and assess ecological risk.		

INSTITUTION (Leader)		DURATION
IMROH, Zagreb (I. Prlić) SCK CEN, Academy for Nuclear Science and Technology, Mol, Belgium (T. Clarijs)	Development of a training curriculum for radiation protection experts in Croatia (HRPE, Bilateral CRO-BE)	2020–2021
IMROH ASSOCIATES: I Prlić (coordinator for CRO), L. Pavelić, M. Surić Mihić (until 28 Feb 2021)		
<p>Lecturers from the SCK CEN Academy and participants from the Republic of Croatia who deal with or intend to deal with radiological protection participated in the educational activities designed by the project. The curriculum was developed by SCK CEN, while the Croatian curriculum proposals were led by M. Surić Mihić before leaving IMROH. The aim of the project is to strengthen the competencies of current and future experts in ionizing radiation protection in Croatia, through the development of a national curriculum for initial training of ionizing radiation experts, as well as identifying potential lecturers for training future experts, with the aim of improving pedagogical and didactic skills. The paper uses a teaching approach according to the recommendations of the International Atomic Energy Agency (IAEA) and the European Commission. The activities envisaged by the project have been partially modified due to pandemic working conditions, which prevented the planned travel of participants from Croatia to Belgium for theoretical and practical training in radiological protection and Belgian lecturers for train-the-trainer training in Zagreb. Trainings were conducted exclusively online, in the form of lectures with active participation. Summary of activities in 2021:</p> <ul style="list-style-type: none"> - the need for education in the field of radiological protection in Croatia was analysed, which would be harmonized with national and European legal requirements and recommendations - a national curriculum for the initial training of ionizing radiation protection experts has been compiled (working version of the module, learning outcomes and target skills) - training “Basic training in radiation protection” was conducted for 16 participants from Croatia (16–20 Nov 2020) and verification was performed in March 2021, when the project officially ended. 		
INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (Z. Kovarik) Research Center for Eco-environmental Sciences, Chinese Academy of Sciences, Beijing, China (Q. Xie)	Effects of selected pesticides on neuronal acetylcholinesterase expression (Bilateral CRO-CN)	2020–2022
IMROH ASSOCIATES: T. Čadež, M. Katalinić, A. Zandona		
<p>Our collaboration focused on several pesticides (metamidophos and fenamiphos) and their toxicity, i.e. on the question of whether it depends on the interaction with acetylcholinesterase or on its expression. A publication is being prepared, and part of the results is presented in a conference poster (301). The planned visits were cancelled, and the project was extended for one year.</p>		
INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (I. Vinković Vrček) Faculty of Electrical Engineering and Computer Science, University of Maribor, Slovenia (S. Gorgieva)	Modified bacterial cellulose as artificial biomimetic membrane for biological blood-brain barrier (Bilateral HR-SI)	2020–2022
IMROH ASSOCIATES: R. Barbir, K. Ilić, B. Pem, I. Pavičić, N. Peranić, N. Kalčec		
<p>This bilateral project also present initiation of common research activities between both groups in the area of bio- and nano-medical research that relies on the continuation of “proof of concepts” already established within both groups.</p>		

INSTITUTION (Leader)	PROJECT	DURATION
IMROH, Zagreb (M. Katalinić) Institute for Pathophysiology, University of Ljubljana, Ljubljana, Slovenia (S. Pirkmajer)	Effect of oxime analogues on skeletal muscle cell viability (Bilateral CRO-SI)	2020–2022
IMROH ASSOCIATES: A. Bosak, A. Matošević, N. Maraković, I. Vrhovac Madunić, A. Zandona		
<p>The effects of two groups of oximes, acetylcholinesterase reactivators, were studied on muscle cells. Selected oximes have in their structure lipophilic functional groups to improve their blood-brain barrier permeability. Therefore, there is a presumption that such compounds, due to their lipophilicity, could interact with non-specific targets in the body, causing serious side-effects. The obtained results indicate that these compounds have cytotoxic effect on muscle cells in a concentration- and time-dependent manner (121). This study did not reveal a difference in a sensitivity between myoblasts and differentiated muscle tubes to the action of oximes, indicating the specificity of these oximes on targets present in muscle cells at all stages of development. Several compounds have been selected for further research. Last year we published obtained results in a scientific article (121) and they were presented as a poster presentation at the Congress of the Federation of European Biochemical Societies, FEBS2021 in July 2021 (313) and the Congress CROTOX 2021 (234). PhD student Ana-Marija Lulić (whose doctoral dissertation will be related to the topic of the project) joined the project. A.-M. Lulić also went through several months of training with project associates in Ljubljana, Slovenia from August to November 2021.</p>		
INSTITUTION (Leader)	PROJECT	DURATION
Faculty of Pharmacy and Biochemistry, Zagreb (A.-M. Domijan) National Institute of Biology, Ljubljana, Slovenia (M. Filipič)	Toxicological profile and interactions of bisphenol A and its analogues (BPAnalogInteract, Bilateral CRO-SI)	2020–2022
IMROH ASSOCIATES: G. Gajski, M. Gerić, K. Matković		
<p>The aim of the project is to examine the toxicity and toxicity mechanisms of BPA and its analogues, BPS, BPF and BPAF individually, but also in combination on a human cell model. Primary human peripheral blood lymphocytes and human liver cancer cells (HepG2) will be used in <i>in vitro</i> studies. Cytogenetic, molecular biological and biochemical methods will be applied in the research, in order to monitor cell damage, cell genome damage, changes in gene expression, effect on the cell cycle, and oxidative stress parameters.</p>		
INSTITUTION (Leader)		DURATION
IMROH, Zagreb (I. Vinković Vrček) Chinese Academy of Sciences, Beijing, China (S. Liu)	Endocrine disrupting mechanism of typical environmental pollutants (EmergeTox, Bilateral CRO-CN)	2020–2022
IMROH ASSOCIATES: I. Pavičić, R. Barbir, K. Ilić Partner: KBC Osijek (Ž. Debeljak)		
<p>During the first year of the project, a total of 4 working meetings were held (every 3 months) with a collaborative research group led by Prof Xiyin Liu of the Chinese Academy of Sciences (CAS), Beijing, China. At the first working meeting held in March 2021, a working plan was established for each research group during the first year of the project. Progress and further profiling of work activities were discussed at the meetings held on June, September, and December 2021. All meetings were held online due to epidemiological conditions and measures in force in the Republic of Croatia and the People's Republic of China. During the first year of the project, according to a random plan, all experiments of testing nanoplastic mixtures with silver nanoparticles <i>in vitro</i> on Jurkat and THP cell line cell models were completed. During this time, additional cooperation was established with the group of Felix Rico from France and with the group of Ivica Aviania from Split in order to apply the method of atomic force microscopy in research. Due to unfavorable epidemiological conditions and measures in China, the Chinese research group was not able to participate in this part of the study. The research resulted in the preparation of two scientific publications that are currently being peer-reviewed in the <i>Journal of the Trace Element in Medicine and Biology</i> and in the <i>Journal of Inorganic Biochemistry</i>.</p>		

