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CROATION AIR POLLUTION PREVENTION ASSOCIATION

INTERNATIONAL CONFERENCE AND
13TH CROATIAN SCIENTIFIC AND PROFESSIONAL MEETING

AIR PROTECTION 2023

Dubrovnik, Croatia
20th - 23rd September 2023

BOOK OF ABSTRACTS

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Croatian Air Pollution Prevention Association
Institute for Medical Research and Occupational Health
Croatian Meteorological and Hydrological Service
European Federation of Clean Air and Environmental Protection Associations - EFCA
International Union of Air Pollution Prevention and Environmental
Protection Associations - IUAPPA

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FOREWORD

The Croatian Air Pollution Prevention Association (CAPPA), the main organizer of „Air Protection" conferences, is a volunteering, non-profit organization that gathers members from the Republic of Croatia in order to protect and promote common professional goals in the field of air protection. Organized activities in the field of air protection started in Croatia 50 years ago, following the foundation of the Yugoslavian Association for Clean Air in 1973 in Zagreb. The Yugoslavian Association for Clean Air was divided into sections according to each Republic. After reorganization in 1983, the Republic Section for Croatia became the Croatian Association for Air Protection, within the Yugoslavian Union of Air Protection Associations. When Croatia declared independence from Yugoslavia, the Association changed its name to the Croatian Air Pollution Prevention Association (CAPPA) and in the coming years joined the International Union of Air Pollution Prevention and Environmental Protection Association (IUAPPA) and The European Federation of Clean Air and Environmental Protection Association (EFCA). Over the years, CAPPA has had numerous activities related to air protection, among which we would like to point out twelve successful „Air Pollution" national conferences (since 1997, every odd year), the 14th International Conference on Air Quality – Assessment and Policy at Local, Regional and Global Scales organized in cooperation with IUAPPA in Dubrovnik in 2003, and ten workshops abroad (every even year since 2000). CAPPA members regularly offer professional help during the preparation of air pollution protection legislation.

On the 50th anniversary of organized activities in the field of air protection in Croatia and the 30th anniversary of CAPPA, it is our great pleasure to organize again an international conference, together with the 13th national „Air Protection" meeting. This year's conference is held in the Astarea hotel in Mlini near Dubrovnik and includes the following topics:

1 - Air quality management
2 - Air pollution sources and emissions
3 - Ambient Air pollution monitoring
4 - Machine learning and air quality modelling
5 - Developing and testing measuring methods
6 - Health impacts of air pollution
7 - Indoor air quality, energy efficiency, and healthy buildings
8 - Climate and Environmental impacts of air pollution

It is also our pleasure to announce the special events during the "Air Protection 2023" conference: the session "*New regime on air protection in Europe*" organised under the auspices of the EFCA, a special session organized by IUAPPA entitled "*Air quality strategies for liveable cities in a changing climate*" as well as the workshop "*A spotlight on indoor air quality*".

More than 150 participants and the 78 submitted presentations in this Book of Abstracts (42 oral and 36 poster presentations) clearly show the interest of the scientific and professional community for the issue of the threatening impact of air pollution on human health and the environment, but also indicate that CAPPA and the Air Protection Conference itself are well-recognized in the country and abroad.

We hope that this year's edition of "Air Protection" will facilitate a successful presentation of results, with fruitful discussions and exchange of ideas, indicate existing and potential problems, and ultimately help reach conclusions about future actions.

The "Air Protection 2023" conference would not be possible without the great effort of the Scientific and Organizing Committee members as well as the Advisory Board members. CAPPA is particularly grateful to all co-organizers and the Conference sponsors.

We wish all of the participants a successful visit and a lovely time in Dubrovnik!

Gordana Pehnec and Ranka Godec

AIR QUALITY MANAGEMENT

Oral presentation

Carmen Galán[1,2], Qasim Farooq[1,2], Jose Oteros[1,2]

MONITORING POLLEN FOR AIR PROTECTION

Keywords: *pollen monitoring, air quality, human health, ecological impacts, automatic sensors*

Airborne pollen poses considerable challenges and implications for air quality, human health, and ecological systems. Comprehensive pollen monitoring plays an indispensable role in understanding and mitigating these impacts, driving progress in air protection strategies. Pollen-related allergy affects a significant portion of the global population, leading to respiratory issues and reducing the quality of life. Accurate, real-time pollen monitoring can provide sufferers with the vital information they need to manage their symptoms effectively. Beyond human health, pollen data also informs studies related to climate change, plant phenology, agriculture, and forensic science. For instance, shifts in pollen seasons may signal changes in local climate conditions, and knowledge of pollen density can help forecast agricultural yields and manage pest outbreaks.

Monitoring methodologies have historically been dominated by the Hirst method, relaying on manual identification, and counting techniques, yielding vital baseline datasets but are limited by their labor-intensive nature and temporal resolution. Recent advances, however, have propelled us into an era of automatic pollen monitoring. These automatic sensors, utilizing different principles such as digital images or digital holography, and machine learning algorithms, promise to revolutionize our approach to air quality assessment. Drawing from our group's recent studies, the application of these technologies has led to notable successes. Challenges persist, such as refining algorithms to identify a broader range of pollen and fungal spore taxa and the need for standardized protocols and calibration methods. Yet, the rapid evolution of these technologies provides optimism for improved air protection strategies.

Challenges do exist, such as expanding the identification capabilities of these sensors to a wider range of pollen and fungal spore taxa and standardizing protocols. In this communication, we highlight our latest research on advancing automatic pollen monitoring. We've made strides in digital imaging and holography techniques to enable more accurate and comprehensive pollen identification. Our findings contribute to improved air protection measures through real-time, continuous monitoring systems.

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Poster presentation

Patricija Kapš

INFORMATION SYSTEM FOR DATA DISPLAY AND STATISTICAL PROCESSING OF AIR QUALITY MEASUREMENT DATA

Keywords: *data control, validation, annual data report*

Inorganic compounds (sulphur dioxide (SO_2), hydrogen sulphide (H_2S), nitrogen oxides (NO, NO_2, NO_x), ammonia (NH_3), carbon monoxide (CO) and ozone (O_3)), volatile organic compound (benzene (C_6H_6)), and particulate matter (PM_{10} and $PM_{2.5}$) concentration measurements are currently being conducted by the Air Quality Measurement System Management Department within the Croatian Meteorological and Hydrological Service (DHMZ) at 24 air quality measurement stations which comprise the national network for continuous air quality monitoring.

For the purpose of data control, data validation and generation of an annual air quality monitoring report, the new information system for data display and statistical processing of air quality measurement data is developed as part of the AIRQ project. It consists of four modules: data control, data validation, administration of user and application settings, and reports.

In the Data Control module, the data collected by the data logger from the air quality measuring stations of the national network for continuous air quality monitoring is controlled. The main window is divided into four tabs: concentrations, zero/span, aggregated data and comments. Data control by opening the "concentration" tab involves loading data for the selected component and for the selected time period, visually reviewing of uncontrolled data, marking data as valid or invalid and flagging controlled data that are then saved in the database. After data control, zero and span values are checked. Aggregated data control is performed on data over a longer time period. The comments tab allows for inputting, editing, reading and printing comments for the selected measuring instrument or the entire measuring station.

The information system creates a dashboard with a list of notifications and a summary of alerts for each station and individual component.

In the Validation module, the measurement data of pollutant concentrations in the air are validated. This module consists of uploading the air quality measurement data from the database, visually reviewing the loaded data, entering correction coefficients, applying them, and saving the data in the database.

The Administration module is used for managing users, roles and actions for editing display styles.

The Report module involves the statistical processing of data based on the permissible limits for each pollutant and the graphical representation of pollutant concentration.

Examples of the information system for data display and statistical processing of air quality measurement data will be presented, focusing on Data control, Validation and Reporting modules.

Air Quality Measurement System Management Department, Croatian Meteorological and Hydrological Service, Ravnice 48, Zagreb, Croatia

Oral presentation

Eva Paulusberger, Kristina Pavlović, Heimo Gursch

STANDARDIZATION OF AIR QUALITY DATA COLLECTION TECHNIQUES

Keywords: *air pollution, data standardization, health data management*

Consistent standardization of air quality and pollution data collection techniques is essential for accurately forecasting, analyzing, and assessing air quality and thus improving impact on public health. The data analysis experts of the European IPChem platform (European Information Platform for Chemical Monitoring https://ipchem.jrc.ec.europa.eu/) have already created standardized templates for differentiating between data owners and data providers and collecting their data through three questionnaires. However, these templates still need more thorough revision which is an active task for 2023 for all seven IDEAL WG2 cluster projects including EDIAQI and, in addition to the criteria assessed, the following issues need to be taken into account when collecting data: [i] a clear distinction between different air pollution data, i.e. indoor air pollution such as sensor data, health data, biological data, environmental data, human biomonitoring data, survey data, indoor air sampling data, climate data, and toxicological data; [ii] the types of data collection or data collection methods are based on surveys, interviews, and questionnaires, as provided by IPChem on the one hand; however, we argue that upon considering data collection also sensorics, sampling, and databases need to be taken into account. Therefore, the pollutants and parameters measured via sensorics, such as mobile spirometers, which can be connected to smartphones, stationary pollutant traps, low-cost sensorics (sentinels), air quality monitoring stations, remote reference stations, filtrations systems, such as ventilation and air condition systems, also need to be comprised when standardizing data. Moreover, [iii] the venues of data collection require a clearer distinction among these three categories: [1] residential/homes/households, [2] public buildings indoors (schools, hospitals, administrative buildings, universities, lecture halls, canteens, nurseries, kindergartens), and [3] outdoor public venues (metro stations, markets). Most prominently, [iv] the data that are measured themselves need to be reported within a standardized chart. Therefore, the EDIAQI project has found a task force to collaborate beyond EDIAQI's four pilots and four campaigns with all seven IDEAL WG2 cluster projects to categorize chemical as well as non-chemical data within an air quality data chart comprising air pollution data definitions within highly structured and less granular categories. The first results show that the streamlined definitions make reporting and data analysis more concise. Reinforcing the use of this standardized air quality data chart could foster the continuous integration of this scale as a new standard within the Horizon Europe Data Management Plan (H2020 Template for Data Management Plan https://ec.europa.eu/research/participants/data/ref/h2020/gm/reporting/h2020-tpl-oa-data-mgt-plan_en.docx), thus significantly improving data management within health cluster activities and leading to a clearer and more effective collection, categorization, assessment, and analysis of air quality data.

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Poster presentation

Mladen Rupčić, Domagoj Mihajlović, Luka Mrvoš

MODERNIZATION OF THE STATE NETWORK FOR CONTINUOUS MONITORING OF AIR QUALITY WITHIN THE AIRQ PROJECT

Keywords: *AIRQ project, state network for continuous monitoring of air quality, measuring equipment for measuring air quality, operational work*

The project "AIRQ – Expansion and modernization of the national network for continuous air quality monitoring" aims 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 (Directive 2008/50/EC, Air Protection Act (NN 130/11, 47/14)). One of the reasons for the modernization of the state network for continuous monitoring of air quality is to meet the minimum number of measuring points per zone and agglomeration, fulfilling the commitment to establish EMEP level 1 and 2 measuring points, fulfillment of data quality conditions and ensuring minimum coverage of data.

Within the AIRQ project, the activities of component 1 comprised the implementation of various public tenders to select the supplier of automatic measuring devices for measuring air quality (SO_2, H_2S, NO_2, NH_3, CO, O_3, PM_{10} and $PM_{2.5}$, C_6H_6, black carbon, greenhouse gases, mercury) together with other auxiliary devices (data loggers, gas dilution units and zero air generators) together with tenders for the construction contractor and delivery of containers (accommodation of measuring equipment). After the successful implementation of tenders in the first phase of the project (2019-2021) during the fall of 2021, the Croatian Meteorological and Hydrological Service (DHMZ), together with other project partners, began the process of modernization of 24 measuring stations, which included the uninstallation of the existing measuring equipment at the stations, construction works at the location from the contractor and installation of measuring and auxiliary equipment for measuring air quality by the DHMZ staff.

The basic elements of the air quality measuring station modernized in the AIRQ project and the activities carried out by DHMZ from autumn 2021 to summer 2023 will be presented. Also, some specifics of the installation of measuring equipment at certain locations will be presented, such as the installation of equipment for measuring black carbon at eight measuring stations, equipment for measuring mercury concentration at one measuring station and equipment for measuring greenhouse gases at two measuring stations.

Croatian Meteorological and Hydrological Service, Ravnice 48, 10000 Zagreb, Croatia

Oral presentation

Stipica Šarčević, Velimir Milić, Darijo Brzoja

IMPLEMENTATION OF THE ATMOSYS SYSTEM OVER CROATIA

Keywords: *ATMOSYS, machine learning, RIO, OVL, forecast, air quality*

ATMOSYS is a suite of air quality management software tools and web apps created specifically to support the implementation of air quality legislation and policies at a regional and urban scale. It comprises of cost-efficient user-friendly tools for predicting air quality episodes, mapping air quality at a high spatial resolution, and supporting decisions on where, when, and how actions should be taken to improve air quality (planning). The ATMOSYS system consists of a regional background model (RIO) and a forecast model (OVL). RIO provides added value on top of an air quality monitoring network by providing an instant overview of the entire region. The RIO model derives real-time, daily, and yearly concentration maps from the national air quality monitoring network. If a city, region, or country exploits a number of air quality measurement stations that are geographically representative of different land use types, RIO can be used to interpolate air quality measurements into a comprehensive air quality map, providing an immediate overview of the air quality status in the region. The OVL model is based on artificial neural networks (NN) methodology. NN forms a group of machine-learning techniques inspired by biological neurons. Their history goes back more than 50 years, but due to the availability of modern computers from the 1980s, they have grown to be a competitive tool that has been applied widely since the mid-1990s. One of the reasons for their success is their capability to make regressive approximations of non-linear functions in high-dimensional spaces, something that is missing in classical statistics. The main advantages of a NN forecasting tool, compared to deterministic atmospheric modeling systems, are the limited need for input data and computer power (in operational mode, training can, of course, be computer intensive). Compared to traditional statistical techniques NN excels by its flexibility. The main drawback is that a NN that is trained by data from a given measuring location can only forecast for that specific location and it cannot give insight into the physics behind the data: a NN merely learns from examples, and it is not suited to generalize to other situations. Implementation of the ATMOSYS system over the Croatian domain will be shown, the first insight into the front-end part of ATMOSYS software, and the advantages and challenges of the practical operating of the system will be discussed.

Croatian Meteorological and Hydrological Service, Ravnice 48, 10000 Zagreb, Croatia

Oral presentation

Jadranka Škevin, **Darijo Brzoja**

EXPANSION AND MODERNIZATION OF THE NATIONAL NETWORK FOR CONTINUOUS AIR QUALITY MONITORING

Keywords: *air quality, national network, AIRQ*

The project "Expansion and modernization of the national network for continuous air quality monitoring - AIRQ," funded under KK.06.2.1.02.0001, constitutes a significant endeavor towards enhancing the management and monitoring of air quality, aiming to achieve efficient control and governance of air quality within urban areas, zones, and agglomerations. This initiative is a part of the Operational Program "Competitiveness and Cohesion 2014 - 2020."

The rationale behind the modernization efforts revolves around several key objectives, including meeting the mandatory requirement of the minimum number of measuring points, establishing EMEP level 1 and 2 measuring points, ensuring compliance with data quality standards by deploying type-approved equipment for specific pollutants, and ensuring sufficient data coverage.

As a result of the project's successful implementation, six new measuring stations were established, and 18 existing stations underwent comprehensive reconstruction. Additionally, a sophisticated model for estimating ground concentrations of pollutants was developed and deployed, bolstering the accuracy and reliability of air quality assessments. Moreover, the chemical laboratories of the Croatian Meteorological and Hydrological Service (DHMZ) and the Institute for Medical Research and Occupational Health (IMROH) were equipped and operationalized to conduct measurements in line with the stringent requirements set forth by the Program for Measuring Pollution Levels in the National network for continuous air quality monitoring (NN 12/2023). Furthermore, a fully functional calibration laboratory was established to calibrate air quality gauges and related measurement instruments, ensuring traceability to international standards. The project also entailed substantial upgrades to the computer infrastructure, supporting both the continuous air quality monitoring network and the meteorological measurement network (upgraded through the METMONIC project).

The primary goal of this endeavor is to fortify the capabilities of DHMZ, ensuring an adequate level of capacity, security, and reliability of the computer infrastructure. This aligns with the broader strategy of computerization across DHMZ, facilitating the undisturbed functioning of the national air quality monitoring network.

The project's total value is EUR 16,606,742, with co-financing provided by the EU Regional Development Fund (85%) and the Republic of Croatia through the Environmental Protection and Energy Efficiency Fund (15%). Through the successful realization of the AIRQ project, Croatia takes a significant step forward in safeguarding the environment and public health through improved air quality monitoring and management capabilities.

Croatian Meteorological and Hydrological Service, Ravnice 48, 10 000 Zagreb, Croatia

Oral presentation

Božica Šorgić[1], Martina Kolovrat[1], Zrinka Vrček[2], Ana Nemet Đurđević[3]

QUALITY OF ACTION PLAN'S MEASURES. HOW TO GET TO CLEANER AIR?

Keywords: *action plan, measures, possibilities*

According to Articles 45, 54 and 55 of Air Protection Act (Official Gazette No. 127/19, 57/22) in zones and agglomerations for which it was determined that the levels of certain polluting substances are above the prescribed limit values (LV), action plans for improving air quality should ensure that limit values are achieved as soon as possible. However, it seems that the measures from previous action plans were not effective enough probably because i.e. none of them include a ban on the use of old heating boilers in households or restrictions on vehicles inside certain areas of the cities while the measures in the energy sector were based on incentives or promotion but did not imply any obligations. What measures can be applied to the main local emission sources that would lead to results and that can actually be implemented on a local scale? How can all relevant stakeholders, cities, counties and the ministry be involved? What are the responsibilities of the cities?