16.2.A.5. UNIVERSITY PROJECTS (2 projects)

INSTITUTION (Leader)	PROJECT	DURATION
Department of Genetics, Kemerovo State University, Kemerovo, Russia (V. Druzhinin)	Relationship of the respiratory microflora composition with the human genome activity and integrity in the residents of coal industrial region	2018–2023
IMROH ASSOCIATE: A. Fučić		
A significant difference in the beta diversity of the microbiome between patients with lung cancer and the control group and the association between the composition of the sputum microbiome and the genome damage of patients with lung cancer were found (21).		
INSTITUTION (Leader)	PROJECT	DURATION
UConn Health, University of Connecticut, Farmington, USA (I. Kalajzic)	Generating new RGS5 mouse model for lineage tracing	2019–2021
IMROH ASSOCIATE: I. Vrhovac Madunić		
The project started in 2019 during the postdoctoral training of I. Vrhovac Madunić in the Laboratory of Prof. I. Kalajzic in Connecticut, USA. Generating a new transgenic mouse (RGS5-CreERT2) suitable for lineage tracing in bone remodeling and regeneration is important for determining cell origin and fate. The aim of the project is to assess whether the RGS5 mouse model is suitable for defining mesenchymal progenitor cells, i.e. to identify perivascular cells within the periosteum <i>in vitro</i> and <i>in vivo</i> . Some of the results of this project were presented at the virtual annual conference The American Society for Bone and Mineral Research (355).		

16.2.B. PROFESSIONAL PROJECTS

PROJECT	CONTRACTOR	LEADER
Service provider: Radiation Dosimetry and Radiobiology Unit		
EAN NORM; European ALARA Network for Naturally Occurring Radioactive Materials Contract no. TREN/H4/51/2005 of the European Commission (EC) (since 2005)	Radioökologie GmbH, Dresden, Germany Project Coordinator IAF	I. Prlić (for CRO)

17. PROFESSIONAL UNITS



17.1. LABORATORY ANIMAL BREEDING UNIT

EMPLOYEES OF THE UNIT

HEAD

Vedran Micek, DVM, professional associate

TECHNICAL ASSOCIATE

Kata Šmaguc, technician

PROFESSIONAL WORK

The Unit breeds laboratory rats, strain HsdBr/Han: Wistar, in accordance with the Animal Welfare Act (OG 102/2017) and other applicable laws, guidelines, and policies. Animals are bred under strictly controlled conditions, under the surveillance of authorised personnel (DVM), and then used as a model in scientific and experimental research. The Unit has facilities that are consistent with legislation and guidelines concerning the breeding and housing of laboratory animals. Since 2016, the Unit has been authorized for performing *in vivo* experiments for a ten-year period. The living conditions of animals are appropriate and contribute to their health and welfare. The housing, feeding, animal care, and experimental procedures are managed by a veterinarian in accordance with contemporary veterinary practices. The animals are kept in steady-state micro environmental conditions and fed with standard GLP-certified laboratory food and water *ad libitum* with altering 12 h light and dark cycles. Sanitation of facilities is performed on a weekly basis in order to reduce the possibility of any external contamination. Breeding colony health monitoring is provided by the Croatian veterinary Institute, Zagreb.



17.2. POISON CONTROL CENTRE (PCC)

EMPLOYEES OF THE CENTRE

HEAD

Željka Babić, PhD, research associate since 1 Jan 2021

ASSOCIATES

Rajka Turk, MSc, professional advisor in science since 1 Jan 2021

Researchers of the Occupational and Environmental Health Unit (Chapter 15.5.).

Researchers of the Analytical Toxicology and Mineral Metabolism Unit (R. Barbir, B. Pem)

PROFESSIONAL WORK

During 2021, the telephone information service of the Croatian Poison Control Center (CPCC) was consulted in 2785 cases of poisoning and suspected poisoning, by health professionals, and the general public. Following requests from the industry, 74 toxicological evaluations and two active substances assessments were prepared for the registration of pesticides according to the Plant Protection Products Act and Regulation (EU) No. 1107/2009 on placing of plant protection products on the market. Following enquiries from the industry, 53 evaluations for the purpose of biocidal products registration and 4 for the authorization according to the Biocidal products Act and Regulation (EU) No. 528/2012 concerning the placement on the market and use of biocidal products were prepared. Opinion on an Annex XV dossier proposing restrictions on substances in single-use baby diapers (381) was prepared for the European Chemicals Agency (ECHA) by the Committee for Risk Assessment's (co)rapporteurs.

Collaboration with the Agency for Medicinal Products and Medical Devices of Croatia in monitoring of drug poisonings (pharmacovigilance) was continued. Further work on the revision of the National Action Plan for sustainable use of pesticides and on the draft proposal for an ordinance on the conditions of distribution and sale of pesticides was continued with the Ministry of Agriculture. Collaboration with the Ministry of Work and Pension System on the amendments of the Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work also continued.

The CPCC participated in the activities of drafting the "National Strategy for Rationalization of the Use of Herbicides Glyphosate in Croatia and the preparation of the Health Impact Assessment of Glyphosate, Aminomethylphosphonic Acid (AMPA) and Gluphosinate", led by the Teaching Institute for Public Health Dr Andrija Štampar.

Annual reports were published in the journal *Archives of Industrial Hygiene and Toxicology* in English and Croatian (166). A professional paper on occupational poisonings recorded at the CPCC in 2019 was published (141). In addition, the results of the analysis of the characteristics of occupational poisoning for which the advice of the CPCC was sought in the period 2015–2019 were presented at CROTOX 2021 (233). Experiences with antiseptic and disinfectant poisoning were presented at the Autumn meeting of the Croatian Society of Occupational Medicine of the Croatian Medical Association and at the toxicological congress CROTOX 2021 (219). The results on more frequent keeping of CPCC numbers at hand by parents who participated in the educational intervention of the completed internal CPCC project "Preventing child poisonings by educational intervention aimed at parents of preschool children" were published (3). The results of a study conducted in collaboration with the staff of the Children's Hospital Zagreb on the characteristics of accidental poisoning of children with analgesics and nonsteroidal anti-inflammatory drugs in the period 2009–2019 were published (2) and presented at the toxicological congress CROTOX 2021 (198). In addition, the results of the analysis of plant poisoning for which CPCC advice was sought in the period 2010–2019 were presented at the same congress (206). Professional article "Profile of incidental exposures to e-cigarette liquids in Europe, 2018–2019" published at the end of 2020 in electronic form, was published in 2021 in printed form (118). The CPCC was involved in a study to monitor the number and characteristics of disinfectant and antiseptic poisoning at European level launched by the COVID working group at the European Association of Poison Control Centers and Clinical Toxicologists. The CPCC staff participated in the undergraduate teaching of toxicology courses at the Department of Biotechnology, University of Rijeka and the Faculty of metallurgy, University of Zagreb, and in the teaching included in postgraduate specialist training in clinical toxicology for medical doctors.

18. RESEARCH AREA ŠUMBAR

HEAD

Josip Tončić, DVM, MSc, professional associate in science

PROFESSIONAL WORK

The Research Area Šumbar is home to activities related to the control, preservation, and improvement of the ecosystem. The most important activities comprise research into the quality of water, air, and soil, as well as background ionising radiation and, if needed, biological samples in correlation with natural and anthropogenic pollution, all with the fundamental goal of preserving human and animal health and a healthy habitat.

During 2021, Šumbar's joint efforts with the Unit for Environmental Hygiene and the Unit for Radiation Dosimetry and Radiobiology continued. Regardless of the COVID-19 pandemic, the programme of monitoring air quality and monthly sampling and measurements of total sediment matter, metal content, and polycyclic aromatic hydrocarbons. The monitoring of background ionising radiation continued by means of the referent station installed at the Area, which measures environmental data. From the end of 2020, the Šumbar was used for measurements of telecommunication electromagnetic fields in the rural environment, which is a comparative metrological data for measurements carried out by the Institute in urban areas in the Republic of Croatia as part of the "Phase II e-School" project. Furthermore, Šumbar is a hunting ground where all legally prescribed measures related to the management of wildlife habitats are strictly adhered to. This includes growing and maintaining the appropriate number of wild animal types. Regular activities cover the construction and maintenance of feeding locations and salt licks, as well as regular reporting of key data to the Ministry of Economy and Sustainable Development of the Republic of Croatia.

19. COMPANY OF THE INSTITUTE

**Occupational Health Polyclinic of the Institute for Medical Research and Occupational Health Ltd.,
Ksaverska cesta 2, Zagreb**

DIRECTOR

Prim Jelena Macan, MD, PhD, permanent scientific advisor (90% of working hours at the IMROH, 10% at the Polyclinic)

ASSOCIATE

Franka Šakić, MSc, senior technician (90% of working hours at the IMROH, 10% at the Polyclinic)

BUSINESS RESULTS

The professional activity of the Occupational Health Polyclinic of the Institute for Medical Research and Occupational Health Ltd continued operating in 2021 providing services in the domain of occupational and sports medicine. The outpatient clinic provided a total of 201 medical services for 62 customers. An occupational medicine specialist delivered 4 judicial-medical expertises for the Municipal Courts in Vinkovci, Rijeka, Karlovac, and Municipal Civil Court in Zagreb. The Psychotherapy Office led by A. Bjelajac, PhD, psychologist and psychotherapist, continued working within the company. The company operated positively in 2021.

20. PUBLISHING

The Institute is the publisher of the scientific journal *Arhiv za higijenu rada i toksikologiju – Archives of Industrial Hygiene and Toxicology*; print: ISSN 0004-1254, online: ISSN 1848-6312.

EDITOR IN CHIEF Nevenka Kopjar ASSISTANT EDITORS Irena Brčić Karačonji, Jelena Macan REGIONAL EDITOR FOR SLOVENIA Marija Sollner Dolenc MANUSCRIPT EDITOR & EDITORIAL ASSISTANT Dado Čakalo COPY EDITORS Dado Čakalo, Makso Herman	TECHNICAL EDITING & LAYOUT Nevenka Kopjar, Makso Herman STATISTICS EDITOR Jelena Kovačić CROATIAN LANGUAGE REVISION Ivanka Šenda SUBSCRIPTIONS Vesna Lazanin PRINT Denona, Zagreb	THE OFFICIAL JOURNAL OF Croatian Medical Association – Croatian Society on Occupational Health Croatian Society of Toxicology Slovenian Society of Toxicology Croatian Radiation Protection Association Croatian Air Pollution Prevention Association Financially supported by the Ministry of Science and Education
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General information about the journal

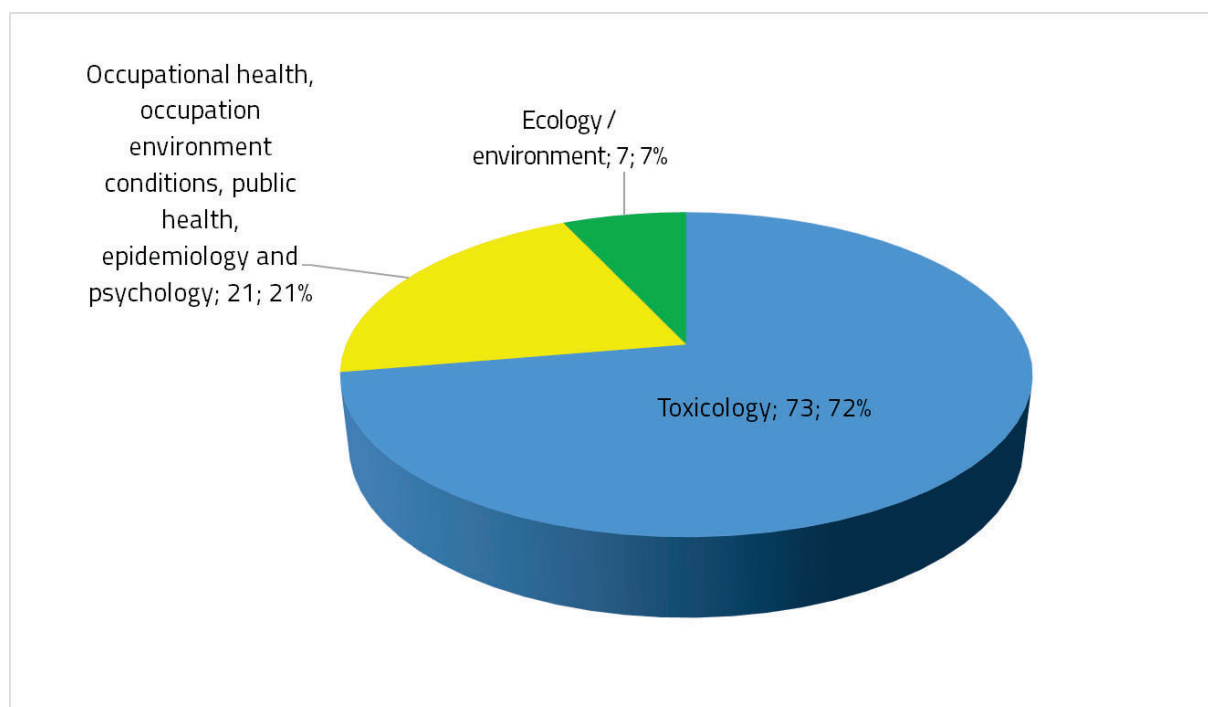
Articles from the fields of occupational health, toxicology, ecology, chemistry, biochemistry, biology, pharmacology, and psychology are edited in line with modern standards. The journal's publication is financially supported by the Ministry of Science and Education of the Republic of Croatia and, to a smaller extent, subscriptions. The *Archives* is issued four times a year.