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Oral presentation

Nina Zovko, Mario Stipetić, Gordan Došen

OVERVIEW OF NEWS IN NATIONAL AIR QUALITY LEGISLATION

Keywords: *state network for air quality monitoring*, *air quality plans*

The aim of this text is to present an overview of the amendments in the national legislation adopted in order to ensure compliance with air quality standards. During the implementation of the Air Protection Act, due to perceived deficiencies mainly in the part related to the adoption and implementation of action plans for air quality in May 2022, the Amendments to the Air Protection Act entered into force. These amendments set out the competences and responsibilities of all stakeholders in the process of adopting and implementing action plans. The competence of the Ministry of Economy and Sustainable Development was determined by giving an opinion on the acceptability of the action plan, which is an integral part of the Decision on the Adoption of the Action Plan. Furthermore, the obligations of the holders of the measures from the action plans are clearly defined and misdemeanour provisions have been added in cases where the implementation and financing of the measures to reduce air pollution determined in the action plan are not ensured, and if the preparation of a two-year report on the implementation of the measures from the action plan is not ensured, or if the implementation of the measures from the action plans is not monitored. Furthermore, in September 2022, a new Regulation on determining the list and locations of measuring stations in the state network for permanent monitoring of air quality and measuring points for monitoring concentrations of certain pollutants in the air was adopted, which determined the locations of 28 existing and 7 new measuring stations of the state network in 5 zones and 4 agglomerations and 3 additional locations for the needs of the EMEP program. Then, in February 2023, a new Program for measuring the level of air pollution in the state network was adopted, which defines pollutants, measurement density and measurement periods for each station of the state network. It consists of Program A, which contains measurements established in agglomerations, and Program B, which contains air quality measurements in zones. Also in March 2023, a new Ordinance on the content, format and procedure for adopting an action plan to improve air quality, as well as the mutual exchange of information and reporting on air quality and obligations for the implementation of Commission Decision 2011/850/EU was adopted, which prescribes in detail the content and format of action plans, as well as the method and deadlines for preparation and adoption, as well as the obligations of the Ministry, local government units (LGUs) and the City of Zagreb. In April 2023, the Air Quality Assessment in the Republic of Croatia for the period 2016-2020 was adopted, which contains a comprehensive five-year analysis of the air quality in Croatia. The purpose of the assessment is to analyse trends, assess the effectiveness of implemented policies and measures, assess the adequacy of monitoring and provide expert basis for the development of plans and strategies for further air protection.

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AIR POLLUTION SOURCES AND EMISSIONS

Oral presentation

Anka Ozana Čavlović[1], Martina Beuk[2], Stjepan Pervan[1], Silvana Prekrat[1]

WOOD BIOMASS EMISSION TRENDS DURING ENERGY PRODUCTION

Keywords: *renewable sources of energy, air pollution reduction, wood fuel*

According to data from the database of the Environmental Pollution Register for seven calendar years in the period between 2010 and 2022, the trend of consumption of wood fuel (solid biomass) and emissions of pollutants from the combustion of wood fuel from industrial furnaces in Croatian wood processing companies and power plants are presented. In 2022, 1,157.5 kt of wood fuel was consumed for energy production in 79 wood processing companies and energy plants. Compared to 2010, the consumption of wood fuel has increased significantly (8.6 times), which is mainly contributed by 25 new energy plants in the last 5 years (11 of them in 2022). Consequently, in the same period compared to 2010, the quantities of pollutants reported to the Environmental Pollution Register increased for carbon dioxide (9.6 times), carbon monoxide 1.6 times), nitrogen dioxide (7.8 times), sulfur dioxide (16.9 times) and solid particles PM_{10} (4.8 times).

For the same period from 2010 to 2022, the European Environmental Agency reports an increase in total economic activity and energy consumption in the EU27, but also reports on the trend of reducing environmental pollution. Although fossil fuels are still the most dominant, represented by 75% compared to other energy sources, after 2010, their share, liquid fuels (a drop of 44%) and coal (a drop of 48%) began to decrease significantly with the increase in the use of natural gas (as a bridge in this transition) and renewable sources of energy (RES), especially solid biomass. In the same period, in the Republic of Croatia, a similar trend of reducing pollutant emissions occurs due to an increase in natural gas consumption by 42% and a decrease in coal consumption by 22%. The share of RES in the EU27 increased to 22% in 2021, which is only 7% more than in 2010. Wood fuel with a 41 % share is the most represented RES in heating and industry in Europe in 2021. Wood fuel consumption has been continuously growing since 2010 with a total increase of 72%.

Improvements in fuel types in the EU27 have resulted in a reduction of pollutant emissions into the air. Compared to 2010, the emission of sulfur dioxide and PM_{10} solid particles decreased by about 70%, nitrogen dioxide by 47% and carbon dioxide by 70%. However, similar to the Republic of Croatia, in the EU27 paper and wood production sector, a slight increase in the share of emissions was recorded from 2010 to 2021, namely for carbon dioxide (2%), carbon monoxide (0.5%), nitrogen dioxide (12.9%), sulfur dioxide (0.1%) and solid particles PM_{10} (7.2%).

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Poster presentation

Snježana Herceg Romanić[1], Gordana Jovanović[2,3], Andreja Stojić[2,3], Mirjana Perišić [2,3]

FATE OF POLYCYCLIC AROMATIC HYDROCARBONS IN INDOOR AND OUTDOOR ENVIRONMENT: PREDICTION OF BENZO[A]PYRENE AND BENZO[B]FLUORANTHENE LEVELS

Keywords: *indoor/outdoor air, source apportionment, explainable artificial intelligence*

Using machine learning and explainable artificial intelligence, the behavior and fate of polycyclic aromatic hydrocarbons (PAHs) as constituents of $PM_{2.5}$ in indoor and outdoor environment of a university building in an urban area of Belgrade (Serbia) was studied. The measurement campaign was performed during a three-month sampling period and 24 h-filter samples were collected simultaneously at indoor and outdoor sampling sites. The concentrations of O_3, CO, SO_2, NO_x, radon, $PM_{2.5}$ and particle constituents including trace metals (As, Cd, Cr, Mn, Ni and Pb), ions (Cl^- , Na^+, Mg^{2+}, Ca^{2+}, K^+, NO_3^-, SO_4^{2-} and NH_4^+) and 16 US EPA priority PAHs were determined. The analysis included 31 meteorological parameters obtained from the Global Data Assimilation System (GDAS). Using R package descriptive statistics, probability density functions, correlation analysis and time series analyses as well as eXtreme Gradient Boosting (XGBoost) model using by applying Shapley Additive exPlanations (SHAP) were performed. Unmix receptor model was applied for source apportionment. To illustrate the potential of SHAP, benzo[a]pyrene (B[*a*]P) and benzo[*b*]fluoranthene (B[b]F) were chosen to characterize environmental conditions that shape their behavior in both indoor and outdoor environments based on factor importance (SHAP values), impacts (SHAP dependency), mutual relations (relative SHAP values), interactions (SHAP interactions) and characterizations (SHAP force). The correlation showed relationships between 5- and 6-ring high molecular weight PAHs and CO. Unmix resolved four source profiles for both the indoor and outdoor environments. The major contributor to PAHs emissions was combustion of low-calorie lignite of poor quality and high moisture content. The PAHs associated with B[*a*]P specific behavior and fate were chrysene (Chry) and B[*b*]F as main factors, followed by benz[*a*]anthracene (B[*a*]A), indeno[1,2,3-*cd*] pyrene (I[*cd*]P), benzo[k]fluoranthene (B[k]F), fluoranthene (Fla), dibenz[a,h]anthracene (D[ah]A), (pyrene) Pyr, and benzo[g,h,i]perylene (B[ghi]P). Less important associations were attributed to CO, As, Cr, $PM_{2.5}$, and soil moisture. Dominantly related with B[*b*]F were B[*a*]P, B[k]F, B[ghi]P, I[*cd*]P, D[ah]A, Chry, B[*a*]A, Fla and Pyr); and minor: CO, Rn, As, Cr, SO_4^{2-}, NH_4^+ and NO_3^-, indicating aerosol formation and oxidative degradation.

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Oral presentation

Zoran Lulić, Vjekoslav Sraga, Goran Šagi, Petar Ilinčić

DETERMINATION OF EMISSIONS FROM INTERNAL COMBUSTION ENGINES

Keywords: *road vehicles, non-road mobile machinery, NRMM, non-road emissions, emission inventory*

Considering the trend of the constantly growing number of road vehicles as well as non-road vehicles and machinery, it is easy to conclude that they have a significant impact on total emissions. On the one hand, this is an obvious problem, and on the other hand, the verification of their impact is still quite unknown to the general public and, often, also to professionals dealing with emissions and environmental protection.

For both of these groups i.e., vehicles and machines, it is characteristic that they are powered by internal combustion engines. Modern internal combustion engines (ICE) are considered rather complicated machines. Therefore, there are unknowns about its working principles and processes within the ICE and even less about the determination of its emissions.

Although looking at the media reports, it can be concluded that electric powertrains will replace ICE in road vehicles and non-road machinery in a relatively short period, it will still take a significant amount of time for that to happen. Within the lecture, a review of different methods of measuring emissions will be given with a particular emphasis on the difference in the measurement of emissions in laboratory conditions and in real driving conditions, i.e., real use cases. A brief review of changes in legislation (Euro 0, 1, 2, ..., 6, 6b, 6dTemp, 6e, 7) and their impact on emission measurement methods is also given.

As the change in legislation introduced verification of emissions in real driving conditions, so-called Real Driving Emissions (RDE), as an obligation in a Type Approval process, the method of determining RDE and the necessary equipment are described, and examples of measurements are shown.

It is known that within the framework of Type Approval (homologation), it is necessary to check vehicle emissions, but what the procedure includes and when all emissions are checked is, as a rule, unknown, so due attention has been paid to the difference between the procedure for determining emissions within the framework of vehicle homologations and periodic technical inspection (PTI).

In the final part, there is a review of the determination of fleet emissions of both vehicles and machines, as well as the problems encountered when creating an emissions inventory.

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Poster presentation

Branko Petrinec, Nora Miljanić, Dinko Babić, Davor Rašeta, Jasminka Senčar

^{137}Cs IN THE AIR OF ZAGREB, CROATIA, IN 2022

Keywords: *radioactivity, ^{137}Cs, ^{134}Cs, activity concentration, gamma-ray spectrometry*

The Radiation Protection Unit of the Institute for Medical Research and Occupational Health has been monitoring and analysing airborne radioactive matter since 1962, which has been carried out as part of the monitoring or environmental radioactivity in the Republic of Croatia. Air is sampled by pumping it through Petiran filters (FPP-15-1.5) positioned 1.5 m above the ground and connected to an ASS-500 HVS (high volume sampler) pump. These samples are subsequently analysed by means of high-resolution gamma-ray spectrometry. This method has been accredited according to the HRN EN ISO/IEC 17025:2017 standard, and it is used for the activity concentration determination of anthropogenic and naturally occurring radionuclides. In the wake of the Chernobyl disaster, a significant amount of anthropogenic ^{137}Cs leaked out into the environment, which has called for monthly checks of its presence in the air. The used gamma-ray spectrometry system is based on a GAMMA-X HPGe ORTEC detector with a resolution of 2.2 keV and a relative efficiency of 74%, all at 1.33 MeV ^{60}Co, coupled with an electronic system and a computer. The energy and efficiency calibration were performed using calibration standards by the Czech Metrology Institute, which covered energies between 40 and 2000 keV. Monthly values of the activity concentration of airborne ^{137}Cs in Zagreb in 2022 are shown. They averaged at 0.57 μBq/m^3, whereas the maximum and minimum values were recorded in December (1.32 μBq/m^3) and August (0.23 μBq/m^3), respectively. Besides ^{137}Cs, we have also monitored ^{134}Cs, a radionuclide that is produced only in nuclear reactors. No ^{134}Cs was found in the air during 2022, which implied that there were no accidents in nuclear power plants during this year.

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Poster presentation

Nikolina Račić[1], Teo Terzić[2], Anja Bošnjaković[3], Mario Lovrić[3], Gordana Pehnec[1], Ivana Jakovljević[1], Zdravka Sever Štrukil[1], Silva Žužul[1], Jasmina Rinkovec[1]

ANALYZING THE RELATIONSHIP BETWEEN GAS CONSUMPTION AND AIRBORNE POLLUTANTS: A CASE STUDY OF ZAGREB, CROATIA

Keywords: *air pollution, gas consumption, metals, PAHs, PCA*

The polycyclic aromatic hydrocarbons (PAHs) and metals present in particulate matter significantly contribute to the health risks associated with air pollution. This paper presents a comprehensive analysis of the relationship between gas consumption and the concentrations of PAHs and metals in the PM_{10} fraction of particulate matter. By utilizing advanced statistical techniques and Python models, the study investigates the potential associations and quantifies the relationship between gas consumption patterns, meteorological conditions and the measured concentrations of PAHs and metals in the atmosphere. To gain insights from the complex dataset, a combination of statistical techniques was used, including Principal Component Analysis (PCA), correlation analysis and Non-Negative Matrix Factorization (NMF). PCA analysis identified patterns and reduced dataset dimensionality, facilitating a better understanding of variable relationships. Variables that are strongly correlated or have similar patterns of variation tend to cluster together in the PCA results. Gas consumption (kWh), mass concentrations of fluoranthene and arsenic in PM_{10} were grouped together, indicating their potential relationship. Mass concentrations of cadmium and lead formed a cluster, suggesting a shared source or common factors influencing the concentrations of these metals in air pollution, while copper, iron, and manganese formed a separate cluster, indicating potential similarities in their sources or influencing factors. Additionally, NMF provided valuable insights by decomposing the data into non-negative components, enabling the identification of the source contributions and temporal variations providing valuable information for understanding PAHs and metals pollution dynamics over the studied period. These insights can inform policymakers, urban planners, and environmental stakeholders in implementing effective strategies to mitigate air pollution and promote sustainable energy consumption practices in the city of Zagreb.

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Poster presentation

Thomas Reichert, Ronny Hanich-Spahn, Peter Brantsch

EMISSIONS OF THE AERONAUTICS MANUFACTURING SECTOR BASED ON GLOBAL MARKET DATA AND ITS POTENTIAL DERIVATION

Keywords: *CO2e-emissions, global aviation manufacturing, ecodesign, re-use and recycling, life cycle assessment*

The aeronautics sector has been regarded as an important contributor to environmental problems, due to fuel consumption and combustion emissions. Additional emissions are coming from aircraft manufacturing, aircraft end-of-life and recycling.

The complexity of aircraft systems and the lack of public data have prevented analysis of aggregated contributions of the value chain to key environmental problems - analysis that could provide valuable insight to reduce environmental impacts. In European-funded projects with partner organizations Fraunhofer developed a new mapping method to quantify the environmental burden of industrial areas, such as the aeronautics manufacturing sector.

The mapping performed by partners usually builds on environmental databases and available market data representing high percentage rates of the sector's sales (e.g. Aviation: 84% in 2017). The mapping results for aircraft production (EDES Project) show that material resources and aircraft manufacturing consumed 69.5 TWh energy (aggregated site-specific energy consumption), emitted therefore 18.1 MtCO2e, and withdrew 475 million m^3 water.

The largest contributions stemming from airframe manufacturers and aluminium alloy production. Carbon emissions predominantly occur in the manufacturing stage while water withdrawals mainly originate from the material production.

Based on the global manufacturing data collected by the partners, Fraunhofer ICT expand the system boundaries for the life cycle assessment with the reuse and recycling quota developed in the ecoDESIGN transversal activity in Clean Sky 2. Applying the processes to the global amounts of materials in the system.

Due to the expected changes in the material mix in the aviation industry, there is as well a forecast derivative possible for future aircraft manufacturing scenarios, as well as different forecast scenarios for variation to the electricity and energy supply changes by using renewable energy.

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Oral presentation

Vjekoslav Sraga, Goran Šagi, Petar Ilinčić, Zoran Lulić

EMISSIONS FROM NON-ROAD MOBILE MACHINERY

Keywords: *NRMM, non-road emissions, emission inventory*

According to their source, emissions are divided into stationary and mobile. Stationary sources include industrial sources (energetics, industrial production and households), while mobile sources usually include means of transport such as road vehicles and rail, air, maritime or inland water traffic. In addition to the above, mobile sources also include non-road mobile machinery (NRMM). This group is often unknown and neglected, and research show that they significantly impact total emissions.

The significance of this impact is most often expressed by the ratio of total emissions to the total energy consumed, which indicates that in total emissions for the same amount of energy used, NRMM contributes more than similar mobile sources.

Their influence was recognised early on so that as far back as 1997, the European Union adopted Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in NRMM. The directive was adopted and amended several times, and in 2016 Regulation 2016/1628 on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for NRMM was adopted.

Given the extremely wide area, that Regulation 2016/1628 encompasses, two Delagated and one Implementing Commission Regulation have been issued to date, expanding the scope and establishing the emission requirements for NRMM in the European Union. The regulation sets out the obligations of Member states, which include ensuring that the NRMM placed on the market or put into service complies with the emission limits specified in the regulation. To achieve this successfully, Member states are required to conduct market surveillance activities to verify the compliance of NRMM with the emission requirements by conducting checks and inspections, taking samples, and performing tests to ensure that the NRMM meets the applicable standards. Those activities are carried out by a technical service, i.e., a testing laboratory designated by the Member State's approval authority.

To fulfill these obligations, the project National Reference Laboratory for Emissions from Internal Combustion Engines for NRMM (NRLE) was launched in the Republic of Croatia, with the goal to establish and equip the laboratory with appropriate measuring equipment and additionally educating the staff who will be able to conduct the planned activities.

The project is currently in the phase of finishing construction works on the reconstructed laboratory building and ending the public procurement of equipment and facilities.

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AMBIENT AIR POLLUTION MONITORING

Poster presentation

Nataša Belšak Šel, Uroš Lešnik

CONTINUOUS 10-YEAR AIR QUALITY MEASUREMENT IN MARIBOR STARTING IN 2013 WITH PMinter PROJECT

Keywords: *PM_{10}, Maribor, PMinter project, air quality*

The dominant air pollutants in middle Europe with a major negative impact on health are currently particulate matter (fine dust, PM_{10}, $PM_{2.5}$), NO_2 (nitrogen dioxide), O_3 (ozone) and B(a)P (benzo(a)pyrene).

Non-compliance of the European limit values for PM_{10} (40 µg/m³ annual average, 35 days with maximum beyond 50 µg/m³ for 24-hour average, Ambient Air Quality Directive EC/50/2008) in Maribor (Slovenia), Klagenfurt and Leibnitz (Austria) has led to the curiosity of exploring the influences of possible dominant sources (traffic, domestic heating, industry) and their contribution rates. Because of that during 2010–2013 National Laboratory of Health, Environment and Food has been a partner of the PMinter project (Operational Programme Slovenia-Austria 2007-2013, Interreg Project). The main objective of PMinter project has been the development of methods and air pollution control plans that facilitate a sustainable improvement of the air quality as well as a reduction of health hazards (because of polluted air) for the people of Klagenfurt in Lower Carinthia, Leibnitz in Southern Styria (Austria) and Maribor in Northern Slovenia.

Along with other research, air quality was measured by means of 10 mobile and stationary measurement stations in the regions of Klagenfurt, Leibnitz and Maribor. In Maribor has been established a stationary measurement station on which air quality has been continuously monitored to this date (Maribor Krekova/Tyrševa).

Outdoor air quality plans, which helped to reduce ambient concentration levels (along with renewal of car fleet, modernisation of heat devices, implementation of energy efficiency policy – thermal insulation of buildings etc) have been proven to be successful. A trend of dropping concentrations of PM_{10} has been seen in measuring location Maribor Krekova/Tyrševa, annual limit value in the period 2013-2021 has been never exceeded, number of exceedances of daily limit value was over prescribed in years 2014, 2015 and 2016. In the 10-year monitoring of air quality, there is a noticeable trend of air quality improvement.