Year	Impact factor (IF)	5-years IF
2020	1.948	2.172
2019	1.727	1.777
2018	1.436	1.606
2017	1.117	1.335
2016	1.395	1.320
2015	0.971	1.019
2014	0.932	1.120
2013	0.727	0.980
2012	0.674	-
2011	1.048	-
2010	0.826	-

The *Archives* is indexed in *SCI-Expanded*, *Medline/PubMed*, *Scopus*, and many other databases. The Impact Factor (IF) for 2021 was 1.948, which is the highest IF value since the journal was listed in *InCites Journal Citation Reports* (Clarivate Analytics). The 5-year IF was 2.172, which is the highest value ever achieved in the journal's history. The *Archives* is currently ranked within the third Quartile (Q3) in the *Public, Environmental & Occupational Health* and the fourth Quartile (Q4) in the *Toxicology* area, based on the previous year's achievements. The citation data of the *Archives* in 2021 was very good. As of 3 Jan 2022, the *Web of Science* database recorded 6,301 citations for articles published since 2008, when the journal was included in the database.

The h-index of the *Archives* for the period 2008–2021 according to the *Web of Science* database is 32.

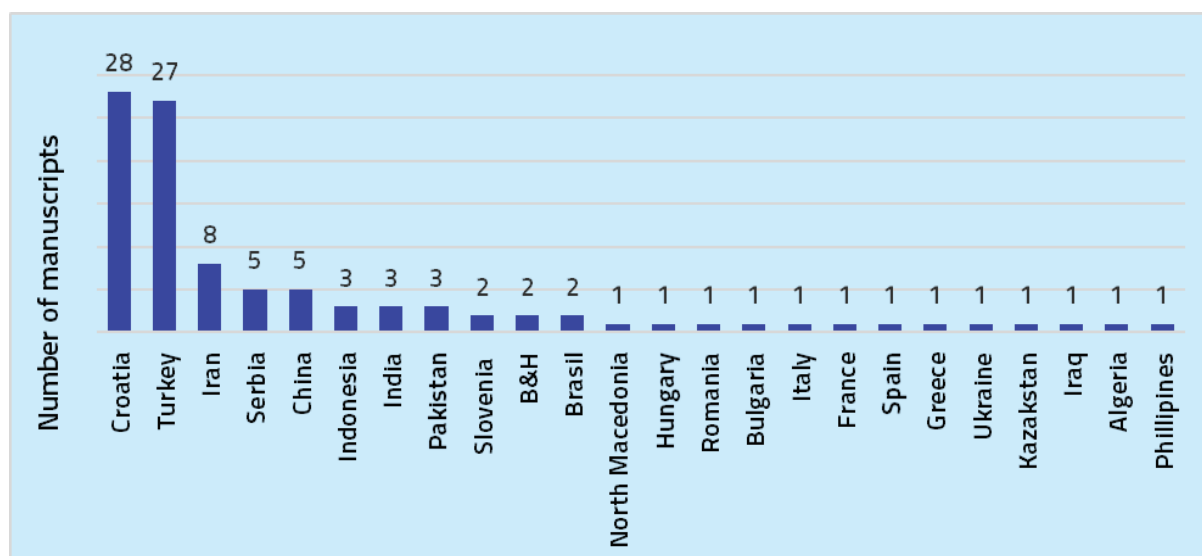
During 2021, the Editorial Office of the *Archives* received 101 submissions, most of which were submitted through the journal's online system available at <https://arhiv.imi.hr> and the remainder by e-mail (arhiv@imi.hr). Most of the submissions covered topics from toxicology (72%), while other papers' topics had to do with occupational health, occupation environment conditions, public health, epidemiology and psychology (21%), and ecology/environment (7%). Most of the manuscripts received referred to original scientific papers (89%), followed by review papers (7%).



Distribution of articles submitted in 2021 according to research areas

The manuscripts were submitted by authors from 24 countries worldwide. The largest number of manuscripts was submitted from Croatia (28 %) and Turkey (27 %), followed by authors from Iran (8%), China (5%), and Serbia (5%). Other countries were represented by less than 5% of the total articles submitted in 2021. The rejection rate was 63%, i. e. 64 out of 101 manuscripts received were rejected. A slightly larger proportion (52%) was rejected due to negative reviews, and the rest by the Editor-in-Chief or an Editorial Board decision because of poor quality or failure to meet the minimum criteria for review.

Each submission is screened for plagiarism by the iThenticate Plagiarism Detection Software. The contained Crossref Similarity Check is used to check the authenticity of a submission against a vast database of scientific literature published worldwide. Access to the aforementioned software system is enabled through the journal's cooperation with its online publisher Sciendo.



Distribution of articles submitted in 2021 according to origin country

In 2021, four regular issues of Volume 72 were published, containing articles published in following categories: Original article (32), Review/Mini-Review (6), Case report (1), and Technical Paper (1). In addition, one short article in the category *In memoriam*, four of them in the category New editions, and three Meeting reports were also published.

According to the attendance on the Portal of Scientific Journals of the Republic of Croatia (HRČAK) during 2021, the *Archives* holds a high position in relation to other journals in the fields of biomedicine and health and the natural sciences. According to analysis on the HRČAK website, the *Archives* had more than 3,2 million of visits in 2021.