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Oral presentation

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ULTRAFINE PARTICLES (UFP) - RECENT TRENDS AND REGULATORY ACTIVITIES

Keywords: *ultrafine particles, particle number concentration, particle size distribution, monitoring*

For many years, mass-based $PM_{2.5}$ and PM_{10} measurements have been standardized (DIN EN 12341:2014) for the regulatory quantification and monitoring of particles in ambient air. However, recent studies reported that ultrafine particles, which are defined as particles equal or smaller than 0.1 μm, seem to be a better indicator of harmful air pollution in urban areas. Therefore, the measurement of the particle number concentration (PNC), which is most representative of ultrafine particles (UFP) has gained much interest and importance.

Reports such as Leipzig Environmental Zone from 2017 (https://publikationen.sachsen.de/bdb/artikel/29757) focusing on UFP and their harmful effects that have been made publicly available helped spread the word on the relevance of UFP monitoring. In 2019, a team of experts summarized the current knowledge on UFP in a white paper on ambient ultrafine particles (https://research.qut.edu.au/ilaqh/2019/11/08/white-paper-on-ambient-ultrafine-particle-evidence-for-policy-makers-published-on-the-efca-website/). This report has been cited by the World Health Organization in the WHO Global Air Quality Guidelines published in September 2021 (https://www.who.int/publications/i/item/9789240034228). For the first time, these guidelines mention the need to expand the common air quality monitoring networks by integrating UFP measurements. It recommends to include size-segregated particle size distributions (PSD) and real-time PNC measurements in addition to simultaneous measurements with other airborne pollutants and characteristics of PM.

In order to harmonize and standardize these measurements, the European Committee for Standardization (CEN) has published the technical specification CEN/TS 16976:2016 for PNC measurements in ambient air using a Condensation Particle Counter (CPC). Based on it, a German standard DIN EN 16976 'Ambient air Determination of the particle number concentration of atmospheric aerosol' is currently being finalized. In addition, the CEN/TS 17434 technical specification for measuring the particle size distribution of ambient air by Scanning Mobility Particle Sizers (SMPS, or 'Mobility Particle Sizer Spectrometer', MPSS, in regulatory terms) was published in 2019.

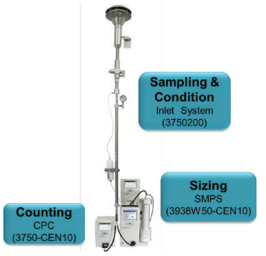

Figure 1: CEN-compliant solution for UFP measurements of PSD and PNC including the dedicated sampling system

Finally, the proposal for a Directive of the EU Parliament and of the Council on ambient air quality and cleaner air for Europe (COM/2022/542 final) was published in October 2022. The intention of this document is to align EU air quality standards much more closely with WHO the aforementioned recommendations.

Against the background of all these regulatory activities, the technical solution for reproducible sampling, conditioning and measurement of UFP as well as the necessary data handling are presented. The complete measurement solution from TSI (see Fig. 1) is compliant with the aforementioned CEN technical specifications and it meets requirements of the ACTRIS European Research Infrastructure Consortium.

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Poster presentation

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SECONDARY AEROSOLS AT AN URBAN BACKGROUND SITE IN THE NORTHERN COAST OF THE ADRIATIC SEA

Keywords: *fine particulate matter, ions, EC, OC*

Air pollution as a consequence of elevated levels of fine particulate matter ($PM_{2.5}$) is a major scientific concern worldwide. Because of its small size and complex chemical composition, $PM_{2.5}$ has the ability to penetrate in the alveolar region of the human respiratory system and cause severe illnesses like cancer or even premature death. $PM_{2.5}$ can be produced as primary particles from anthropogenic and/or natural sources. Depending on ambient temperature, relative humidity, solar radiation, and other oxidizing pollutants present in the air, $PM_{2.5}$ are also produced as secondary products from its gaseous precursors. In coastal environments, $PM_{2.5}$ can contribute to nutrient enrichment and acidification and influence complex sea-surface microlayer reactions. The World Health Organization (WHO) advises regulating $PM_{2.5}$ levels in the air as well as its chemical composition in order to determine possible sources and predict potential harmful influences on human health and the environment.

The aim of this study was to determine the mass concentrations of elemental (EC), organic (OC), and total carbon (TC) as well as water-soluble inorganic anions (Cl^-, NO_3^-, SO_4^{2-}) and cations (Na^+, NH_4^+, K^+, Mg^{2+}, and Ca^{2+}) at an urban background site located in the northern part of the Adriatic coast and examine their levels, seasonal and yearly variations and to determine its possible sources. $PM_{2.5}$ mass concentrations were investigated from January 1st 2017 to December 31st 2021. $PM_{2.5}$ sampling was conducted in parallel on two samplers during 24-hour periods from approximately 55 m^3 of ambient air on Pall quartz fiber filters pre-fired at 850°C for 3 hours for determination of carbon content and on PTFE and Pall quartz filters for determination of water-soluble ions content. Mass concentrations of $PM_{2.5}$ samples were determined gravimetrically according to the standard EN 12341:2014. Carbon content was measured according to the standard EN 16909:2017 with the thermal-optical transmittance method (TOT) and EUSAAR_2 temperature program. The content of water-soluble ions was determined by ion chromatography according to the standards CEN/TR 16269:2011 and EN 16913:2017.

The obtained results showed that in each year during the period of measurement, the annual average $PM_{2.5}$ mass concentration did not exceed the limit value of 25 μg m^{-3}, and higher $PM_{2.5}$ mass concentrations were observed during the winter season. The average TC mass contribution to the total $PM_{2.5}$ mass was 33%, of which 21% SOC (secondary OC), 7% POC (primary OC), and 5% EC. Carbon mass concentrations revealed strong seasonality with low values in summer and high values in winter. Clear seasonal variations were also observed for Cl^-, NO_3^-, K^+, and Na^+ with higher values in the winter season, while for SO_4^{2-} and NH_4^+ higher values were observed in the summer season. The average value of OC/EC mass ratio around 6.5 pointed to the contribution of secondary organic aerosols, while factor analysis indicated the presence of several other air pollution sources present in the northern part the of Adriatic coast.

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Oral presentation

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MASS CONCENTRATIONS OF CARBON POLLUTANTS IN PM_1 AT AN URBAN BACKGROUND LOCATION

KEYWORDS: *five-year trend, correlations, EC, OC, LVG, PAHs, WSOC*

Long and short-term exposure to ambient air pollution can trigger acute and chronic illnesses (cardiovascular diseases and asthma) or infectious diseases, preterm birth, earlier mortality, and adverse neuropsychological effects. The most important anthropogenic sources of primary particulate matter in cities are exhaust and non-exhaust emissions from road traffic as well as incomplete fuel combustion (diesel and gasoline) and resuspension from street surfaces. The mass concentration of particulate matter with an aerodynamic diameter below 1 μm (PM_1) and its chemical composition depend strongly on the surrounding sources of pollution (traffic, household heating, road salting during colder periods, etc.), as well as meteorological factors (i.e., low ambient temperatures, temperature inversions, precipitation).

The aim of this study was to determine and compare levels of elemental carbon (EC), organic carbon (OC), total carbon (TC), water-soluble OC (WSOC), polycyclic aromatic hydrocarbons (PAHs), and levoglucosan (LVG) mass concentrations as well as black smoke index (IBS) in PM_1 particles between seasons and years, in order to find the possible existence of trends for individual pollutants in PM_1 at one urban background location in Zagreb during a 5-year period.

Daily samples of PM_1 particle fraction were collected on pre-fired quartz fiber filters from January 1st, 2018 to December 31st, 2022 and their mass concentrations were determined gravimetrically. Samples were analyzed for OC, TC, WSOC, and, EC with thermal/optical transmittance method using a EUSAAR_2 protocol, PAHs were determined using high-performance liquid chromatography with a fluorescence detector, and time-programmed changes in excitation and emission, LVG was analyzed by high-performance anion-exchange chromatography with pulsed amperometric detection, while IBS was determined with the EEL43M Smokestain reflectometer.

Results of the 5-year measurements showed seasonal variations of mass concentrations for carbon species in PM_1. The higher mass concentrations of measured/analyzed carbon pollutants were observed during the cold periods, while lower mass concentrations were recorded during the warmer periods of the 5-year campaign. The five-year trend and mutual correlations are presented and discussed.

ACKNOWLEDGEMENTS: *These measurements were conducted within the internal scientific project of the Institute for Medical Research and Occupational Health "Organic content of PM_1 particle fraction" (PI: R. Godec).*

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Poster presentation

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MONTHLY ACTIVITY CONCENTRATIONS OF ^{7}BE IN THE AIR OF ZAGREB, CROATIA

Keywords: *radioactivity, ^{7}Be, activity concentration, gamma-ray spectrometry*

Monitoring and analysis of airborne radioactive matter has been done by the Radiation Protection Unit of the Institute for Medical Research and Occupational Health as a part of monitoring the environmental activity in the Republic of Croatia since 1962. Samples were collected by pumping the air through Petiran filters (FPP-15-1.5) positioned 1.5 m above the ground and connected to an ASS-500 HVS (high volume sampler) pump. High-resolution gamma-ray spectrometry method, accredited according to the HRN EN ISO/IEC 17025:2007 standard, was used to analyse the collected samples. High-resolution gamma-ray spectrometry is used to determine activity concentrations of anthropogenic and naturally occurring radionuclides, which are either of terrestrial or cosmogenic origin. One of the most important gamma emitters in the air is cosmogenic ^{7}Be, which is produced in the upper Earth's atmosphere as a result of interactions between cosmic rays and airborne atoms. It has a relatively short half-life of 53.3 days. Being naturally occurring, ^{7}Be is always present in the air and is regularly monitored because changes in its concentration might signal unusual disturbances in the atmosphere. Gamma-ray spectrometry system used in this research is based on a GAMMA-X HPGe ORTEC detector with a resolution of 2.2 keV and a relative efficiency of 74%, all at 1.33 MeV ^{60}Co, coupled with an electronic system and a computer. The energy and efficiency calibration were performed using calibration standards by the Czech Metrology Institute, which covered energies between 40 and 2000 keV. Monthly values of the activity concentration of airborne ^{7}Be in Zagreb in 2022 averaged at 3.81 mBq/m^{3}. The maximum was recorded in May (5.79 mBq/m^{3}) and minimum values were measured in December (1.54 mBq/m^{3}). According to UNSCEAR 2000, the average value for troposphere is 12.5 mBq/m^{3}, which exceeds the values measured in Zagreb.

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Poster presentation

Nenad Periš, Angela Stipišić

AIR QUALITY IN THE AREA OF THE CITY PORT OF SPLIT

Keywords: *air, particulate matter, heavy metals, SO_2, NO_2, CO*

Maritime transport, together with road and air transport represent a source of environmental pollution. According to the report on the impact of European maritime transport on the environment, published in 2021 by the European Environment Agency, maritime transport is a significant source of gas emissions, particularly CO_2 and SO_2.

The reason for the increasing number of passenger ships and cruise ships in the City Port of Split every year due to the size and exceptional location of the City Port of Split on the Mediterranean. Potential sources of air pollution are not only maritime traffic but also the proximity of the bus and railway station, along with increased road traffic in the port.

Air quality measurements were carried out in the area of the City Port of Split by the Public Health Institute of Split and Dalmatian County, by measuring the following pollutants: particulate matter fractions $PM_{2.5}$ and PM_{10}, metals (As, Cd, Ni and Pb) in particulate matter, and gases NO_2 and SO_2. Measurements of NO_2 showed that the hourly value in the period of 2018 exceeded the limit value (LV) 8 times (LV for NO_2 is 200 μg/m^3, must not be exceeded more than 18 times during the year). Daily values of PM_{10} in the period of 2018 exceeded the limit value 4 times (LV is 50 μg/m^3, must not be exceeded more than 35 times during the year). Air quality in the City Port of Split was assessed according to the Regulation on air pollutant levels (OG 77/20). Regarding the amount of measured concentration of pollutants in the ambient air, in 2018 the air quality was of the first category, i.e. clean or slightly polluted air.

The reduction of maritime traffic in 2020 is a consequence of the COVID-19 pandemic however it is expected to increase again. The pollutants' levels in the air are consequently also expected to rise. Therefore, the Public Health Institute of Split and Dalmatian County has restarted air pollution measurements in May 2023.

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Poster presentation

Jasmina Rinkovec[1], Marija Antolak[1†],
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MONITORING OF HYDROGEN SULPHIDE AND MERCAPTANS IN THE AIR IN THE VICINITY OF THE ZAGREB CENTRAL WASTEWATER TREATMENT PLANT

Keywords: *air pollution, H_2S, R-SH, spectrophotometry*

The Central Wastewater Treatment Plant Zagreb (CWWTZ) is the first wastewater treatment concession in Croatia and it enables the City of Zagreb to comply with the European Union's ecological standards in the field of environmental and water protection. The monitoring of specific air pollutants in the area of possible influence of wastewater treatment plant on the surrounding air has been carried out since the plant began operating.

Hydrogen sulphide (H_2S) and mercaptans (R-SH) belong to the group of compounds with unpleasant and irritating odours, and their elevated concentrations in the air can significantly impact the quality of life. In Croatia, the Regulation on Levels of Air Pollutants (OG 77/2020) prescribes concentration limit values (LV) based on the quality of life (odour annoyance) for 24-hour concentration averages (5 μg/m^3 and 3 μg/m^3 for H_2S and R-SH, respectively) as well as the frequency of permitted exceedances during the calendar year (≤ 7 times).

Daily samples of hydrogen sulphide and mercaptans were collected at five monitoring stations (CWWTZ and the surrounding area) for thirty days each during winters and summers over a five-year period (2018-2022). Mass concentrations of hydrogen sulphide and total mercaptans were determined spectrophotometrically.

At all five of the monitoring stations, average mass concentrations of hydrogen sulphide for winter periods ranged from 0.67 μg/m^3 (2020) to 2.38 μg/m^3 (2021), while higher values were obtained in summer periods, from 0.63 μg/m^3 (2019) to 10.78 μg/m^3 (2021). In the period 2018-2020, levels of H_2S were below LV during both monitoring periods. However, during the summer periods of 2021 and 2022, 24-hour H_2S mass concentrations exceeded LV at one (18 times) and three (20, 11 and 11 times) stations, respectively. Since 7 exceedances of the limit value are allowed during the year, the air quality at these monitoring stations was considered unsatisfactory, i.e. the results indicated that the air quality was of the 2nd category (polluted air) with regard to H_2S.

For mercaptans, the average mass concentrations during the winter period ranged from 0.38 μg/m^3 (2018) to 1.41 μg/m^3 (2021), while they were slightly lower in summer periods, ranging from 0.31 μg/m^3 (2018) to 1.13 μg/m^3 (2022). During the five-year monitoring of mercaptans, the LV was never exceeded for both, winter and summer periods.

Occasional exceedances of H_2S limit values indicate the need for further continuous monitoring of air quality in the area of possible influences of the wastewater treatment plant.

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Poster presentation

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TRADESCANTIA ANDERSONIANA: A NEW PLANT SPECIES FOR *IN SITU* BIOMONITORING OF AIR QUALITY

Keywords: *Tradescantia, air quality in situ monitoring, genotoxicity, micronuclei*

The *Tradescantia* micronucleus assay is the most widely used bioassay to detect genotoxins in the environment. This type of test is based on detecting micronuclei, which refer to clastogenic and aneugenic effects in meiotic pollen tetrad cells. Several species of the genus *Tradescantia* can be used but here we wanted to compare two species of plants belonging to the genus, in particular, *Tradescantia* clone #4430, and *Tradescantia andersoniana* which has never been used before for these types of studies. These plants can be exposed to chemical and complex mixtures in different ways, but *in situ* biomonitoring is the most widely used. In the first part of this work, we wanted to better understand the interspecies differences in the spontaneous mutation rate and the reaction of a single species to two known mutagens. The mutagens investigated were maleic hydrazide (MH) and ethyl methane sulfonate (EMS) at different concentrations: 1, 2, and 4 mM for MH and 0.25, 0.5 and 1 mM for EMS. Initial results showed a linear increase in the number of micronuclei as the concentration of the maleic hydrazide mutagen increased in both species analyzed. An interesting response was found, however, for the ethyl methane sulfonate mutagen: it showed toxic effects and inhibition of tetrads production at the highest tested concentration (1 mM) in *Tradescantia andersoniana* and a slight decrease in tetrad production in the case of the clone #4430. These interesting results showed that the two *Tradescantia* species have different characteristics and thus, responses. In the second part of this work, we used these two species to conduct an *in situ* biomonitoring study in the area of Borgo Val di Taro, Italy, to assess the air quality. Specifically, the overall objective of the study was to provide homogeneous and comparable data on the quality of the environment, and in particular on the presence of airborne genotoxic agents. The first results showed a good level of air quality in fact, the number of micronuclei remains under the literature threshold, but this study allowed us to indicate *T. andersoniana* as one of the most suitable species for environmental biomonitoring using *Tradescantia*.

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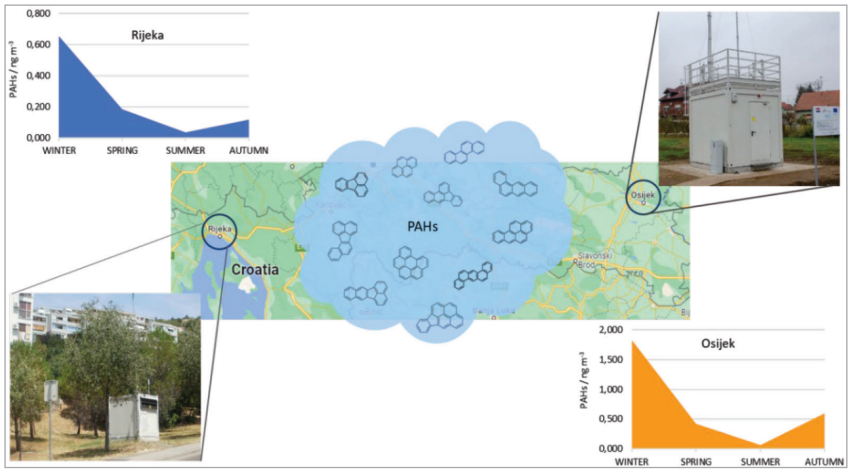
Poster presentation

Zdravka Sever Štrukil, Ivana Jakovljević, Gordana Pehnec, Ivan Bešlić

LEVELS OF POLYCYCLIC AROMATIC HYDROCARBONS IN URBAN AREAS OF OSIJEK AND RIJEKA

Keywords: *PM_{10} fraction, AIRQ project, HPLC*

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals that occur naturally in coal, crude oil, gasoline, fossil fuels and can be released into the air during the incomplete combustion of wood, biomass or fossil fuels. The less efficient the burning process is, the more PAHs are released. Levels of PAHs in urban air may be 10 times greater than those found in rural areas. Because long-term exposure to PAHs can cause cataracts, kidney and liver damage, jaundice and in some cases cancer, it is very important to give PAHs high priority when considering air quality management and the reduction of their impacts. Sampling of the PM_{10} fraction was carried out at two locations, in the city of Osijek in eastern, continental Croatia and the city of Rijeka in western, coastal Croatia. Both monitoring stations are part of the national network for continuous air quality monitoring and were equipped as part of the AIRQ project ("Expansion and Modernisation of the National Network for Continuous Air Quality Monitoring"). At both locations, 24-hour samples were collected continuously for 30 days in every season in 2022. Concentrations of 11 measured PAHs (fluoranthene (Flu), pyrene (Pir), benzo(a)anthracene (BaA), chrysene (Kri), benzo(b)fluoranthene (BbF), benzo(k)fluoranthene (BkF), benzo(a) pyrene (BaP), dibenzo(a,h)anthracene (DahA), benzo(ghi)perylene (BghiP) and indeno(1,2,3-cd)pyrene (IP)) were determined by high performance liquid chromatography (HPLC) with a fluorescent detector. In Osijek, the average mass concentrations of PAHs were 2 to 3 times higher than those measured in Rijeka, except in autumn, when they were as many as 5 times higher in Osijek (0.598 ng m^{-3}) compared to Rijeka (0.118 ng m^{-3}). A similar seasonal variation was observed at both locations, following the decreasing trend winter > autumn > spring > summer and winter > spring > autumn > summer in Osijek and Rijeka, respectively.



Institute for Medical Research and Occupational Health, Ksaverska c. 2, 10000 Zagreb, Croatia

Poster presentation

Iva Smoljo[1], Gordana Mendaš[1], Gordana Pehnec[1], Dragana Mutavdžić Pavlović[2]

TEMPORAL VARIATIONS AND SOURCES OF SEMIVOLATILE ORGANIC COMPOUNDS IN PM_{10} PARTICLE FRACTION

Keywords: *PAHs, OCPs, PCBs, temporal distribution, source analysis*

Air pollution in both cities and rural areas, according to the latest data from the World Health Organization, causes 4.2 million premature deaths worldwide. Particulate matter (PM) is recognized as a special risk to human health, causing respiratory and cardiovascular diseases such as cancer of the respiratory tract, with increasing evidence of effects on other organ systems as well. Polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and organochlorinated pesticides (OCPs) are among the group of semivolatile components of PM known for their carcinogenic and mutagenic potencies. Although PCBs and OCPs were banned decades ago under the Stockholm Convention, their levels are still being detected in all environmental compartments due to their persistence and long-distance transport. In the European Union, there is a legal obligation to monitor PAHs in the PM_{10} particle fraction in ambient air, but the measurements are limited to a smaller number of measuring stations compared to the other parameters that are monitored. PCBs and OCPs are not covered by air protection regulations, and data on their concentrations in PM in Croatia are scarce.

In this study, a one-year campaign was conducted in 2022 at an urban background station located in Zagreb, Croatia, to investigate the temporal variations and the sources of PAHs, OCPs, and PCBs in the PM_{10} particle fraction (particles with an equivalent aerodynamic diameter < 10 μm). Weekly PM_{10} samples were collected continuously from approximately 700 m^3 of ambient air on quartz fiber filters (Pall, 90 mm) pre-fired at 400 °C for 4 hours. Mass concentrations of PM_{10} were determined gravimetrically. Filters were extracted in the solvent mixture of hexane and dichloromethane by accelerated solvent extraction, concentrated under a gentle nitrogen stream, and analyzed. Analysis of 12 PAHs was performed by gas chromatography coupled with triple quadrupole mass spectrometry (GC-MS/MS) and analysis of 17 PCBs and 7 OCPs by gas chromatography with electron capture detector (GC-μECD). Molecular diagnostic ratios were used to determine the sources of PAHs, while α-HCH/γ- HCH, β-/(α+γ)-HCH ratios and homologous group distributions were used to determine the sources of OCPs and PCBs, respectively.

This study represents the first results of simultaneous measurements of PAHs, PCBs, and OCPs in the PM_{10} particle fraction in Zagreb, which in addition to the knowledge about levels, temporal changes and sources, provide their intercomparison as well as comparison with similar locations around the world.

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Poster presentation

Suzana Sopčić, Ranka Godec, Ivan Bešlić, Gordana Pehnec

ANHYDROSUGAR DISTRIBUTION IN DIFFERENT PARTICULATE MATTER FRACTIONS AND THEIR SEASONAL PATTERN

Keywords: *levoglucosan, biomass burning, HPAEC-PAD, seasonal variations*

The presence of levoglucosan and its isomers in airborne particulate matter in southeastern Europe has so far been rarely studied. They are known as tracers for biomass burning and are quite reliable markers since they only form by cellulose and hemicellulose pyrolysis. The current EU directive on ambient air quality has still not been regulated with regard to the monitoring of levoglucosan as a biomass burning tracer, which could explain the lack of information in terms of annual levels, seasonal variations, meteorological condition dependence, etc. Besides the annual levels and seasonal variations, which are expected due to different origins of anhydrosugars throughout the year, it is important to get better insight into the presence of such compounds in different particle fractions. Although there is no evidence of anhydrosugar toxicity, information regarding the distribution of anhydrosugars between particle size fractions and their composition is in general valuable for the health aspect since it is known that the smaller the particle is, the deeper the penetration into the respiratory system. This research aimed to determine the mass concentrations of levoglucosan, mannosan, and galactosan in particle fractions PM_{10}, $PM_{2.5}$, and PM_1, to find the relation between anhydrosugars bounded to three different size fractions and to determine their seasonal dependence. The samples of all three fractions were collected simultaneously at an urban background monitoring station by a low volume referent sampler with an airflow of 55 m^3/day. The mass of collected samples was determined gravimetrically according to the EN 12341:2014 standard. After sample preparation, which included ultrasonic extraction in ultrapure water and centrifugation, the samples were analyzed by high-performance anion-exchange chromatography with pulsed amperometric detection. Results showed that the average mass concentrations of PM_{10}, $PM_{2.5}$, and PM_1 decreased in the following order of seasons: winter, spring, summer, and autumn. The maximum 24-hour mass concentration obtained for the PM_{10} fraction was 65 μg m^{-3}. Average mass concentrations of anhydrosugars were the highest during the winter season followed by autumn, spring, and summer when the levels of mannosan and galactosan were often below the limit of detection. In every particle fraction, the levels of levoglucosan were the highest compared to mannosan and galactosan. Linear regression analysis of data collected in the winter season revealed that levoglucosan was mostly present in particles with smaller aerodynamic diameters, $PM_{2.5}$ and PM_1. Results showed that more than 85% of levoglucosan is bounded to $PM_{2.5}$ fraction when compared to PM_{10} fraction, while the relation between PM_1 and $PM_{2.5}$ fraction revealed that more than 75% of levoglucosan is bounded to PM_1 fraction.

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Oral presentation

Liina Tõnisson, Honey Alas, Leizel Kecorius, Sebastian Düsing, Mira Pöhlker

SEMANTIC WEB APPROACH FOR INDOOR AIR QUALITY: ONTOLOGY DESIGN

Keywords: *indoor air pollution, semantic web, taxonomy, ontology, Human-Centered Ontology Engineering Methodology, air quality data*

The European Environmental Agency reported that most urban populations were exposed to concentrations of fine particulate matter ($PM_{2.5}$) and particulate matter of ≤10 μm in diameter (PM_{10}) above World Health Organization (WHO) recommendations, that is 74% and 42%, respectively. Importantly, air pollution is currently one of the leading causes of premature death in the world. A systematic review and meta-analysis from 2020 noted that in 2017 household air pollution was associated with 1.8 million deaths and more than 60 million disability-adjusted life years globally. According to the Environmental Protection Agency, indoor levels of pollutants may be up to 100 times higher than outdoor pollutant levels and have been ranked among the top 5 environmental risks to the public. Indoor air pollution is correlated with significant respiratory health effects. The negative health effects range from attenuated lung growth and development in childhood to accelerated lung function decline and are determined by chronic obstructive pulmonary disease later in life.

Smart home devices, equipped with modern air quality sensors, collect relevant data on pollutants. Indoor pollutants can therefore be tracked and mapped to related negative health effects to advance help disease prevention. There is a need of developing a robust, scalable, and consistent indoor air quality ontology domain model that plays an imminent role not only in the advance of indoor air quality monitoring systems but also serves as an element in the related diseases management systems. This research is based on Human-Centered Ontology Engineering Methodology (HCOME). HCOME is a collaborative ontology engineering methodology, that supports active user involvement and iterative processing as the agile development methodology does. The study presents a review of existing ontologies in the indoor pollution domain and contributes to science with a state-of-the-art ontology for indoor air quality. We present a semantics-based approach for characterizing and exposing the air quality data, so that the ontology can be made available for the purpose of the pilots in the Evidence Driven Indoor Air Quality Improvement (EDIAQI) project.

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Poster presentation

Vedran Vađić, Predrag Hercog, Bojan Abramović

AIR QUALITY MONITORING AT DUBROVNIK AIRPORT, CROATIA

Keywords: *Dubrovnik Airport, air quality, environment*

Air quality measurements at the new measurement station Dubrovnik Airport (DA), Croatia, were started in May 2019. Measurement of nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), benzene and particulate matter fraction PM_{10} and $PM_{2.5}$ were established. All measurements were carried out by the Ekonerg Air Quality Monitoring Laboratory. Measurement of NO_2, SO_2, O_3 and benzene were carried out with automatic reference methods. Measurement of PM_{10} and $PM_{2.5}$ fractions of particulate matter were carried out with non-referent automatic methods and the preparation of an equivalence study according to the reference method is planned.

The measurement station is suburban, situated in the south-eastern part of Dubrovnik Airport, very close to potential emission sources from air transport without any disturbance to the airflow in the vicinity. Measurement station should indicate emissions from air transport and their impact on air quality. It is located 250 meters from the runways. Ćilipi, a neighbourhood in the immediate vicinity, is located in the south, right next to the airport. On the south and west side is the Adriatic Sea, and on the north and east is the mainland. The station is connected by the internet with the control computer in the Ekonerg Air Quality Monitoring Laboratory from where raw data is submitted every hour to the Air Quality Portal in Croatia managed by the Ministry of Economy and Sustainable Development.

Air quality monitoring results for all pollutants were analysed for the period May 2019 to December 2022. Measurement data showed that the concentrations of NO_2, SO_2 and benzene were significantly lower than the limit values (LV) and even lower than the upper and lower assessment thresholds. The average annual concentrations of suspended particles PM_{10} and $PM_{2.5}$ were also significantly lower than the limit value and below the upper and lower assessment thresholds. Daily concentrations of PM_{10} also did not exceed the allowed number of days exceeding the daily LV.

Concentrations of O_3 exceeded the environmental objective because the target value was exceeded more than the allowed 25 days per calendar year averaged over three years and the air quality was in the second category regarding to ozone. As ozone is a very well-known as a global pollution issue, action on a local level is insufficient to reduce ozone concentrations in the air; it is necessary to take action at the regional and global levels.

EKONERG – Energy and Environment Protection Institute, Koranska 5, Zagreb, Croatia

MACHINE LEARNING AND AIR QUALITY MODELLING

Poster presentation

David Cemernek, Alexander Hiebl, **Lorenz Dirry**

KNOW-CENTER DATA PLATFORM: A CENTRAL DATA MANAGEMENT ACCESS POINT FOR EDIAQI

Keywords: *data management system, FAIR principles, collaborative research, data analytics and data discovery*

The EDIAQI (Evidence Driven Indoor Air Quality Improvement) project operates within the field of air quality monitoring and environmental science. As air pollution continues to pose significant health risks and environmental challenges, the project aims to create science-based solutions for monitoring indoor and outdoor air pollutants. Given the complex nature of the field which involves multiple data sources, measurements and analyses, there is a crucial need for a central data access point. The Know Data Platform (KDP) is a data management system developed by the Data Management for AI team at Know-Center to support these demands in the EDIAQI project. Built on the iRODS data management system, the KDP ensures secure and distributed storage while adhering to the FAIR principles for improved data findability, accessibility, interoperability, and reusability. KDP utilizes Metalnx as its graphical user interface, allowing users to easily upload, download and share data, as well as manage permissions and metadata. Elastic search enables efficient data discovery through keyword searches and filters, ensuring that users can quickly locate relevant data based on their needs. Additionally, the KDP incorporates Keycloak as its authentication system to ensure secure access to the platform. By integrating Keycloak into the KDP, the platform ensures that only authorized individuals can access and interact with the research data, enhancing data security and privacy. For data analytics, the platform offers JupyterHub and Apache Zeppelin, providing a collaborative and interactive environment for researchers to analyze and work with shared data. JupyterHub supports Jupyter notebooks, while Apache Zeppelin focuses on data analytics with built-in support for various data sources. By having a centralized data access point, collaborators can easily access and utilize the data collected from the EDIAQI pilots and campaigns. This facilitates collaborative research, enables accurate assessments of air quality, and supports the development of revised standards and regulatory measures.

Know-Center, Sandgasse 36, 8010 Graz, Austria

Poster presentation

Michael Forsmann[1], Astrid Sevelsted[1], Morten Rasmussen[1], Mario Lovrić[1,2]

A NEW MODEL-BASED INDOOR AIR QUALITY INDEX (IAQI) AND ITS ASSOCIATION WITH CHILDHOOD RESPIRATORY DISEASES

Keywords: *Indoor Air quality, health outcomes, respiratory illnesses, assessability.*

Childhood asthma and respiratory illnesses are common diseases among multiple risk factors. Indoor air pollution has previously been linked to respiratory illness. Air quality indices and estimations are commonly based on one or several pollutants measured. However, indoor air quality is a complex matter influenced not only by particulate matter or volatile organic compounds but also the microbial composition, allergens, and a multitude of rarely characterized pollutants also related to the habits of inhabitants. Simultaneous measuring of multiple determinants is rarely feasible, and novel approaches are needed to estimate Indoor air quality.

Based on data from the two clinical birth cohorts COPSAC2000 and COPSAC2010, we here present a model-based approach to infer an Indoor Air Quality Index (IAQI) from available data on indoor air quality, using a mixed effect regression model for longitudinal data. The approach is based on learning indoor air pollutant levels and modeling them from potential sources, such as the presence of pets, carpets, and other sinks for pollution, outdoor environment, etc.

The COPSAC2000 cohort of 411 high-asthma-risk children born around the year 2000 was used to generate the IAQI. The cohort is data-rich with three indoor measurements of $PM_{2.5}$, black carbon, formaldehyde, acetal, and acetone at ages 6, 12, and 18 months. Utilizing the detailed data on early life family exposures, IAQI is generated and validated with the actual air pollution measures. The inferred model can be applied in the later COPSAC2010 cohort of 700 children born around 2010, where detailed indoor air quality measurements are lacking. The result is a larger cohort of 1111 children with an estimated IAQI in early life. This aim is to associate the IAQI with health outcomes utilizing the deep phenotyping of asthma and health in both birth cohorts; including nasal microbiome; repeated metabolomics; repeated lung function measurements and clinically based diagnosing of asthma and related diseases.

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Poster presentation

Vesna Gugec, Darijo Brzoja, Velimir Milić, Stipica Šarčević

PRACTICAL EXAMPLE OF USING ADMS 6 DISPERSION MODEL FOR ASSESSING AIR POLLUTION IMPACT FROM THE WASTE INCINERATION PLANT IN ZAGREB, CROATIA

Keywords: *case study, incineration plant, ADMS 6, dispersion modeling*

The project aiming to establish a comprehensive infectious medical waste management system at Zagreb clinical hospital is included as a strategic initiative in the National Recovery and Resilience Plan, focusing on the healthcare system of the Republic of Croatia. The objective of the project is to implement an integrated system for the management of infectious medical waste that adheres to overarching principles of environmental protection, precautionary measures, sustainability, technological feasibility, economic viability, resource conservation, and overall environmental, human health, economic, and societal impacts. The proposed facility for managing infectious medical waste is planned to be constructed within the premises of the Rebro hospital complex, situated in the Maksimir district of Zagreb.

ADMS 6, an advanced dispersion model primarily utilized for assessing the impact on air quality resulting from existing and proposed industrial installations, enables the simulation of diverse buoyant and passive releases into the atmosphere. Meteorological and emission data are used within the model to calculate parameters such as the boundary layer height and the Monin-Obukhov length, along with a skewed Gaussian concentration distribution to determine dispersion under convective conditions. ADMS 6 is capable of including other input data such as building heights, terrain configuration, and surface roughness. The models' notable features account for dry and wet deposition processes, and NOx chemistry schemes as well.

In this study, the ADMS 6 model was employed to evaluate the potential air quality impact arising from the construction of the infectious medical waste management facility at Zagreb clinical hospital. The input technical data utilized was obtained from the environmental impact study conducted for the infectious medical waste management facility at Zagreb clinical hospital. The meteorological data used was sourced from the meteorological station - Zagreb Maksimir.

The results reveal the dispersion and dilution of the plume within the surrounding neighborhood area. It is evident that the influence of nearby buildings and the geographical positioning of the hospital, particularly the incinerator, play a significant role in determining the spread of pollution.

Croatian Meteorological and Hydrological Service, Ravnice 48, 10000 Zagreb, Croatia

Oral presentation

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PREDICTIVE ANALYTICS OF AMBIENT PM_{10} CONCENTRATIONS USING GENETIC ALGORITHM

Keywords: *air pollution, PM_{10}, prediction algorithm*

Ambient PM_{10} concentrations have a major impact on human health. Due to their small size, the particles penetrate deep into the lungs and represent a significant risk for the respiratory and cardiovascular systems. Despite strict regulation, a major part of the population is breathing air with pollution levels above the Air Quality Guidelines (World Health Organisation). The accuracy of the prediction models gives the possibility to the decision makers to reduce emissions with short-term measures. If the prediction model can predict the contributions of individual source groups (for example, traffic), this can give us the possibility to predict the change in air quality due to lower traffic intensity (for example, a ban on older vehicles with high emission rates in the city center on polluted days). To achieve that, machine learning with a genetic algorithm was used to find an optimal definition of the prediction model, with 26,280 hourly samples of PM_{10} ambient concentrations, detailed traffic data (categories and speed) and ambient conditions (temperature, relative humidity, pressure, wind speed and direction, rain rate). The acquired statistical model is human interpretable, and analysis has shown compliance with other studies. We find the model itself more accurate than other methods, especially when a smaller learning population is used for forecasting. From 2457 forecasted daily values for the period January 1st 2013 to March 31st 2020, it was accurate 2245 times (91%), if compared to real measured values. Results also show that the impact of traffic is decreasing on the test site. The presented prediction model cannot predict exceptional events (fireworks, burning of wood). Despite being used only for forecasting of PM_{10} in this case, the model can also be used for predicting other pollutants (NO_X, NO_2). However, the accuracy in these cases should be verified.