Cover pages of all Archives' issues published in 2021 (Volume 72)



In October 2021, a *Supplement* issue was published comprising abstracts from the 6th Croatian Congress of Toxicology with International Participation (CROTOX 2021), held in Rabac (3–6 Oct 2021). The issue was copyedited and prepared for print by M. Herman, while technical editing was done by I. Brčić Karačonji.

Throughout 2021, the journal continued to operate in accordance with high standards of editorial work comparable to foreign journals. The *Archives* is a regular member of the Committee on Publication Ethics (COPE) and the Editors are members of the Mediterranean Editors and Translators and European Association of Science Editors (EASE).

The regular publication of the journal and its successful operation during 2021 was achieved by the enthusiasm of the Editorial Office, and due to their large number of working hours spent in daily activities such as language and technical editing, print layout preparation, maintenance of the online submission system and manuscript management, digitalization of old volumes, and other administrative affairs within the journal.

The journal is available free of charge to the foreign and domestic scientific public through the link <https://hrcak.srce.hr/aiht> (all regular issues published from 1946 to the present and the most important supplements are available). Full text articles are also available through Sciendo's service (<https://content.sciendo.com/view/journals/aiht/aiht-overview.xml>). Since 2021, full text articles have been available on *PubMed Central* as well (<https://www.ncbi.nlm.nih.gov/pmc/journals/3972/>).

A. OVLAŠTENJA INSTITUTA

- Ministarstvo zdravstva RH – ovlaštenje za provođenje Programa specijalističkog usavršavanja doktora medicine u području medicine rada i sporta, u dijelu programa Profesionalne bolesti, bolesti u svezi s radom i profesionalna toksikologija.
Ovlaštenje od prosinca 2018. vrijedi do izdavanja novog rješenja.
- Ministarstvo gospodarstva i održivog razvoja RH – dozvola za obavljanje djelatnosti praćenja kvalitete zraka.
Ovlaštenje vrijedi do 10. prosinca 2025.
- Ministarstvo gospodarstva i održivog razvoja RH – dozvola za obavljanje djelatnosti osiguranja kvalitete mjerenja i podataka kvalitete zraka (referentni laboratorij) za metode:
 - HRN EN 12341:2014 (EN 12341:2014): Određivanje masene koncentracije PM₁₀ i PM_{2,5} frakcije lebdećih čestica
 - HRN EN 14902:2007 (EN 14902:2005), HRN EN 14902/AC:2007 (EN 14902:2005/AC:2006): Određivanje koncentracije Pb, Cd, As i Ni u PM₁₀ frakciji lebdećih čestica
 - HRN EN 16909:2017 (EN 16909:2017): Određivanje masenih koncentracija elementnog i organskog ugljika u lebdećim česticama u vanjskom zraku
 - HRN EN 15549:2008 (EN 15549:2008): Određivanje koncentracija benzo(a)pirena u vanjskom zraku
 - HRI CEN/TR 16269:2017 (CEN/TR 16269:2011): Određivanje masenih koncentracija aniona i kationa u lebdećim česticama
 - HRS CEN/TS 16645:2016 (CEN/TS 16645:2014): Određivanje koncentracija benzo(a)antracena, benzo(b)fluorantena, benzo(j)fluorantena, benzo(k)fluorantena, dibenzo(a,h)antracena, indeno(1,2,3-cd)pirena i benzo(ghi)perilena u vanjskom zraku
 - HRN EN 16913:2017 (EN 16913:2017): Određivanje masenih koncentracija aniona i kationa u lebdećim česticama PM_{2,5} sakupljenim taloženjem na filtrima.
 Ovlaštenje vrijedi do 10. prosinca 2025.
- Ministarstvo unutarnjih poslova, Ravnateljstvo civilne zaštite – ovlaštenje za obavljanje poslova radiološke sigurnosti:
 - mjerenje operativnih dozimetrijskih veličina potrebnih za procjenu osobnog vanjskog ozračenja osoba
 - redovito godišnje ispitivanje zatvorenih radioaktivnih izvora i/ili električnih uređaja koji proizvode ionizirajuće zračenje u medicinskim djelatnostima i ispitivanje zatvorenih radioaktivnih izvora i/ili električnih uređaja koji proizvode ionizirajuće zračenje u nemedicinskim djelatnostima te davanje mišljenja na osnovi mjerenja i proračuna
 - radiološki nadzor mjesta rada i ispitivanje uvjeta rada te izrada dokumenata iz kojih je vidljivo udovoljava li radni okoliš, prostorije i uvjeti rada propisanim uvjetima radiološke sigurnosti
 - ispitivanje i praćenje vrste i aktivnosti radioaktivnih tvari u zraku, tlu, moru, rijekama, jezerima, podzemnim vodama, oborinama, vodi za piće, hrani i potrošačkim proizvodima i
 - ispitivanje koncentracije radona i radonovih potomaka u zraku.
 Ovlaštenje vrijedi do 10. prosinca 2025.
- Ministarstvo poljoprivrede RH – ovlaštenje za obavljanje analiza: hrana, hrana za životinje, prirodna mineralna, prirodna izvorska i stolna voda.
Ovlaštenje od travnja 2016. vrijedi do izdavanja novog rješenja.

B. SURADNE USTANOVE

Sporazumi o suradnji

RED. BR.	NAZIV USTANOVE	GODINA POTPISIVANJA
1.	Institut za istraživanje i razvoj održivih eko sustava	2005.
2.	Medicinski fakultet Sveučilišta J. J. Strossmayera u Osijeku	2013.
3.	Sveučilište u Rijeci	2013.
4.	Sveučilište u Zagrebu	2013.
5.	Grad Zagreb	2014.
6.	Institut „Jožef Stefan“	2014.
7.	Nastavni zavod za javno zdravstvo „Dr. Andrija Štampar“	2014.
8.	Sveučilište u Mostaru	2014.
9.	Sveučilište u Zadru	2014.
10.	Veterinarski fakultet Univerziteta u Sarajevu	2014.
11.	Hemijski fakultet Univerziteta u Beogradu	2015.
12.	Hrvatski zavod za javno zdravstvo	2015.
13.	Institut za fiziku	2015.
14.	Ministarstvo unutarnjih poslova RH	2015.
15.	Agencija za lijekove i medicinske proizvode RH	2016.
16.	Ericsson Nikola Tesla d. d.	2016.
17.	Klinički bolnički centar Zagreb	2016.
18.	Rudarsko-geološko-naftni fakultet Sveučilišta u Zagrebu	2016.
19.	Sveučilište Sjever	2016.
20.	Grad Kaštela	2017.
21.	Nuklearna elektrana Krško	2017.
22.	Institut za hemiju, tehnologiju i metalurgiju, Beograd, Srbija	2018.
23.	Metalurški fakultet Sveučilišta u Zagrebu, Sisak	2018.
24.	Prirodno-matematički fakultet Univerziteta u Novom Sadu, Srbija	2018.
25.	Prirodno-matematički fakultet Univerziteta u Sarajevu, BiH	2018.
26.	Sveučilište Jurja Dobrile u Puli	2018.
27.	Javna ustanova „Park prirode Medvednica“	2018.
28.	Institut za higijenu i tehnologiju mesa, Beograd, Srbija	2018.
29.	AVANCO d. o. o.	2019.
30.	Prehrambeno-tehnološki fakultet Sveučilišta J. J. Strossmayera u Osijeku	2019.
31.	Medicinski fakultet Sveučilišta u Zagrebu	2019.
32.	Javna ustanova „Park prirode Kopački rit“	2019.
33.	Agronomski fakultet Sveučilišta u Zagrebu	2020.
34.	Fakultet medicinskih znanosti, Univerzitet „Goce Delčev“, Štip, Sjeverna Makedonija	2020.
35.	Hrvatski geološki institut, Zagreb	2020.
36.	Prirodoslovno-matematički fakultet Sveučilišta u Zagrebu	2020.
37.	Veterinarski fakultet Sveučilišta u Zagrebu	2020.
38.	Visoka škola Ivanić-Grad	2020.
39.	Instituto za jadranske kulture i melioraciju krša, Split	2021.
40.	Međimursko veleučilište u Čakovcu	2021.
41.	Hrvatska agencija za poljoprivredu i hranu, Osijek	2021.
42.	Hrvatski zavod za javno zdravstvo, Zagreb	2021.
43.	Institut „Ruđer Bošković“	2021.

Ostale znanstvenoistraživačke i stručne suradnje

USTANOVE U REPUBLICI HRVATSKOJ

1. Agencija za lijekove i medicinske proizvode (HALMED)
2. Agronomski fakultet Sveučilišta u Zagrebu
3. Aquatika – slatkovodni akvarij Karlovac
4. CARNet, Zagreb
5. Državni hidrometeorološki zavod, Zagreb
6. Ekenerg d. o. o., Zagreb
7. Fakultet elektrotehnike i računarstva Sveučilišta u Zagrebu
8. Fakultet kemijskog inženjerstva i tehnologije Sveučilišta u Zagrebu
9. Fakultet zdravstvenih studija Sveučilišta u Rijeci
10. Farmaceutsko-biokemijski fakultet Sveučilišta u Zagrebu
11. Fond za zaštitu okoliša i energetske učinkovitost, Zagreb
12. Gekom d. o. o., Zagreb
13. Hrvatska agencija za poljoprivredu i hranu, Osijek
14. Hrvatski institut za istraživanje mozga, Zagreb
15. Hrvatski sindikat male privrede, obrtništva, uslužnih djelatnosti i stranih predstavništava, Zagreb
16. Hrvatski veterinarski institut, Zagreb
17. Hrvatski zavod za javno zdravstvo, Zagreb
18. Institut „Ruđer Bošković“, Zagreb
19. Jamnica plus d. o. o.
20. Kaznionica u Lepoglavi
21. Klinička bolnica Merkur, Zagreb
22. Klinički bolnički centar Osijek
23. Klinički bolnički centar „Sestre milosrdnice“, Zagreb
24. Klinički bolnički centar Zagreb (KBC Zagreb)
25. Klinika za dječje bolesti, Zagreb
26. Klinika za ženske bolesti i porode, KBC Zagreb
27. Medicinski fakultet Sveučilišta u Rijeci
28. Medicinski fakultet Sveučilišta u Zagrebu
29. Ministarstvo unutarnjih poslova RH, Ravnateljstvo civilne zaštite, Sektor za radiološku i nuklearnu sigurnost
30. Ministarstvo gospodarstva i održivog razvoja RH, Zagreb
31. Nastavni zavod za javno zdravstvo „Dr. Andrija Štampar“, Zagreb
32. Nastavni zavod za javno zdravstvo Primorsko-goranske županije, Rijeka
33. Nezavisni sindikat znanosti i visokog obrazovanja, Zagreb
34. Odgojni zavod Turopolje, Velika Gorica
35. Odjel za biotehnologiju Sveučilišta u Rijeci
36. Petrokemija d. d., Kutina
37. Prehrambeno-biotehnološki fakultet Sveučilišta u Zagrebu
38. Prehrambeno-tehnološki fakultet, Sveučilište J. J. Strossmayera u Osijeku
39. Prirodoslovno-matematički fakultet Sveučilišta u Splitu
40. Prirodoslovno-matematički fakultet Sveučilišta u Zagrebu
41. Sabor RH, Zagreb
42. Stomatološki fakultet Sveučilišta u Zagrebu
43. Sveučilište J. J. Strossmayera u Osijeku, Odjel za kemiju
44. Sveučilište u Zadru, Odjel za ekologiju, agronomiju i akvakulturu
45. Škola narodnog zdravlja „A. Štampar“, Medicinski fakultet Sveučilišta u Zagrebu
46. Veterinarski fakultet Sveučilišta u Zagrebu
47. Zavod za javno zdravstvo Brodsko-posavske županije, Slavonski Brod
48. Zavod za javno zdravstvo Istarske županije, Pula
49. Zavod za javno zdravstvo Koprivničko-križevačke županije, Koprivnica
50. Zavod za javno zdravstvo Osječko-baranjske županije, Osijek
51. Zavod za javno zdravstvo Zadarske županije, Zadar