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Oral presentation

Velimir Milić, Vesna Gugec, Stipica Šarčević, Darijo Brzoja

MODELING QUALITY OBJECTIVES - BENCHMARKING

Keywords: *air quality models, FAIRMODE, benchmarking, statistical indicators, model quality objectives*

All models are a simplified representation of reality, so the question arises about their quality. It is important to determine whether the used model is fit for its intended purpose. This is especially important to anyone who will use the modeled results in real-world applications. FAIRMODE community developed a standardized approach to benchmarking air quality models. It takes into account the definition of useful statistical indicators and the definition of criteria they have to meet in order for the model to be deemed fit for purpose. The core set of statistical indicators uses pairs of modeled and measured data (both yearly averages and time series data). The core set of statistical indicators are Root Mean Square Error (RMSE), Correlation coefficient (R), Normalized Mean Bias (NMB), and Normalized Mean Standard Deviation (NMSD). This core set is then used to build up other indicators. It is important to note that the uncertainty of measured data is taken into account. Usually, the allowed deviation between modeled and measured concentrations is twice the measurement uncertainty. FAIRMODE has developed a standalone IDL based model evaluation software to assist with the benchmarking process (FAIRMODE DELTA - A&P) that is available to download (https://aqm.jrc.ec.europa.eu/Section/Assessment/Background). One can not only rely on comparing statistical indicators. All relevant factors (characteristics of the model in use, quality of input data, location of measurements) must be included in the analysis. The best example, that is common, is comparing measurements from urban traffic sites with regional models. Since urban traffic sites are not representative of a large area, it is unreasonable to expect that any regional model can reproduce measured concentrations. Regional models will underestimate concentrations at urban traffic sites, so it is best to leave such stations out of the benchmarking process. FAIRMODE DELTA – A&P tool provides two instructive output diagrams. For example, benchmarking scores for LOTOS-EUROS simulation of PM_{10} for the year 2017 are provided. The first diagram is the „Target plot" that visualizes the main aspects of model performance. It provides quick insight into what stations satisfy the model quality objective and also provides the most important source of error. In our example, most of the inconsistency is due to correlation, and negative bias. The second diagram is the „Summary Report", which is a complementary table that includes an overview of statistics for observed concentrations, temporal and spatial statistics.

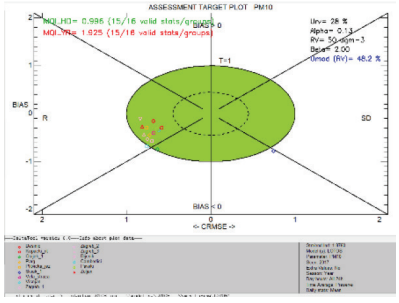

Figure 1 FAIRMODE DELTA Assessment target plot

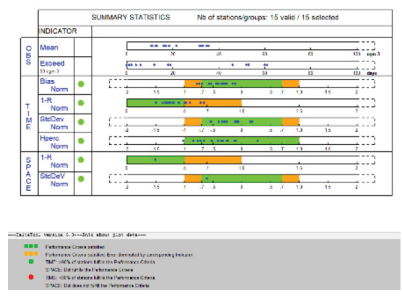

Figure 2 FAIRMODE DELTA Summary statistics

Croatian Meteorological and Hydrological Service, Ravnice 48, 10000 Zagreb, Croatia

Poster presentation

Kristina Pavlović[1], Valentino Petrić[2],
Hussain Hussain[1], Emmanuel Karlo Nyarko[3], Heimo Gursch[1], Roman Kern[1], Mario Lovrić [3,4]

MACHINE LEARNING MODEL DEGRADATION FOR THE PREDICTION AND FORECASTING OF HOURLY AMBIENT PM_{10}, NO_X AND O_3 POLLUTANT CONCENTRATIONS

Keywords: *air pollution, air quality, machine learning, long-term prediction, hybrid models*

Accurate prediction of air pollutant concentration is essential for developing strategies to reduce said concentration, predict the effects air pollutants cause and contribute to the understanding of the impact on public health. The application of machine learning models in the prediction of air pollutant concentrations has already been applied successfully. However, the potential for long-term prediction is still to be researched. This study investigates the predictive power of diverse machine learning models for long-term air pollutant concentrations and analyzes how the predictions deteriorate over time and across seasons. Air quality data were collected from five monitoring stations in the city of Graz and used for model training and validation. The target variables were hourly concentration of nitrogen monoxide (NO), nitrogen dioxide (NO_2), ozone (O_3) and particulate matter (PM_{10}), while the independent features were temporal, satellite and meteorological variables. The training data spans the period from January 1st, 2014, to March 15th, 2019, and the testing data set extends one year further.

The utilized machine learning algorithms include Random Forest, Prophet, long short-term memory networks (LSTM), convolutional neural networks (CNN) and multi-layer perceptron's (MLP). Furthermore, a hybrid model was generated using Random Forest as a baseline with features from the Prophet model. For each pollutant and each measurement station, a model was trained on the training set and predicted for the testing set. The predictions were then analysed by calculating root mean square error (RMSE) as the performance measure. Lastly, the mean RMSE is calculated across the stations for each pollutant and compared between the models to identify the most suitable model for each pollutant regarding their degradation in long-term predictions.

The results show that in the case of the NO_2 pollutant the prediction quality degrades during the colder months of the year, but the models are overall stable. A similar pattern can be seen for PM_{10}. For NO there seems to be a degradation for some of the algorithms, while our hybrid model shows good stability over time. O_3 remains relatively stable over time compared to the other pollutants but has more variance when comparing models to each other. For all pollutants, considering RMSE, the hybrid model was performing best, including long-term predictions.

This study contributes to a deeper understanding of the predictive capabilities achievable by machine learning models for air pollution. The results give valuable insights into the effectiveness of different machine learning models for the prediction of air pollutant concentrations and their temporal and seasonal variations.

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Oral presentation

Michael Poelzl[1], **Mario Lovrić[2,3]**, Roman Kern[1,4]

FEASIBILITY OF TRANSFER LEARNING FOR THE PREDICTION OF PM_{10} IN MEASUREMENT NETWORKS

Keywords: *machine learning, modelling, air quality, pollution*

Increasing individual mobility and industrialization leads to a rise in air pollution, especially in urban areas. Particulate matter with an aerodynamic diameter less than 10 μg/m³ (PM_{10}) is commonly used to determine urban air quality. People with respiratory conditions are particularly affected by low air quality. Therefore, predicting an increase in air pollutants is of paramount importance.

Since PM_{10} concentration is influenced by meteorological factors, machine learning (ML) models trained on large meteorological and air quality data sets appear suitable for short and long-term pollution prediction. However, air quality monitoring stations are costly, which makes building a dense sensor network for accurate predictions not economically viable. Further, existing ML methods cannot be directly applied, since they expect data to follow certain assumptions, most prominently the independent and identically distributed data assumption. For different stations and especially for different cities, distribution, and dataset shifts are expected, potentially introducing a bias in the predictions.

To overcome those restrictions, techniques that allow predictions even if the data does not match historical records are explored. We address the lack of knowledge in understanding the gap, which can be observed as a dataset shift. In our experimental setup, meteorological and pollutant data from measurement stations in Graz, Austria, and data from one measurement station in Zagreb, the capital of Croatia are used. Both cities occasionally violate the EU regulation's maximum number of days (35), on which a daily mean value for PM_{10} of 50 μg/m³ is exceeded. Common ML models such as Random Forests (RF), Multilayer Perceptrons (MLP), Long-short-term memory (LSTM), and Convolutional Neural Networks (CNN) are explored to predict particulate matter in both cities. This allows for model selection as a base for further analysis of individual and joint influence factors.

Our detailed analysis of PM_{10} suggests that similarities between the models and the meteorological features exist and can be further exploited. Hence, advanced ML techniques, such as transfer learning, are applicable to close gaps in the air quality measurement network. To sum up, the results show the feasibility of different transfer learning techniques to improve particulate matter prediction on a city-level transfer from Graz to Zagreb.

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Oral presentation

Jurgo Preden, Veiko Rütter

REAL-TIME & COST-EFFECTIVE INDOOR AIR QUALITY MONITORING AND MANAGEMENT

Keywords: *indoor climate dashboard, indoor climate management*

Accurate assessment of indoor air quality is a pre-requisite for good air quality management. Typically, short-term audits or spot measurements are used for assessing indoor air quality in a building. The current paper presents an automated solution that offers continuous real-time monitoring and analysis of critical building indoor climate parameters and visualization of the analysis results.

A Cloud-based solution was developed in the context of the building energy and indoor climate digital audit (DigiAudit) (a project supported by Horizon 2020 agreement 856602) project for automatic air quality class and thermal comfort class assessment in any building. The solution can be seamlessly integrated with existing sensors in a building. If a building is lacking necessary sensors, new wireless air quality sensors can be deployed within a few hours. Estonia has established indoor air quality and thermal comfort classes for buildings, these established classes are used for the assessment of buildings in the DigiAudit solution. The regulation to be adopted specifies the temperature levels for different times of the year (winter, summer, intermediate) and also CO_2 levels for indoor air quality. The data reported by the sensors is analysed by the algorithms developed by researchers at Tallinn University of Technology, air quality and thermal comfort classes are calculated and stored for every room in the building for a week, a month and also a year. Also, an aggregate assessment for the entire building is calculated based on the collected data. All the assessments can be viewed in an Interactive dashboard, where aggregate data can be viewed at a building level and detailed data at a room level.

In the context of the EDIAQI (Evidence Driven Indoor Air Quality Improvement) project a new type of sensor will be introduced to the system that also provides data on VOC, PM and NO_X, enabling a more accurate assessment of indoor air quality. These sensors will be also deployed in buildings in Tallinn, Estonia in the context of the project pilot. Similarly, automatic air quality assessment will be performed based on these newly collected data.

For management of air quality adequate ventilation is required in a building. The trivial solution is to ventilate the building at a maximum level (provided outside air facilitates this), however this approach is not energy efficient. A solution where data from the indoor climate assessment system is used to control ventilation intensity based on actual ventilation need – actual indoor air quality will be presented. Machine learning methods are used to train the AI control algorithms to achieve accurate control. In the future the facility manager can specify the desired indoor air quality and thermal comfort classes for the building and the system will automatically adjust building systems to maintain the desired level. The facility manager will also have an overview of the actual indoor air quality and thermal comfort classes calculated based on measured data, can assess if a building is performing at the desired level.

Thinnect Inc., Tallinn 11624, Estonia

DEVELOPING AND TESTING MEASURING METHODS

Oral presentation, Introductory

Martine Van Poppel, Jelle Hofman,
Jan Peters, Bart Baeyens, Jo Van Laer, Maarten Spruyt, Borislav Lazarov

AIR QUALITY SENSOR NETWORKS FOR EVIDENCE-BASED POLICY MAKING: GOOD PRACTICES ON CALIBRATION, VALIDATION AND SET-UP

Keywords: *sensor performance, test protocol, sensor networks, pilot studies, traffic*

Recent advances in sensor and Internet of Things (IoT) technologies have resulted in a wide range of commercially available "lower-cost" sensor systems that allow for quantification of relevant urban pollutants, e.g., particulate matter (PM_{10}, $PM_{2.5}$), nitrogen dioxide (NO_2) and ozone (O_3), at a much higher spatiotemporal resolution. These tools allow regional or local authorities to set up dedicated monitoring campaigns more easily. However, these lower-cost sensor technologies typically suffer from a lower accuracy when compared to the regulatory equivalent or reference methods. Moreover, they can be sensitive towards environmental conditions and other pollutants and experience sensor drift over time. This presentation will give insights in sensor validation, on-site data quality procedures and the set-up of a sensor network.

European standardization of test protocols to evaluate the performance characteristics of sensor systems is needed and is an important step to include sensor system measurements into the monitoring of air quality for regulatory and non-regulatory purposes. TC264 WG42 (Working Group 42 of Technical Committee 264 on Air Quality of the European Committee for Standardization) has been working on a protocol for the evaluation of sensor systems for air quality monitoring. A protocol to evaluate gas sensors, is already available and a protocol for PM sensors is currently being developed. The protocol defines procedures and requirements for the evaluation of sensor systems and applies to sensor systems as individual measurement devices to be used for indicative measurements/objective estimation as specified under Directive 2008/50/EC. Examples of laboratory test performed following to the protocol will be presented.

Two case studies were performed comprising a network of two commercially available sensor systems (Airly, Kunak) at three locations. The case studies addressed policy questions related to (1) the evaluation of the impact of local traffic interventions near a school and (2) the impact assessment of local traffic at a central square prior to the introduction of a new mobility plan. The sensor systems were benchmarked at a regulatory air quality monitoring station (AQMS) at different time intervals.

Both pilots demonstrate that air quality sensor networks can be used to quantify air quality impacts from local traffic (measures) if a proper methodological setup (background normalization) and data quality (recurrent calibration and co-location) procedures are used. A blueprint was developed to help local authorities in setting up local air quality senor networks.

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Poster presentation

Dario Dabić, Goran Purić

QUANTIFYING ENVIRONMENTAL CONTAMINATION: METHOD FOR DETERMINING POLYCYCLIC AROMATIC HYDROCARBONS IN AIR AND PM_{10}/$PM_{2.5}$ PARTICLE MONITORING

Keywords: *PUF, high volume sampler, accelerated solvent extraction, air quality, PM_{10}*

It is widely recognized that the presence of polycyclic aromatic compounds (PAHs) in the environment poses ecological risks, as they have been found to be toxic to biota. Moreover, certain PAHs are classified as carcinogenic and mutagenic, raising concerns about their potential long-term effects on human health. Furthermore, determining the mass of PM_{10} allows for estimating particle concentrations in the air and provides important information about air quality and human and environmental exposure. Therefore, the determination of overall PAHs concentrations in the air and the mass of PM_{10} is essential for assessing environmental quality, evaluating human exposure, and identifying potential sources of contamination.

Gravimetric determination was employed to measure suspended particulate matter in the air, specifically focusing on PM_{10} and $PM_{2.5}$, during the year 2022 at Puntijarka. The highest recorded mass concentration of PM_{10} in 2022 was in May, reaching 42.5 μg/m^3 at the Puntijarka station, while for $PM_{2.5}$ it was 32.8 μg/m^3. The range of average maximum and minimum values for PM_{10} in 2022 was between 2.1 μg/m^3 and 22.8 μg/m^3, while for $PM_{2.5}$ it was between 1.2 μg/m^3 and 14.7 μg/m^3.

To monitor cross-border pollution of PAHs, samples (polyurethane foam-(PUF) and PM_{10}) were collected in four different regions of Croatia using a high-volume sampler (DIGITEL DHA 80). The collected samples were then subjected to extraction using an accelerated solvent extraction system (Dionex ASE 350). To select the optimal extraction conditions for PAHs from collected air samples using ASE, various parameters such as solvent volume and type, extraction cell temperature, number of extraction cycles, etc., were investigated. The optimal conditions were determined, which involved using dichloromethane as the solvent (60% of the cell volume), maintaining an extraction cell temperature of 100 °C, and performing two cycles of extraction.

The concentration of PAHs in the air is determined using gas chromatography coupled with mass spectrometry (GC-MS/MS). The analytical method underwent thorough validation to ensure its suitability for the quantitative analysis of PAHs in air samples. By employing optimized methods, which yields extraction recoveries (> 80%) we can effectively monitor levels of PAHs in the air collected using a high-volume sampler. This methodology enables the assessment of both the gas phase (PUF) and airborne particle-bound PAHs, which is crucial for comprehending their distribution, transport, and fate in the atmosphere.

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Oral presentation

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EXPERIENCES IN FIELD CALIBRATION ON SENSOR SYSTEMS WITHIN THE EUROPEAN AirSensEUR PROJECT

Key words: *AirSensEUR, calibration, MLR, air quality sensors*

In 2020, the project "Deployments of lower cost ambient air quality sensor systems in urban environments" was initiated, co-funded by the European Union and involving 4 institutions (JRC, VITO, NILU and IMROH) from 4 countries (Italy, Belgium, Norway and Croatia). As part of the project, 100 sensor sets (AirSensEUR type) were installed in 4 cities (City of Zagreb, 17 sets) to test their reliability and ability to measure air quality in different weather conditions and different locations. The field calibration results of the AirSensEUR sensor systems will be presented. Calibration consists of establishing a deterministic relationship between the known measured values and raw sensor responses. Multiple Linear Regression (MLR) was mostly used for the calibration method in the project. Most of the MLR models use covariates such as meteorological parameters, e. g., air temperature (T_{air}) and relative humidity (RH), and cross-sensitivities from gaseous interferons, e.g., NO_2, NO, and O_3, to improve calibration. This dependency is related to the physicochemical properties of sensors according to the type of electrolyte, electrode, or semiconductor material, etc. The PM-sensors are sensitive to RH, which can be modelled by using the so-called Kohler theory to account for particle growth due to high RH. The sensor time-drift is rarely included in calibration covariates, since calibration is carried out over a few weeks and therefore the long-term drifting information is generally scarce. The calibrations were performed on CO, NO, NO_2 O_3, PM_{10}, $PM_{2.5}$ and PM_1 sensors.

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Oral presentation

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TESTING THE EFFICIENCY OF LOW-COST SENSOR SYSTEMS FOR NEAR REAL TIME MONITORING OF AEROSOL AND GASEOUS POLLUTANTS

Keywords: *field measurement campaign, characterization, correlation trends*

Air pollution remains the largest environmental health risk in Europe. EU member states continuously monitor key air quality parameters through their national monitoring networks, established according to Directive 2008/50/EC. Low-cost sensing systems provide enhanced spatial coverage of ambient air quality parameters, as well as serving for indoor air quality and personal exposure monitoring. They provide real-time, high-resolution data, at a cost of up to three orders of magnitude lower compared to standard/reference instruments. The data quality provided by these systems should be thoroughly characterised and the applicability must be investigated and defined.

Since December 2022, an intensive field measurement campaign is implemented, in order to evaluate the performance of two low-cost sensing systems proposed to be deployed during the InChildHealth project (2022-2026). A total of 7 devices were installed at an urban background and an urban traffic station in Athens, Greece. The stations are equipped with high quality reference instrumentation for the measurement of particulate matter and key gaseous species (NO_2, O_3, SO_2, CO, CO_2). The campaign will continue until June 2023, covering both cold and warm period.

Analysis of the initial data demonstrated that these systems may provide meaningful results for PM mass concentrations in different size fractions (PM_{10}, $PM_{2.5}$, PM_4 and PM_1). This is even evident at relatively low levels, as measured at the urban background station. Similar correlation trends were observed for all devices when assessed against the reference instruments (both in terms of correlation coefficients and slopes of linear regression), validating the good comparability of data obtained by the different low-cost instruments. Nevertheless, an underestimation of the PM concentrations was observed during days impacted by long-range transport of African dust, more pronounced with increasing particle size (Figure 1). Critical challenges related to the use of low-cost sensors, such as the detection threshold, range of concentrations, and linearity will be addressed, for both aerosol and gaseous pollutants.

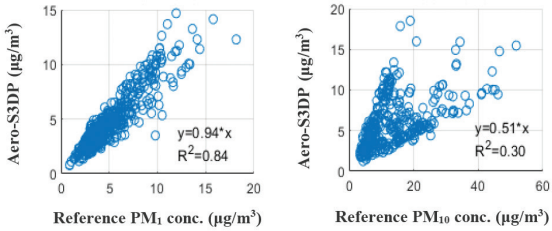

Figure 1 Linear regression analysis of 1-h PM_1 and PM_{10} concentrations obtained by low-cost & reference instruments

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Oral presentation

Predrag Hercog, Mario Šantolić, Mario Bilić

QUALITY CONTROL OF DILUTION UNITS FOR DYNAMIC DILUTION IN A CALIBRATION LABORATORY FOR AIR QUALITY

Keywords: *air quality, dilution units, quality control, z' score, En number*

The aim was to present one way of quality control for dilution units in a calibration laboratory for the calibration of instruments for monitoring air quality, using an example from practice in the Ekonerg calibration laboratory (UML). Dilution units are used to dilute reference gases (Primary Reference Material, PRM, Certified Reference Material, CRM) with purified air in order to generate the desired concentrations of gases in the air by the method of dynamic dilution. Using this method, a wide range of mixing ratios or concentrations of the diluted reference gas in the air can be achieved. Since the measurement uncertainty of the calibration gas is one of the most important components of the Calibration and Measuring Capabilities (CMC) of the calibration laboratory, the quality control of the operation of these devices is essential for laboratory quality control. Although the measurement traceability of the mass flow controllers (MFC) is ensured by calibrating the flow, in practice it has been shown that, for routine QC, control of the mixing ratio is better. This can be done indirectly using laboratory reference instruments for air quality. This approach is based on external quality control through proficiency testing (IS) at the EU Reference Laboratory for Air Quality (ERLAP) every other year and internal control that is carried out before and after the calibration of each of the dilution units in the laboratory itself. The proficiency assessment at the IS is based on the calculation of two parameters – the z' score and En number –calculated from the results and associated measurement uncertainties reported, and assigned values and their measurement uncertainties given by ERLAP. The z' score evaluates the accuracy of the laboratory at the measurement uncertainty given by the reference methods, so it is suitable for the assessment of test laboratories. The En number evaluates the accuracy of the results depending on the reported measurement uncertainty, so it is suitable for the evaluation / "defense" of the CMC of calibration laboratories. In seven IS for inorganic gases from 2009 to 2022, the Ekonerg UML achieved 98.7% z' score and 98.3% En number satisfactory results. Not passing the z' score happened only in the first year and only for O_3. This resulted in the corrective action of changing to a higher level of measurement traceability (CRM to PRM). After that, in the last 10 years, the passing rate was 100% for both criteria. Internal quality control consists of two procedures. In the first one, the En number is evaluated. It is calculated from the results from a referent instrument for a gas of known concentration, generated by the dilutor before and after its calibration and the measurement uncertainty of CMC on that concentration level. If the En number is < 1, it is proven that the dilutor generated gas concentrations with a measurement uncertainty at or below the CMC throughout the entire calibration period. In the second procedure, the same measurements are repeated with gas generated with other dilutors used in the UML. From the obtained results, the En number is calculated in the same way for all dilutors. If the En numbers are < 1, this means that other dilutors also give concentrations of the calibration gas within the CMC. These procedures, with minor changes, have been used in Ekonerg UML since 2019 and have always given satisfactory results.

EKONERG-Energy and Environmental Protection Institute, 10 000 Zagreb, Koranska 5, Croatia

Poster presentation

Tajana Horvat[1], Ivana Jakovljević[1], Iva Smoljo[1], Gordana Pehnec[1], Goran Gajski[2]

DEVELOPMENT AND OPTIMIZATION OF A TD-GC/MS METHOD FOR MEASUREMENT OF VOCs IN INDOOR AIR

Keywords: *indoor air pollution, volatile organic compounds (VOCs), gas chromatography*

In today's increasingly urbanized societies, the majority of their time people spend in indoor environments. Their activities influence indoor air quality, emitting various organic pollutants such as volatile organic compounds (VOCs). According to the World Health Organization (WHO), VOCs are defined as compounds with a boiling point of less than 250°C measured at a standard atmospheric pressure of 101.3 kPa. Also, VOCs comprise different chemical substituents such as alcohols, ketones, aldehydes, esters, halogens, amines, etc., that are emitted to the atmosphere from natural and anthropogenic sources. The most common indoor sources of VOCs are domestic products like cosmetics and sprays, cleaning solutions, cooking, smoking, off-gassing from building materials, renovation, and wood products for furniture or parquet. Concentrations in households mostly depend on ventilation and season. Previous studies have shown that indoor air has higher VOC concentrations compared to ambient air.

Some VOCs are important pollutants due to their carcinogenic and mutagenic impact on human health. Currently, regulations on the maximum allowed concentrations of VOCs in indoor air do not exist in the European Union.

The aim of this study was to develop and optimize an analytical method for the determination of nineteen VOCs (C_1 – C_9) in indoor air by thermal desorption coupled with gas chromatography and mass spectrometry (TD-GC/MS).

For the method development, thermal desorption multi-bed tubes packed with a combination of porous polymer, graphitised carbon black, and carbonised molecular sieves were used. TD tubes were spiked with a standard mix (CRM4877, Supelco) containing nineteen VOCs and were conditioned before the desorption analysis. Conditioning involved the continuous flow of high-purity carrier gas. Spiked TD tubes were heated in a desorber at elevated temperatures according to the temperature programme up to 320°C.

For the purpose of achieving better chromatography peak resolution and responses of nineteen VOCs, method parameters such as MS temperatures, hold time, and carrier gas flow were optimized.

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Poster presentation

Marija Jelena Lovrić[1], Silvije Davila[1], Gordana Pehnec[1],
Goran Gajski[1], Gianna Karanasiou[2], Panagiotis Demestichas[2], AIRWINGS Team[2]

PRELIMINARY COMPARISON OF AIR QUALITY SENSOR MEASUREMENTS WITH DATA FROM REFERENT MONITORING STATIONS – EDIAQI PROJECT

Keywords: *air quality, low-cost sensor measurements, pollutants, particulate matter, meteorological data*

Over the past few years, there has been a significant increase in the use of low-cost sensors for air quality monitoring. The relationship between the concentration of pollutants and their sources is one of the main topics of interest in environmental and health studies. The impact of air quality on human health has been widely researched with the conclusion that monitoring air quality is more important than ever, whereas recent studies have become more focused on indoor air quality monitoring. For the purposes of the Zagreb – pilot part of the EDIAQI (Evidence Driven Indoor Air Quality Improvement) project, two outdoor air quality sensors were placed in Zagreb, the capital of Croatia, for testing the sensors in real conditions. The sensors were placed at reference monitoring stations that are part of the Zagreb air quality monitoring network. One sensor was placed in the northern part of the city, at the Institute for Medical Research and Occupational Health (IMROH), which is an urban background station, and another one at the air quality monitoring station Peščenica in the eastern part of Zagreb with an industrial background. Considering the fact that sensor measurement accuracy and precision in previous studies have shown significant dependency on the location of the sensor, the purpose of this work was to determine the correlation between sensor measurements and the data collected at the reference monitoring stations. Particulate matter ($PM_{2.5}$ and PM_{10}), NO_2 and meteorological data (temperature, humidity, and atmospheric pressure) were chosen as relevant air quality parameters that can be used to determine data correlations. Hourly and daily averaged data for a time period of two months (April/May 2023) were collected from both sources. Statistical analysis was performed using Python libraries for data analysis. All of the results in this work are part of preliminary testing and further research will be carried out through the EDIAQI project.

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Poster presentation

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SAMPLING AND QUALITATIVE DETERMINATION OF ASBESTOS IN SOLID MATERIALS (AIR QUALITY ISO 22262-1)

Keywords: *asbestos, fibers, air quality, polarized light microscopy*

In the past, asbestos was used in a wide range of products. Three types of asbestos have found wide commercial use. Chrysotile was used in construction and industry for fire protection, heat insulation and sound insulation, in asbestos-cement products, as well as in woven, spun, felt and paper products.

Amosite and crocidolite account for almost all remaining asbestos use. Amosite was used as fire protection and in thermal insulation products. Crocidolite was used as fire protection and in thermal insulation and chemical insulation products, and was particularly important for the production of high-pressure asbestos-cement pipes for the delivery of potable water.

Materials containing anthophyllite are rare, but are also used as a filler and reinforcing fiber in composite materials, and as a filter media. Tremolite asbestos and actinolite asbestos have not been used commercially to any great extent. Other minerals may also occur as asbestos. For example, richterite asbestos and winchite asbestos occur in mass fractions between 0.1% and 6% associated with vermiculite, which was formerly mined in Libby, Montana, USA. Vermiculite from this source was widely distributed and is often found as loose insulation and as an integral part of a range of building materials and fire protection materials. The mass fraction of asbestos in products can be from 100% to 0.1%. The standard Air Quality ISO 22262-1 specifies the procedures for collecting samples and qualitative analysis of solid materials for the presence of asbestos. The primary method used to identify asbestos is polarized light microscopy (PLM). Although the norm specifies the possibility of visual assessment of the mass fraction of asbestos within very wide ranges, the accuracy and repeatability of such an assessment is very limited. The need to quantify asbestos in the material depends on the maximum mass fraction that defines the material containing asbestos. The definition of asbestos material goes from "any asbestos" to 0.1%, 0.5% or 1%.

The appearance of tremolite, actinolite or richterite/winchite is usually the result of natural contamination of the ingredients, and the detection of these minerals does not necessarily mean that the mass fraction of asbestos is greater than 0.1%. Since these minerals are not specifically mined and used, they can also appear in materials as non-asbestos or asbestos analogues, or as a mixture of both. Evaluation of these types of materials may require more detailed analysis.

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HEALTH IMPACTS OF AIR POLLUTION

Oral presentation, Introductory

Edoardo Franceschini[1], Mattia Acito[1], Tommaso Rondini[1],
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EFFECT-BASED TOOLS FOR MONITORING THE TOXICOLOGICAL EFFECTS OF AMBIENT AIR POLLUTANTS

Keywords: *air pollution, effect-based monitoring tools, genotoxicity, micronucleus test, comet assay*

Chemical monitoring of air pollutants under the European Union's Directives requires the chemical determination of only a limited number of xenobiotics. However, several ambient air monitoring studies have revealed the occurrence of even larger numbers of anthropogenic substances in the atmosphere than those covered under legal obligations. Chemical screening approaches allowing the detection and quantification of many chemicals in parallel confirm that contaminants co-occur in complex mixtures of many chemicals. Even if some of these pollutants might be present at low concentrations, general concerns raise about potential combination effects. Furthermore, it is known that from the sheer presence of a chemical its contribution to a combined effect cannot be deduced and that an explicit consideration of mixture toxicity should be warranted. Effect-based tools are suggested to complement monitoring efforts to detect specific effects directly rather than basing an evaluation on the concentration information for single compounds. Moreover, effect-based tools allow the detection of cumulative effects and are useful for bridging the gap between chemical contamination and biological effects.

Effect-based tools are generally categorized into three main classes, primarily depending on the monitoring approach: (i) bioassays, both *in vitro* and *in vivo*, which measure the toxicity of environmental samples under defined laboratory conditions, on cellular or individual levels, respectively; (ii) biomarkers, biological responses at the cellular or individual (organism) levels, measured in field-exposed organisms; (iii) ecological indicators, measuring changes observed at higher biological organization levels (*i.e.*, the population and/or community).

Genotoxicity endpoints, such as primary DNA damage (as evaluated by the comet assay) and cytogenetic effects (*e.g.*, micronuclei), can be evaluated both in *in vitro*/*in vivo* bioassays and in biomonitoring approaches where they assume the role of biomarkers in field-exposed individuals. Genotoxicity biomarkers are generally divided into "exposure biomarkers" measuring the interactions of a genotoxic xenobiotic or its metabolites with DNA (*e.g.*, primary DNA damage), and "effect biomarkers" measuring irreversible negative health effects (*e.g.*, chromosome aberrations, micronuclei). Among others, the comet assay and the micronucleus (cytome) test are the most widely used biomarkers in human biomonitoring/molecular epidemiology studies evaluating health effects in populations with residential exposure to airborne pollutants.

Overall, approaches using effect-based monitoring tools contribute to supporting public health policy and increasing the sensitivity of people to air pollution concerns.

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Oral presentation

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INDOOR AIR POLLUTION AFFECTS ALLERGIC DISEASES IN CHILDREN

Keywords: *allergy, asthma, children, indoor air quality*

Allergic diseases (asthma, rhinitis, rhinoconjunctivitis, eczema) are the most common chronic condition in children and represent a significant public healthcare issue worldwide. Environmental factors, particularly indoor and outdoor air pollution, have a crucial role in the development and clinical features and manifestations of these conditions. In order to gain better insight into the complex relationships between indoor air pollution and allergic diseases, we analyzed large-scale cohort and air quality data from the FP7 Atopica (Atopic diseases in changing climate, land use and air quality, Grant agreement number: 282687) cohort. 4015 children aged 4 to 9 years were recruited in daycare facilities and primary schools between 2012 and 2014 in 3 distinct geographical regions in Croatia differing in air quality data (with a focus on ragweed pollen concentrations) and other factors: Slavonia, Zagreb and surroundings and Dalmatia. Clinically relevant data and biological samples (whole blood) were collected, including data on atopy and allergy (skin prick test to a standard palette of inhaled allergens, ISAAC phase II questionnaire, total serum immunoglobulin E - IgE) along with other data - demographic, socioeconomic, lifestyle data, pollen symptom, and medication diaries during ragweed pollination seasons, outdoor and indoor air quality data, etc. Within the Horizon EDIAQI (Evidence Driven Indoor Air Quality Improvement) project (Grant agreement number: 101057497) we analyzed this retrospective cohort data in relation to air quality data using state-of-the-art machine learning algorithms (random forest) and logistic regression. The logistic regression model revealed that the predictor variable "using central heating" is statistically significant in predicting sensitization to house dust mites (p= 0.03, coef.= -0.50). Similar effects were observed for "using central heating" and wheezing or whistling in the chest, a common symptom in asthma (p= 0.00, coef.= -0.50). Additionally, the model revealed an inverse trend for the variable "heating using fossil fuels," indicating its significance in predicting allergy symptoms to ragweed pollen (p= 0.02, coef.= 0.52). The source of heating may affect allergic diseases and allergy symptoms in children. Central heating seems to have a protective role in the development of allergic phenotypes, whereas using fossil fuels (coal or wood) seems to increase the risk of manifesting allergy symptoms (primarily rhinitis and rhinoconjunctivitis) to ragweed pollen, probably due to the increased production of different pollutants (CO_2, SO_2, particulate matter) when burning fossil fuel in households.

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Poster presentation

Goran Gajski[1], Marko Gerić[1], Ivana Banić[2], Mirta Milić[1], Vilena Kašuba[1], Luka Delić[1], Katarina Matković[1], Gordana Pehnec[3], Bojana Žegura[4], Mirjana Turkalj[5], Ivana Vrhovac Madunić[6], Vedran Micek[7], Davorka Breljak[6], Mario Lovrić[8]; Work Package 5 of the EDIAQI project

EVIDENCE DRIVEN INDOOR AIR QUALITY IMPROVEMENT (EDIAQI): AN OUTLINE OF TOXICOLOGICAL STUDIES

Keywords: *indoor air quality, human biomonitoring, in vitro, in vivo, health effects*

Understanding the mechanistic basis of indoor air pollution toxicity is dependent on the characterization of both exposure and biological responses. Hence, in the frame of Work Package 5 of the Horizon Europe "Evidence driven indoor air quality improvement (EDIAQI)" project, we aim to investigate the short- and long-term effects of indoor air pollution on human health. This will be done by implementing a two-way approach, by building on existing data from well-established and well-characterized cohorts using state-of-the-art machine learning algorithms as well as by recruiting new cohorts and implementing new research strategies. The project will thus focus on the evaluation and quantification of the effects of exposure to various chemical and biological pollutants on the development and specific clinical features of asthma and allergy in children as a vulnerable population. In addition to human biomonitoring, EDIAQI will also focus on *in vitro* and *in vivo* toxicological studies using cell and animal models. The genotoxic effects of indoor pollutants and their complex mixtures will be assessed in several models, including human blood, lung, and liver cells in 2D and 3D conformation. To evaluate the genotoxic effects and mechanism of action (MoA) of indoor pollutants, we will measure primary DNA damage and complex cytome damage using a battery of bioassays. As for the *in vivo* part of the project, a (sub)chronic inhalation toxicity study will be conducted in juvenile Wistar Hannover rats to determine the potential adverse effects of the selected indoor air pollutants in relation to dosage on mammalian pulmonary function. Whole-body plethysmography will be used to measure lung function as a primary endpoint effect on the respiratory system followed by a set of different measurements as well as genotoxicity assessment. Overall, by providing scientifically based data, the project aims to understand the sources, routes of exposure, and health effects of indoor air pollution.

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THE USE OF HISTORICAL DATA TO ASSESS THE CYTOGENETIC EFFECTS OF AIR POLLUTION ON THE HUMAN POPULATION

Keywords: *air pollution, general population, peripheral blood cells, genome instability, public health*

According to the World Health Organization (WHO), 99% of the world's population lives in areas where air quality limits are exceeded, leading to 6 million premature deaths annually. Air pollution is a variable complex mixture of particles, solids, and gases, of which particulate matter (PM), some polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOC) have been classified as human carcinogens. Moreover, WHO estimates a 15% increase in lung cancer mortality risk for every 10 μg/m^3 of $PM_{2.5}$ increase. Since DNA damage is considered one of the crucial events in cancer initiation, and there is a large database of historical data from human biomonitoring studies in our laboratory, the study aimed to associate genomic instability data evaluated by the comet assay (*N*=123) and the cytokinesis-block micronucleus (CBMN) assay (*N*=130) in the healthy Zagreb (Croatia) human population with air pollution data in the period from 2011 to 2015. Even though the majority of air quality parameters, including toxic metals and various PM constituents, were below regulatory limits and lower than those observed in neighbourning urban areas, levels of benzo(a)pyrene (B[a]P) and PM_{10} occasionally exceeded regulatory limits. Factor analysis of air pollution exposure data obtained for the examined period revealed four factors: PM, two metal factors (Mn, Cu, Fe, Zn, and Pb, Cd, As, Zn), and the fourth representing other pollutants (NO_3^-, Cl^-, organic carbon (OC), elemental carbon (EC), and B[a]P-negatively with SO_4^{2-}). For both sets of historical data, we did not observe a significant positive association between the parameters tested and measured air pollution parameters. Moreover, from our previous studies, we established an association of cytogenetic data with sun (UV) exposure, which is higher during the warmer part of the year, unlike air pollution, which is higher during the colder part of the year. Nevertheless, we will focus our future research on many other health-related biomarkers of exposure and effect to establish the impact of air pollution on the Croatian population, as well as to develop models predicting cytogenetic descriptors based on the air quality data.