USTANOVE U INOZEMSTVU

1. Academic Medical Centre, Amsterdam, Nizozemska
2. Backweston Laboratory Campus, Ministarstvo poljoprivrede, hrane i pomorstva Republike Irske
3. Bundesamt fur Strahlenschutz, Salzgitter, Njemačka
4. Department of Biology and Pharmaceutical Botany, Medical University of Łódź, Łódź, Poljska
5. Fakulteta za kemijo in kemijsko tehnologijo Univerza v Ljubljani, Slovenija
6. Faculty of Science, University of Hradec Králové, Češka
7. Florida State University, Tallahassee, FL, SAD
8. Helmholtz Zentrum München Deutsches Forschungszentrum für Gesundheit und Umwelt, München, Njemačka
9. Hemijski fakultet Univerziteta u Beogradu, Beograd, Srbija
10. Hungarian Institute for Public Health, Budimpešta, Mađarska
11. Institut de Recherche Biomédicale des Armées, Brétigny-sur-Orge cedex, Francuska
12. Institut für Chemie, Universität Graz, Austrija
13. Institut für Physikalische und Theoretische Chemie, Technische Universität Graz, Graz, Austrija
14. Institut für Soziale Ökologie, Alpen-Adria-Universität Klagenfurt, Austrija
15. Institut za fiziku Univerziteta u Beogradu, Beograd, Srbija
16. Inštitut za biokemijo, Medicinska fakulteta, Univerza v Ljubljani, Ljubljana, Slovenija
17. Institut za hemiju, tehnologiju i metalurgiju, Univerzitet u Beogradu, Beograd, Srbija
18. Inštitut za patološko fiziologiju, Medicinska fakulteta, Univerza v Ljubljani, Ljubljana, Slovenija
19. Institute for Nuclear Research, Hungarian Academy of Sciences, Debrecen, Mađarska
20. Institute of Basic Medical Sciences, University of Oslo, Oslo, Norveška
21. Institute of Macromolecular Chemistry, Academy of Sciences of the Czech Republic, Prag, Češka
22. Institute of Nature Conservation of Polish Academy of Sciences, Krakow, Poljska
23. Institute of Organic Chemistry and Biochemistry of the CAS, Prag, Češka
24. International Atomic Energy Agency, Beč, Austrija
25. Joint Research Centre of the European Commission, Bruxelles, Belgija
26. Max Planck Institute for Chemistry, Njemačka
27. Nacionalni inštitut za biologijo, Ljubljana, Slovenija
28. NILU – Norwegian Air Research Institute, Norveška
29. NMR laboratórium, Pannon Egyetem, Veszprém, Mađarska
30. Paul Scherrer Institute, Švicarska
31. Prirodno-matematički fakultet, Univerzitet u Kragujevcu, Srbija
32. Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Peking, Kina
33. The Scripps Institute of Science, CA, SAD
34. Umweltbundesamt (UBA), Langen, Njemačka
35. UHasselt University Belgium, Campus Diepenbeek, Agoralaan Gebouw H, Diepenbeek, Belgija
36. Universidad Autónoma de Tlaxcala, Universidad Nacional Autónoma de México, Meksiko
37. Universität Osnabrück, Osnabrück, Njemačka
38. Universitätsklinikum Hamburg-Eppendorf (UKE), Hamburg, Njemačka
39. University of California at San Diego, La Jolla, CA, SAD
40. University of Melbourne, Melbourne, Victoria, Australia
41. University of Rouen, Mont-Saint-Aignan, Francuska
42. University of Strasbourg, Strasbourg, Francuska
43. Univerzita Hradec Králové, Hradec Králové, Češka
44. VITO – Flemish Institute for Technological Research, Belgija
45. VVM – Flemish Environment Agency

C. PRIHODI INSTITUTA

RED. BR.	VRSTA PRIHODA	IZNOS (HRK)	%
A	PRIHODI IZ DRŽAVNOG PRORAČUNA	42.239.749	39,85
1.	Plaće i rashodi za zaposlene	27.686.735	26,12
2.	Programsko financiranje Instituta	3.729.403	3,52
3.	Nacionalno sufinanciranje projekta REC IMI	7.730.656	7,29
4.	Bilateralni projekti	654.898	0,62
5.	Potpore za prijavu projekata, popularizaciju i <i>Arhiv</i>	161.702	0,15
6.	Projekti i doktorandi Hrvatske zaklade za znanost	2.276.355	2,15
B	PRIHODI OD PRUŽENIH USLUGA NA TRŽIŠTU	14.688.615	13,86
7.	DHMZ – Program mjerenja razine onečišćenosti u Državnoj mreži	3.446.260	3,25
8.	Gradski ured za gospodarstvo, energetiku i zaštitu okoliša, Zagreb	2.380.676	2,25
9.	Klinički bolnički centar Zagreb	640.805	0,60
10.	Ministarstvo unutarnjih poslova RH, Zagreb	243.715	0,23
11.	Klinički bolnički centar „Sestre milosrdnice“, Zagreb	713.680	0,67
12.	Zagrebačke otpadne vode d. o. o., Zagreb	166.326	0,16
13.	Klinička bolnica Dubrava, Zagreb	442.550	0,42
14.	Fond za financiranje razgradnje i zbrinjavanja radioaktivnog otpada NEK	960.200	0,91
15.	Eurofins Croatiakontrola d. o. o., Zagreb	283.500	0,27
16.	Hrvatski zavod za zdravstveno osiguranje, Zagreb	157.600	0,15
17.	CARnet – Hrvatska akademska i istraživačka mreža, Zagreb	1.350.000	1,27
18.	Zavod za javno zdravstvo Koprivničko-križevačke županije, Koprivnica	212.064	0,20
19.	Nastavni zavod za javno zdravstvo „Dr. Andrija Štampar“, Zagreb	114.375	0,11
20.	Međunarodna zračna luka Zagreb d. d.	120.840	0,11
21.	Zagrebački holding d. o. o. Zagreb	114.680	0,11
22.	Opća bolnica Koprivnica	105.979	0,10
23.	Opća bolnica Varaždin	264.950	0,25
24.	Rockwool Adriatic d. o. o. Potpićan	118.960	0,11
25.	Arysta LifeScience Great Britain Ltd.	187.000	0,18
26.	STSI Integrirani tehnički servisi d. o. o., Zagreb	176.065	0,17
27.	Universität Osnabrück, Osnabrück, Germany	130.960	0,12
28.	Syngenta Crop Protection AG, Basel Switzerland	149.600	0,14
29.	Ispitivanje i mjerenje radioaktivnosti uzoraka	340.679	0,32
30.	Ocjena ekološke prikladnosti objekata	294.118	0,28
31.	Dozimetrija izvora zračenja	939.786	0,89
32.	Laboratorijske usluge – pacijenati	151.780	0,14
33.	Laboratorijske analize i toksikološke ocjene uzoraka	457.987	0,43
34.	Pretplata <i>Arhiv</i> , ugovori IMI	23.480	0,02
C	PRIHODI OSTVARENI IZ OSTALIH IZVORA	49.063.975	46,29
35.	Prihodi iz EFRR-a za financiranje projekta REC IMI	45.160.314	42,61
36.	EU projekti	3.140.263	2,96
37.	Međunarodni projekti	286.139	0,27
38.	Sveučilište Sjever	140.093	0,13
39.	Prihodi od dividendi, kamata i pozitivnih tečajnih razlika	54.792	0,05
40.	Refundacije troškova	198.776	0,19
41.	Ostali prihodi i sufinanciranje troškova	83.598	0,08
A+B+C	UKUPNI PRIHOD	105.992.339	100,00