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RAGWEED (*Ambrosia* spp.) POLLEN INFLUENCE ON AIR QUALITY IN CROATIA

Keywords: *air quality, ragweed pollen, biological air pollution, Croatia*

Global warming and environmental pollution directly affect air quality, and this must be seen through the interaction of various factors that have a significant impact on human health. The most important factors are meteorological indicators and the concentration of pollutants and pollen allergens in the air. Ragweed pollen, as an important component of biological air pollution, is directly responsible for the increase in respiratory allergies in the Republic of Croatia, especially in urban areas. The aim of this research is to show the presence of ragweed pollen in the air of selected localities in Croatia in the period from 2018 to 2022. The presented air quality is based on the results of biological parameters of air quality monitoring with an emphasis on ragweed pollen collected from the Croatian Aerobiological Network stations (Osijek, Beli Manastir, Đakovo, Našice, Virovitica, Slavonski Brod, Sisak, Kutina, Popovača, Varaždin, Koprivnica, Karlovac, Zagreb, Rijeka, Pula, Labin, Pazin, Poreč, Zadar, Šibenik, Split, Metković, Dubrovnik).

The ragweed pollination season is shown through indicators: beginning and end of the pollination season, duration of pollination, average maximum daily concentration, pollen index, allergic potential, and risk of exposure to ragweed pollen. The risk of exposure to ragweed pollen was assessed according to the Ragweed Pollen Alert System (R-PAS) (>10 and >100 p. grains/m^3 of air). Based on the obtained results, a ragweed pollen calendar was created for each researched area.

Considering the prevalence of ragweed in Croatia and its significant impact on air quality and human health, it is necessary to encourage and continue aerobiological research because they are the basis for creating action plans for ragweed spread control and assessing the impact of allergenic pollen on human health.

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AMBIENT AIR POLLUTION AND CARCINOGENIC ACTIVITY AT THREE URBAN LOCATIONS IN CROATIA

Keywords: *PM_{10}, PAHs, benzo(a)pyrene, HPLC*

Polycyclic aromatic hydrocarbons (PAHs) are a large group of semi-volatile organic matter forms with two or more aromatic rings. They originate from a variety of sources. Natural sources of PAHs include large forest fires and volcanic eruptions. Anthropogenic sources include emissions from the industry (coal, crude oil, heavy and light metals, etc.), waste combustion and the burning of various plastics without control. Automobile exhausts as well as domestic heating are important sources in urban locations. Because of the widespread distribution of PAHs in ambient air and their potential for carcinogenic and mutagenic effects on human health, the US EPA has classified sixteen species as priority pollutants; ten of sixteen were determined under this research.

In this study, the mass concentrations of ten measured PAHs in PM_{10} particle fraction were determined, and their carcinogenic activity was calculated. 24-hour samples of PM_{10} particle fraction were collected on quartz filters from about 55 m^3 of air over 70 days in the cold period and 60 days in the warm period at three locations in Croatia. Location A is an urban background station with a moderate traffic density in central Croatia with a population of 790,017 inhabitants. Location B was an urban background station in the north-east of Croatia with a population of 35,312 inhabitants and location C was an urban industrial station in the east of Croatia with 50,039 inhabitants. PAH concentrations were determined by liquid chromatography (HPLC) with a fluorescence detector. The following PAHs were analysed: fluoranthene (Flu), pyrene (Pyr), benzo(a)anthracene (BaA), chrysene (Chry), benzo(b)fluoranthene (BbF), benzo(k)fluoranthene (BkF), benzo(a)pyrene (BaP), dibenzo(a,h)anthracene (DahA), benzo(ghi)perylene (BghiP), and indeno(1,2,3-cd)pyrene (IP).

At all of the locations the mass concentrations of all measured PAHs and their carcinogenic activity were higher in the cold period compared to the warm period. In the cold period, the highest concentrations of all PAHs were observed at location C, followed by location B and then A. In the warm period, the highest concentrations of all PAHs were also at location C, while the lowest were at location B. The total carcinogenic activity was estimated to be the highest at location C and was in average 8.308 ng/m^3 and 0.173 ng/m^3 during the cold and warm periods, respectively, while at location A it was 3.232 ng/m^3 during cold and 0.120 ng/m^3 during the warm period. At location B total carcinogenic activity was 4.350 ng/m^3 and 0.075 ng/m^3 for cold and warm period, respectively.

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EVALUATION OF GENOTOXICITY BIOMARKERS BASED ON THE EXPOSURE TO AIR POLLUTANTS IN COLDER AND WARMER PERIODS IN THE GENERAL POPULATION OF ZAGREB (CROATIA)

Keywords: *air pollution, genotoxicity, human biomonitoring*

The growing demand for energy, the use of fossil fuels, the increase in traffic, as well as the increase in industrial production greatly contribute to air pollution in cities. It affects the environment and human health. The air in urban areas is a complex and variable mixture of various chemical compounds whose mechanism of action is not fully understood. Human biomonitoring provides very important information about environmental exposure and helps identify potential health risks. The aim of this study was to evaluate the comet assay descriptors and the frequency of micronuclei (MNi) in the human population living in Zagreb (Croatia) and relate them to air quality measurements. The study was conducted during the colder and warmer period of the 2021/2022 year and involved 60 healthy subjects (34 females and 26 males) aged 36±7 years living in Zagreb (Croatia). Both seasons were included because our earlier study showed that the concentration of air pollutants differs depending on the season. The assessment of primary DNA damage and chromosome/chromatid breaks were done according to standard comet assay and micronucleus test protocols, respectively. Air quality data was provided by an accredited laboratory and are part of the local and national network for air quality monitoring. Benzene, toluene, ethylbenzene, and isomeric xylenes (BTEX) were analysed in whole blood using headspace solid-phase micro extraction (SPME) followed by gas chromatography-mass spectrometry (GC-MS). All measured outdoor air pollution parameters were below the regulatory limit except for benzo[a]pyrene bound to PM_{10} particle fraction, which exceeded the regulatory annual limit level. The % tail DNA in peripheral blood lymphocytes of the participants was 1.22 ± 0.50% (colder period) and 1.78 ± 1.56% (warmer period), while the MNi frequency was 4.42 ± 3.67 (colder period) and 4.80 ± 4.18 (warmer period) and these results agree with our previous findings for the general population. We also used supervised machine learning methods to develop predictive models for % tail DNA and MNi based on biomarkers of air quality which indicated several polycyclic aromatic hydrocarbons (PAHs), $PM_{10,}$ $PM_{2.5,}$ and benzene as the best potential predictors. Taken together, we did not observe the major impact of air pollution on cytogenetic biomarkers, while our models can now be applied to other Croatian areas with different compositions of air pollutants.

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Poster presentation

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GENOTOXIC ACTIVITY OF TWO POLYCYCLIC AROMATIC HYDROCARBONS, BENZO[b]FLUORANTHENE AND BENZO[ghi]PERYLENE

Keywords: *PAHs, B[b]F, B[ghi]P, DNA damage, chromosomal damage*

Air pollution is one of the most important environmental risk factors for health, estimated to cause between four and nine million deaths worldwide, and is therefore of increasing concern to the environmental and health research community, environmental agencies and regulators, industry, and the public. Epidemiological studies have found a strong link between air pollution and respiratory diseases, increased incidence of respiratory infections, and even cancer. Major air pollutants include particulate matter, ozone, carbon monoxide, sulphur dioxide, nitrogen dioxide, lead, volatile organic compounds, and polycyclic aromatic hydrocarbons (PAHs). PAHs have a high toxic potential in terms of cytotoxicity, genotoxicity, mutagenicity, and carcinogenicity. These pollutants are formed during the incomplete combustion of wood, coal, fossil fuels, tobacco, and even food preparation. Consequently, PAHs can be ingested orally through contaminated food and by inhalation of polluted air. They include hundreds of chemicals with two or more fused aromatic rings. Some of them, such as benzo[b]fluoranthene (B[b]F) and benzo[ghi]perylene (B[ghi]P), have been identified as priority pollutants by various environmental agencies, partly because of their occurrence and partly because of their toxicity. They are classified by the International Agency for Research on Cancer (IARC) as possible human carcinogens (Group 2B) and as not classifiable, because of limited or inadequate experimental evidence (Group 3), respectively. Nevertheless, there is limited information on their potential genotoxic effects. Therefore, the aim of the present study was to evaluate their genotoxic activity in the human hepatocellular carcinoma cell line (HepG2), which has already been shown to be very sensitive for detecting (geno)toxic effects of xenobiotic compounds including PAHs. Cytotoxicity was determined by the MTT assay and genotoxicity by the comet assay and cytokinesis block micronucleus (CBMN) assay. The study showed that benzo[b]fluoranthene and benzo[ghi]perylene can affect DNA integrity and thus pose a risk to the exposed population. Therefore, it is urgent to further evaluate their risk to the healthy population.

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HEPATIC 3D CELL MODEL - A SENSITIVE APPROACH FOR DETERMINING THE ADVERSE (GENO)TOXIC ACTIVITY OF AIR POLLUTANTS

Keywords: *benzo[a]pyrene, B[a]P, 3D models, genotoxicity, flow cytometry, confocal microscopy*

Polycyclic aromatic hydrocarbons (PAHs) are considered one of the most serious human health problems and are formed by the incomplete combustion or volatilization of carbon (e.g., tobacco, wood, coal, petroleum, coal-tar-based seal coat products, etc.). Human exposure is associated with numerous diseases, including asthma and cancer in a number of target organs such as the liver and lungs. Benzo[a]pyrene (B[a]P), as the main representative of PAHs, is a ubiquitous environmental pollutant found in air, surface water, soil, and sediments. BaP is metabolized by cytochrome P450 to carcinogenic metabolites that form DNA adducts and cause mutations and malignant transformations. It is classified as a known human carcinogen (Group 1) by the International Agency for Research on Cancer (IARC). The main sources of human exposure to BaP are contaminated food, tobacco smoke, and polluted air. Currently, one of the most commonly used experimental systems for studying the adverse effects of environmental pollutants in vitro are liver cell lines grown in two-dimensional (2D) monolayers. However, most hepatic cells cultured in 2D lack relevant hepatic properties, especially enzymes from the II phase of metabolism making extrapolation of results to in vivo conditions questionable. Compared to 2D, three-dimensional (3D) models have improved cell-cell and cell-matrix interactions and exhibit higher levels of liver-specific functions. In the present study, the spheroids formed from the human hepatocellular carcinoma (HepG2) cell line developed by the forced floating method and cultured under static conditions were used to test the genotoxic activity of BaP, which is a genotoxic model compound for air pollutants. After three days of cultivation, spheroids were exposed to non-cytotoxic BaP concentrations for 24 (0.1, 1, 10, and 20 μM) and 72 (0.001, 0.01, 0.1, 1, and 10 μM) hours. Subsequently, the suspension of viable cells from spheroids was obtained by mechanical degradation and enzymatic (trypLE and collagenase I) digestion. After exposure, viability (MTS assay) and division of cells (Ki67 marker) in the spheroids, growth of spheroids (planimetry by light microscopy) were examined, and live/dead staining (confocal microscopy) and cell cycle analysis (Hoechst 33258) were performed. In addition, flow cytometry was used to detect the induction of DNA damage with Anti-H2AX pS139 antibodies that specifically recognize DNA double strand breaks. The results showed that BaP affected the growth of HepG2 cells by arresting them in the S phase of the cell cycle, reduced the growth of spheroids, and induced DNA damage after 24 h and 72 h of exposure. In summary, the research conducted using the model air pollutant BaP demonstrated that the hepatic 3D cell model is a sensitive approach that can be used for the assessment of the genotoxic activity of air pollutants.

This study was supported by the Slovenian research agency: Program P1-0245, Horizon Europe project Twinning for excellence to strategically advance research in carcinogenesis and cancer (CutCancer; 101079113) and Evidence driven indoor air quality improvement (EDIAQI; 101057497).

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INDOOR AIR QUALITY, ENERGY EFFICIENCY AND HEALTHY BUILDINGS

Oral presentation

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MEASUREMENTS OF INDOOR RADON CONCENTRATIONS IN DWELLINGS IN THE CITY OF ZAGREB, CROATIA

Keywords: *radon, indoor, radioactivity, air quality*

Radon is a naturally occurring radioactive gas, which may be found in high concentrations in indoor environments, such as homes and workplaces. Radon is known to be one of the leading causes of lung cancer, hence monitoring of radon concentrations is necessary and it is handled through national policies and regulations. According to EU Council Directive 2013/59/Euratom, the reference level for annual average activity concentration in indoor air is 300 Bq/m^3.

The measurements of radon can be conducted with active (for short-term measurements) or passive (for long turn measurements) detectors.

Within the EDIAQI (Evidence Driven Indoor Air Quality Improvement) project, radon measurements were carried out in dwellings in Zagreb, Croatia. Both active detectors (charcoal canisters) and passive detectors (solid-state nuclear track detectors – SSNTD) were used. Charcoal canisters were exposed for 72 h and measured using gamma-ray spectrometry, while SSNTD were exposed for 1-3 months, and processed chemically in the laboratory. Both methods are in accordance to the ISO 11665-4 Standard.

The results will show the differences in radon activity concentrations by building floor, as well as the differences by locations of dwellings in the city of Zagreb. The results will provide valuable knowledge on radon concentrations being one of the risk factors associated with indoor air pollutants.

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Poster presentation

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RADON IN THE REPUBLIC OF CROATIA: AN OVERVIEW OF THE CURRENT STATE AND A NEED FOR AN ACCREDITED MEASUREMENT METHOD

Keywords: *radioactivity, ^{222}Rn, radioactive gas, activity concentration*

Radon (^{222}Rn) is a naturally occurring radioactive gas that is produced by the radioactive decay of radium (^{226}Ra) within the uranium (^{238}U) decay chain. It gives the largest contribution to the average annual radiation dose per capita. Radon may significantly affect air quality, especially in closed spaces. Its largest concentrations are usually found in the ground floor and in cellars, as well as in other places which are in a direct contact with soil. After smoking, the most common cause of lung cancer is exposure to high radon concentrations. Hence elevated concentrations of radon in the air may affect air quality and have adverse effects on human health. The 2013/59/Euratom Directive by the European Commission establishes a framework for protection from exposure to radon in human dwellings and workplaces. In the Republic of Croatia (RC), this is regulated by several legal documents (NN141/13; 39/15; 130/17; 118/18; 21/22; 114/22; NN38/2018; 8/22) and the Action plan for radon in 2019 – 2024 (NN118/18). It has been established that the activity concentration in dwellings and workplaces should not exceed 300 Bqm^{-3}. The first systematic measurements of radon activity concentrations in households were carried out in 2003-2005, using 6000 detectors in 8 counties. It has been found that the activity concentrations were in the range 10-1600 Bqm^{-3}, that is, there are microlocations within some counties where the activity concentration exceeds the reference level several times. The current problem in the RC is the absence of a laboratory accredited for long-term measurements of radon concentrations. The Institute for Medical Research and Occupational Health (IMROH) is accredited according to the HRN EN ISO/IEC 17025 standard, which permits measurements by means of high-resolution gamma-ray spectrometry but only for exposures of up to 3 days. This is currently being supplemented by the method of measuring nuclear traces according to ISO 11665-4 (Measurement of radioactivity in the environment — Air: radon-222 — Part 4: Integrated measurement method for determining average activity concentration using passive sampling and delayed analysis). Once this has been completed, IMROH will become the only institution in the RC accredited for implementing the Action plan for radon.

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Oral presentation

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AWARENESS OF INDOOR AIR POLLUTION IN CROATIAN ADULTS – THE FIRST RESULTS FROM THE EDIAQI PROJECT

Keywords: *indoor air pollution, knowledge, behaviors, attitudes, health risk, scale development, indoor air quality*

Pollution of the household environment is often wrongly perceived as being less endangering than outdoor air pollution. Indoor air pollutants can have short- and long-term adverse health effects, especially if exposure is related to children's respiratory health. Related knowledge, behaviors, and attitudes towards indoor air pollution could be important in raising awareness and designing effective measures to reduce poor health outcomes associated with indoor air pollutants.

This study is part of the Horizon Europe project "Evidence Driven Indoor Air Quality Improvement (EDIAQI)", in which the relationships between indoor air quality and health outcomes (asthma, allergy) will be investigated. The purpose of the current study within EDIAQI was to assess the awareness of indoor air pollution in adults from different Croatian regions (urban and rural) to construct measures of knowledge, behaviors, and attitudes toward indoor air pollution. Since no previous study has examined awareness of indoor air quality and pollution in Croatian adults, preliminary data were gathered from 151 participants through self-administered online questionnaires, using the snowball sampling technique.

After item analysis, a reliable set of 14 items (α = 0.85) was constructed for measuring attitudes towards indoor pollution, a set of 15 items for indoor environmental knowledge (α = 0.52), and 8 items for behaviors against pollution in households (α = 0.71). The mean values for knowledge were 7.4/15 and for attitudes 4.1/5, indicating medium knowledge and optimal attitudes. The mean value for various housekeeping behaviors was pretty high at 2.4/3 and measured differently - some were very well implemented (56% of participants vacuuming floors more than once a week), whereas others were insufficiently practiced (40% of participants with gas or wooden stoves, or with air conditioner maintenance less than once a year).

On a risk scale ranging from 1 to 5, only 5% of respondents considered that pollution of their household environment represents a high or very high risk for their health, whereas 22% considered that outdoor air pollution represents a high or very high health risk. 46% reported they can protect themselves from the effects of their household air pollution to a very high or high extent. At the same time, 54% estimated that they are not informed at all or are little informed about indoor air pollution. 21% of participants reported not getting information about indoor air pollution anywhere.

Further data gathering and analyses will reveal the limitations of the proposed measures and future steps toward raising awareness of indoor air pollution in Croatia.

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Poster presentation

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INDOOR AIR QUALITY IN NURSERIES: CASE STUDIES IN MEDITERRANEAN CLIMATE

Keywords: *CO_2, TVOCs, PM, nursery, Mediterranean climate*

Numerous studies suggest that over a third of European children suffer from bronchial asthma or allergies. The incidence of respiratory conditions is steadily rising, and a distinct connection between academic achievement and indoor air quality (IAQ) is apparent. Enhanced indoor air quality in school environments leads to a reduction in the need for pediatric healthcare services. The objective is to assess the schools' capacity to mitigate pollution effects by identifying and evaluating key environmental parameters. The project also aims to raise the awareness within the education sector about IAQ-related issues and promote improvements.

The methodology involves characterizing both IAQ and outdoor air quality through on-site measurements of environmental variables. Awareness activities are also planned to engage the educational community in the project.

The monitoring process entails in situ measurement campaigns in selected classrooms of each school. Representative spaces are chosen, and outdoor air samples are collected to understand pollutant transfer. Indoor comfort parameters (temperature, humidity), and IAQ indicators ($PM_{2.5}$, TVOCs, CO_2) werw measured.