D. PUBLIKACIJE DJELATNIKA INSTITUTA U 2021. GODINI

KATEGORIJA PUBLIKACIJE	BROJ RADOVA
D.1. Znanstveni, pregledni i stručni radovi (+ prihvaćeni za objavu u 2022.)	141 (+11)
Radovi u časopisima indeksiranim u bazi WoS	126
Radovi u časopisima indeksiranim u bazi WoS prihvaćeni za objavu u 2022.	11
Radovi u časopisima indeksiranim u ostalim bazama	5
Radovi u neindeksiranim časopisima	3
Radovi u zbornicima skupova održanih u RH i virtualno	1
Radovi u zbornicima skupova održanih u inozemstvu i virtualno	6
D.2. Knjige, časopisi, zbornici	13
Autor ili urednik knjige	1
Rad ili poglavlje u knjizi	9
Urednik časopisa ili zbornika	3
D.3. Ostale publikacije	7
Tiskana izdanja	5
Elektronička izdanja	2
D.4. Kvalifikacijski radovi	25
Radovi djelatnika Instituta	9
Radovi pristupnika s mentorom/sumentorom na Institutu	16
D.5. Kongresna priopćenja na skupovima održanim u RH i virtualno	103
Sažetci u časopisima indeksiranim u bazi WoS	38
Sažetci u ostalim časopisima i knjigama sažetaka	62
Sažetci u elektroničkom izdanju	3
D.6. Kongresna priopćenja na skupovima održanim u inozemstvu i virtualno	58
Sažetci u časopisima indeksiranim u bazi WoS	16
Sažetci u ostalim časopisima i knjigama sažetaka	33
Sažetci u elektroničkom izdanju	9
D.7. Izvještaji stručne djelatnosti	24
Nacionalni projekti, ugovori i suradnje	23
Međunarodni projekti, ugovori i suradnje	1
UKUPAN BROJ RADOVA OBJAVLJENIH U 2021. (+ prihvaćenih za objavu u 2022.)	371 (+11)

D.1. ZNANSTVENI, PREGLEDNI I STRUČNI RADOVI

Radovi u časopisima indeksiranim u bazi WoS

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3. BABIĆ Ž, KOVAČIĆ J, FRANIĆ Z, ŠAKIĆ F, PRESTER Lj, VARNAI VM, CVIJETIĆ AVDAGIĆ S, BJELAJAC A, MACAN J, TURK R. Prevention of poisonings by educational intervention aimed at parents of preschool children. *Int J Inj Contr Saf Promot* 2021;28:486-93. (znanstveni rad, Q4)
4. BABIĆ LEKO M, JURASOVIĆ J, NIKOLAC PERKOVIĆ M, ŠPANIĆ E, SEKOVANIĆ A, ORCT T, LUKINOVIĆ ŠKUDAR V, BAČIĆ BARONICA K, KIĐEMET-PISKAČ S, VOGRINC Ž, PIVAC N, BOROVEČKI F, HOF PR, ŠIMIĆ G. The association of essential metals with APOE genotype in Alzheimer's disease. *J Alzheimers Dis* 2021;82:661-72. (znanstveni rad, Q2)
5. BARBIR R, CAPIJAK I, CRNKOVIĆ T, DEBELJAK Ž, DOMAZET JURAŠIN D, ĆURLIN M, ŠINKO G, WEITNER T, VINKOVIĆ VRČEK I. Interaction of silver nanoparticles with plasma transport proteins: A systematic study on impacts of particle size, shape and surface functionalization. *Chem Biol Interact* 2021;335:109364. (znanstveni rad, Q1)

6. BARBIR R, PEM B, KALČEC N, KASTNER S, PODLESNAIA K, CSÁKI A, FRITZSCHE W, VINKOVIĆ VRČEK I. Application of localized surface plasmon resonance spectroscopy to investigate a nano-bio interface. *Langmuir* 2021;37:1991-2000. (znanstveni rad, Q2)
7. BARBIR R, RAMÍREZ JIMÉNEZ R, MARTÍN-RAPÚN R, STRASSER V, DOMAZET JURAŠIN D, DABELIĆ S, DE LA FUENTE JM, VINKOVIĆ VRČEK I. Interaction of differently sized, shaped, and functionalized silver and gold nanoparticles with glycosylated versus nonglycosylated transferrin. *ACS Appl Mater Interfaces* 2021;13:27533-47. (znanstveni rad, Q1)
8. BATELJA-VULETIC L, TOMASOVIC-LONCARIC C, CEPPI M, BRUZZONE M, FUCIC A, KRSTANAC K, BORAS VUCICEVIC V. Comparison of androgen receptor, VEGF, HIF-1, Ki67 and MMP9 expression between non-metastatic and metastatic stages in stromal and tumor cells of oral squamous cell carcinoma. *Life (Basel)* 2021;11:336. (znanstveni rad, Q2)
9. BENKOVIĆ V, BOROJEVIĆ N, ŠIKIĆ D, HORVAT KNEŽEVIĆ A, MILIĆ M. DNA damage assessment in peripheral blood of Swiss albino mice after combined exposure to volatile anesthetics and 1 or 2 Gy radiotherapy *in vivo*. *Int J Radiat Biol* 2021;97:1425-35. (znanstveni rad, Q1)
10. BENKOVIĆ V, MARČINA N, HORVAT KNEŽEVIĆ A, ŠIKIĆ D, RAJEVAC V, MILIĆ M, KOPJAR N. Potential radioprotective properties of arbutin against ionising radiation on human leukocytes *in vitro*. *Mutat Res Genet Toxicol Environ Mutagen* 2021;872:503413. (znanstveni rad, Q3)
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15. ČADEŽ T, KOLIĆ D, ŠINKO G, KOVARIK Z. Assessment of four organophosphorus pesticides as inhibitors of human acetylcholinesterase and butyrylcholinesterase. *Sci Rep* 2021;11:21486. (znanstveni rad, Q1)
16. ČAVLOVIĆ AO, BEŠLIĆ I. Application of photometry in determining the dust mass concentration of hardwoods. *Wood Res* 2021;66:678-88. (znanstveni rad, Q3)
17. ČAVLOVIĆ AO, BEŠLIĆ I, ZGORELEC Ž, OŽEGOVIĆ J. Reliability of the measurement method in determining the mass concentration of hardwood dust. *BioResources* 2021;16:643-54. (znanstveni rad, Q2)
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D.6. KONGRESNA PRIOPĆENJA NA SKUPOVIMA ODRŽANIM U INOZEMSTVU I VIRTUALNO

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