The focus on specific parameters is highlighted:

- CO_2 concentration: CO_2 is used as an indicator of ventilation rates and IAQ. Levels above 1000 ppm suggest poor ventilation in all nurseries.
- $PM_{2.5}$ concentration: Fine inhalable particles, $PM_{2.5}$, are monitored, with control limits based on WHO standards (annual limit: 10 μg/m^3, daily limit: 25 μg/m^3). $PM_{2.5}$ exceeds the limit for this indoor pollutant from 10 am to 5 pm.
- TVOCs concentration: Total volatile organic compounds (TVOCs) are assessed as a collective measure of indoor air pollutants. Thresholds for occupant sensitivity range from 120 ppb to 1200 ppb. Most of the time, the monitoring results are below the limit of 1200 ppb.

The project's outcomes have the potential to drive positive changes in educational facilities, enhancing both students' well-being and their educational experience.

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Oral presentation

Daikin Airconditioning Central Europe (presented by **Hrvoje Krapanić**)

INDOOR AIR QUALITY IN SCHOOLS IN SLOVAKIA

Keywords: *monitoring, air purifier*

The COVID-19 pandemic has brought the quality of the indoor environment to the center of our attention. Both experts and the general public are realizing how big of a role it plays in our lives and how much the environment where we spend most of our time can affect human health.

Concern about the air quality in homes, offices, and commercial buildings is now evident among us. In the private sector, the pressure to improve the indoor environment has grown and its higher importance, which is now also supported by building certification programs (e.g. WELL, BREEAM or LEED, etc.), is contributing in no small part to certified buildings being more marketable. Here, the market tends to steer things in the right direction. However, reconstructing public buildings remains a challenge, as new construction is sporadic.

School and preschool facilities are considered the most neglected even though school children are a particularly vulnerable population group. There are more than 50 000 schools in Central & Eastern Europe with over 600 000 classrooms and more than fifteen million students learning in them.

Children spend more time at school than anywhere else, except at home. Since the negative effects of some airborne pollutants on human health are scientifically proven, it is unfortunate that such pollutants are also widely found in school environments. Indoor air quality (IAQ) basically impacts: a) student concentration and performance and b) health.

This paper shows the results of indoor air quality monitoring in 20 schools all over Slovakia over the June, August and September 2021. It includes results of testing and comparing the classroom air quality with and without an air purifier and also with and without a ventilation unit installed. Measuring temperature and humidity, particulate matter (PM) concentration and CO_2 concentration, it was shown that IAQ in the classrooms without ventilation is poor and the measured values often exceeded the allowed and recommended thresholds and therefore is a health risk for students and staff. Especially poor situation was with CO_2 concentration. By installing heat recovery ventilation in one of the classrooms with one the worst measured values, significant improvement of CO_2 concentration was achieved (June, July vs August, September). Overall advice given, in order to ensure better or even maintain good indoor air quality, is to consider installing forced (mechanical) ventilation.

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Poster presentation

Marko Marić, Danijel Grgec, Zdravko Orsag

PHYSICAL, CHEMICAL AND BIOLOGICAL FACTORS AFFECTING INDOOR AIR QUALITY

Keywords: *indoor air quality (IAQ), sick building syndrome, microbiological air analysis*

Ventilation of buildings is an important factor, which affects not only heating and cooling but also indoor air quality (IAQ). The compliance of physical air qualities to legislative norms, does not necessarily guarantee good air quality. In addition to physical qualities, it is also necessary to determine chemical and biological factors when testing air quality. Physical qualities include air temperature, relative humidity and rate of air circulation. When measuring air temperature it is important for it to be equal throughout the room. Besides air temperature, an important physical factor is also air relative humidity. Air conditioning technology assumes a lower and an upper humidity limit of 35% and 70% respectively. At humidity levels below 35%, which may arise during winter in well-heated rooms due to drying clothes, carpets, furniture and so on, dust can appear more easily. The glow of dust on heated objects can create gases that irritate the respiratory system. Furthermore, drying mucous membranes of the upper respiratory tract can also appear. For this reason, it is recommended to moisturize dry air with humidifiers during winter time. At air humidity levels higher than 70%, the scent of mold can be felt and damp can damage materials. Construction materials of the building, CO_2 levels, paint, carpets and formaldehyde are often cited as possible causes of occupants' nuisances, causing the sick building syndrome (SBS) in commercial and residential buildings. Indoor chemical pollutants have diverse origins and are present in our homes as VOCs emitted from products we purchase. The World Health Organization has highlighted eight specific chemical pollutants that have a negative effect on our air quality by 50 experts (benzene, carbon monoxide, formaldehyde, nitrogen dioxide, naphtalene, polycyclic aromatic hydrocarbons (PAHs), radon and tetra- and tri-chloroethylene) Air can also be contaminated with bacteria, fungi and mites. These microorganisms can affect health, either by infection or, by more commonly, by causing allergic reactions. According to the Portuguese standard "Diario da Republica n.° 235/2013, 1° Suplemento, Serie I de 2013-12-04" the concentration of the total number of bacteria in the indoor air must be lower than the concentration of the outdoor air + 350 CFU/m^3) and total number the mold of the indoor air should be lower than that of the outdoor air. Many researches indicate that people spend approximately 90 % of their time indoors. Thus, for many people, the health risks may be greater due to exposure to air pollution indoors than outdoors. Through our experience of testing indoor air quality, requested by various companies or individuals, the problem was mainly a high concentration of bacteria or mold in the air because of not regularly maintaining the ventilation system or not ventilating the space.

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Oral presentation

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ELEMENTAL ANALYSIS OF PARTICULATE MATTER IN INDOOR WORKING ENVIRONMENTS

Keywords: *particulate matter, metal workshops, X-ray fluorescence*

Particulate matter (PM) is a mixture of particles and liquid droplets suspended in the atmosphere and is one of the most important air pollutants. Its fine fraction $PM_{2.5}$ (particles less than 2.5 μm in diameter) is of particulate interest because it can easily enter the human respiratory system and potentially have adverse effects on human health. Monitoring outdoor PM levels is very important, but since people spend most of their time indoors, it is especially important to monitor indoor PM levels, both in homes and workplaces.

One of the indoor workplaces with significant PM production are the metal workshops, where metal processing techniques such as welding, cutting, grinding, or polishing generate PM with high heavy metal levels. In order to monitor PM production in different work environments, $PM_{2.5}$ samples were collected in 7 different metal workshops where different metal processing techniques and materials (steel, stainless steel, aluminium) are used. Particulate matter was collected on thin PTFE filters, using a cyclone sampler, with a temporal resolution between 30 min and 8 hours, depending on the particle production in the workshop.

The harmful effects of air pollution depend not only on the total concentration or its composition. Simultaneous exposure to different substances, due to their interaction, can enhance or reduce the effect. Therefore, it is important to characterize the different pollution sources in detail. For this purpose, the concentrations of S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, and Pb in each sample were determined by the X-ray fluorescence technique, while the total particle concentrations were determined gravimetrically.

The concentrations measured in the workshops depended on the materials and techniques used. The highest $PM_{2.5}$ concentrations were measured for steel welding, reaching 2900 $\mu g/m^3$, while the lowest (comparable to the outdoor concentrations) were measured for aluminium cutting. In steel workshops, concentrations of Fe, Mn, and Zn were predominant, often accounting for about 50% of the total $PM_{2.5}$ mass. Zn concentrations were highly dependent on the material used and were around the detection limit when mild steel was used, while they were comparable to Fe concentrations when stainless steel was processed. Mn was recognized as a marker for welding, being one of the components of the welding electrodes. In the workshops where aluminium parts were processed, $PM_{2.5}$ showed almost the same characteristics as in the outdoor air. All measured concentrations were within the limits set for indoor workplaces.

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Oral presentation

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THE FERRARA PILOT IN THE EDIAQI PROJECT: SAMPLING AND ANALYSIS FOR UNDERSTANDING THE INDOOR AIR QUALITY IN RESIDENTIAL LOCATIONS

Keywords: *EDIAQI, indoor air quality, Ferrara, CO_2, PM, VOCs, residential*

Nowadays, the main problem regarding the guidelines for indoor air quality is related to the differences among the various EU Member States. It is possible to evidence how the same compound can have different reference values across Europe: a "good" example is a carcinogenic compound such as formaldehyde, for which different exposure limits among the EU Member States are stipulated. These large differences cause confusion and it is necessary to set similar conditions across Europe. It is therefore important to perform sampling and measurement campaigns in different European countries in order to obtain information on the levels of the main pollutants and define threshold limits that can be assumed for the entire European area, which is the main scope of the EDIAQI project.

In this context, this text would like to present the preliminary results of the Ferrara Pilot. The main gaseous pollutants reported by the WHO guidelines have been determined and investigated: benzene, carbon monoxide, formaldehyde, naphthalene, nitrogen dioxide, particulate matter, polycyclic aromatic hydrocarbons (as benzo[a]pyrene), volatile organic compounds, etc. Furthermore, the focus has been shifted to other and novel compounds, not still reported in the regulations but considered hazardous for human health such as submicron particles or plasticizers like phthalates which are endocrine disruptors and cause damage to human health. Finally, microplastics are direct consequences of plasticizer exposure: they are very difficult to investigate but their measurement indoors is a fundamental aspect for obtaining knowledge on human exposure.

For the analysis, the authors identified different scenarios, because each scenario can be characterized by specific indoor pollutants. In this project, and in the Ferrara Pilot especially, the following scenarios, commonly across Europe, were considered: residential (meaning houses and public offices) and recreational sites (i.e., cinemas, theaters, restaurants), hospitals, schools. The differences were reflected in the different exposure and deposition rates in the respiratory system of each category. The measurements were performed by means of automatic and offline samplers along with more innovative and technological equipment such as sensors. These last analyzers will be preliminarily tested and validated for reaching the same accuracy and precision of the master instruments.

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Poster presentation

Valentino Petrić, Veronika Žlabravec, **Dorotea Jalušić**, Dejan Strbad

PREDICTING WEEKLY INDOOR AIR QUALITY IN AN OFFICE SPACE USING LOW-COST SENSORS AND ARTIFICIAL INTELLIGENCE

Keywords: *low-cost sensors, artificial intelligence, office spaces, predictive model*

Indoor air quality (IAQ) is of utmost importance in maintaining a healthy and productive environment, especially within office spaces where workers spend a significant amount of time. Numerous studies have shown that buildings with lower concentrations of air pollutants have notably higher cognitive scores compared to those with elevated pollutant levels. Consequently, this study presents an innovative approach aimed at accurately predicting weekly IAQ within office spaces by utilizing low-cost sensors and artificial intelligence (AI) techniques. By harnessing advancements in sensor technology, the proposed system effectively collects real-time data on a multitude of IAQ parameters, encompassing temperature, humidity, carbon dioxide (CO_2) levels, volatile organic compounds (VOCs), and particulate matter (PM) concentrations. These strategically positioned low-cost sensors meticulously capture the spatial distribution of IAQ throughout the office environment. Moreover, the integration of outdoor sensors further enables an investigation into the intricate relationship between outdoor surroundings and indoor air quality. In order to gain comprehensive insights, the system also incorporates temporal data, encompassing factors such as the day of the week and day/night cycles. The collected data is processed and analyzed through the development of an AI-based predictive model. Various machine learning algorithms, including Random Forest, Multiple Linear Regression, KNN, and clustering, are employed to train the models. These models effectively forecast IAQ levels for the upcoming week, taking into account the diverse range of factors that impact indoor air quality. The integration of low-cost sensors with AI techniques offers numerous advantages. Firstly, it empowers continuous monitoring of IAQ, thereby enabling timely interventions and the implementation of preventive measures crucial for maintaining a healthy environment. Secondly, this integration provides cost-effective solutions for IAQ monitoring, obviating the need for expensive and intricate sensor setups. Lastly, the predictive capabilities of the AI model actively contribute to the management of IAQ while optimizing HVAC systems, consequently fostering enhanced energy efficiency. This research substantially contributes to the field of IAQ management by proposing an efficient and affordable methodology for accurately predicting weekly IAQ within the office spaces. Consequently, the proposed system empowers facility managers and occupants to make well-informed decisions and take proactive actions towards improving IAQ, thereby enhancing occupant health, comfort, and overall productivity in the workplace.

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Oral presentation

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THE ROLE OF CO_2, PM, AND VOCs IN THE EVALUATION OF INDOOR AIR QUALITY IN SCHOOLS

Keywords: *IAQ, CO_2, PM, VOCs, schools, students, management, scholar activities*

This text attempts to describe an approach for indoor air quality (IAQ) monitoring plans in schools and above all to improve the comprehension and assessment of indoor concentration levels of some chemical pollutants. In particular, the authors would like to discuss the results of a study conducted on CO_2 and PM_{10} levels measured in real-time in hot and cold season in different classrooms of primary and secondary schools present in a large Italian urban area in order to understand the IAQ, the importance of opening windows (natural ventilation), state and identify possible improvement actions to be taken.

The aim is to guide interventions to improve the health of students and staff. The proposed methodology is based on the simultaneous study of chemical (indoor/outdoor $PM_{2.5}$, NO_2, CO_2) and physical (temperature, humidity) parameters by means of automatic analyzers coupled with gaseous compounds (benzene, toluene, ethylbenzene, xylenes, formaldehyde and NO_2) sampled by denuders. The important novelty is that all the data were collected daily in two different situations, i.e., during school activities and outside school activities, allowing us to evaluate the exposure of each student or person. The different behaviors of all the measured pollutants during the two different situations are reported and commented on. Finally, a statistical approach will show how the investigated compounds are distributed around the two components of combustion processes and photochemical reactions.

The relationship among microclimatic conditions, PM and CO_2 is crucial for this evaluation. Particularly, CO_2 is an inert gas, odorless and colorless, and is naturally present in the atmosphere. Basically, CO_2 concentrations indoors are higher as they are emitted mainly through the respiratory path of the occupants.

Finally, the authors would like to underline that indoor air quality cannot be considered an occasional and individual problem to be remedied with simple mitigative actions. It has become a global phenomenon that concerns every citizen, whether they are workers or not, and places of residence, workplaces, schools, hospitals, transport and care in each country. The occurrence of the COVID-19 pandemic must make it clear that indoor air quality is a priority parameter in designing a building. Greater integration is needed to ensure that energy efficiency interventions are carried out with indoor air quality playing a clear and central role. Energy efficiency and indoor air quality must not conflict with one another but must be complementary.

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Poster presentation

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INVESTIGATION OF MICROPLASTIC CONCENTRATION AND SOURCES IN SCHOOL INDOOR AIR: IMPLICATIONS FOR CHILDREN'S HEALTH

Keywords: *microplastic, indoor air quality, aerosol*

Recent research has highlighted the prevalence of microplastics (MPs) in a variety of environmental mediums, such as brine, freshwater, potable water, outlet water, soil, sludge, precipitate, and submarine sandstone, as well as in aquatic biological clocks, such as clam shells, mussels, whales and sea turtles. However, the most pressing concern is the presence of MPs in the atmosphere. According to the World Health Organization, 7 million people die each year due to environmental and household air pollution, with each individual inhaling up to 16.2 pieces of plastic every hour from clothing and plastic litter. While most research has focused on outdoor environments, recent studies have suggested that microplastics may also be present in indoor air, including the air within educational institutions such as schools. This study seeks to determine the quantity, characteristics, and sources of microplastic particles present in the indoor air of school.

Air samples were collected via a passive sampling approach. A glass fiber filter (pore size, 1.6 μm, 47 mm, "Branchia") in a glass Petri dish and an empty pre-cleaned glass Petri dish were exposed to the indoor air to collect microplastic samples. The filter was placed at a height of about 70–75 cm above the ground, corresponding to the height of a student's table. The duration of the passive sampling was chosen to be one week. Duplicate samples were collected. To eliminate possible microplastics adhered to the used material (e.g., Petri dishes, tweezers, filter holder), all material was previously rinsed in triplicate with a mixture of ethanol and MilliQ water. After 7 days, the Petri dish was closed, covered with aluminium foil, and transferred to the laboratory for further analysis. Then, the amount, shape, size, color, and chemical composition of microplastic particles were determined with an optical microscope and a LUMOS II μ-FTIR spectrometer.

Initial investigations uncovered the presence of microplastics in the air inside the school. The concentrations varied among the samples, with higher levels detected in classrooms when classes were in session. The most common types of microplastics observed were fibers. The majority of microplastic particles ranged in size from 10 μm to 1 mm, indicating the potential for inhalation by students and staff.

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Poster presentation

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ANALYSIS OF MICROPLASTIC IN INDOOR AIR WITHIN THE "JamINNO+" PROJECT

Keywords: *air sampling, LDIR imaging, microplastics analysis*

Microplastics (MP) are emerging contaminants widely distributed in the environment. While the presence and distribution of MP in aquatic and soil ecosystems have been extensively investigated in the past decade, airborne MP have recently gained more interest from scientists and the public. Currently, there are no standard operation protocols for MP analysis in the environment. Depending on the type of sample and chemical properties of MP, sampling, sample preparation and analysis are quite challenging and often include more than one analytical method for qualitative and quantitative analysis. Depending on the methods used for the analysis of MP, some pre-treatment procedures are usually required to separate MP particles and remove unwanted organic and inorganic material that may interfere during the analysis.

There have been very few studies on the presence of MP in outdoor air, and data on sampling and analysis of indoor air are even more scarce. Sampling strategies for indoor air analysis can be focused on the active sampling of indoor air with sampling pumps or passive sampling and analysis of dust collected either with vacuum pumps or by deposition into suitable containers.

Here we present the preliminary results of active sampling of indoor air directly on gold coated polycarbonate filters and an analysis of MP using a Laser Direct Infrared (LDIR) Chemical Imaging System (Agilent, model 8700). The filter was analysed before and after the sampling. Sampling was conducted using the Mini volume sampler Sven Leckel for indoor use, with a controlled flow rate of 200 L/h. For the purpose of method development conducted as part of the "JamINNO+" project, air was sampled from a multipurpose room with an area of 47 m^2, serving as an office, repository and maintenance. The results showed that the composition of the collected particles was polyamide (47%), chitin (16%), rubber (7%), carbonate (5%), polyethylene terephthalate (2%) and others (< 2%). With an automated analysis workflow, 15% of particles were undefined. Most particles (83%) were smaller than 30 μm, 11% ranged between 30 and 50 μm and the rest were in the 50 μm to 500 μm range.

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CLIMATE AND ENVIRONMENTAL IMPACTS OF AIR POLLUTION

Oral presentation

Nirvana Franković Mihelj, Lucija Juko

CONTRIBUTION OF GREEN INFRASTRUCTURE TO IMPROVING LIVING CONDITIONS IN URBAN AREAS

Keywords: *green infrastructure, European Green Deal, climate change adaptation*

As a Member of the European Union, Croatia is committed to the climate-related ambition stated in the European Green Deal, the aim of which is to fulfill the obligation arising from the Paris Agreement. The Green Infrastructure document calls for a full integration of green infrastructure concepts into sectoral policies, EU financial instruments and spatial planning, and it is an important factor in the climate change adaptation strategy.

Strategic development of the green infrastructure in the Republic of Croatia, as an important element that can have a favourable impact on human health and life, is gaining momentum rapidly, and in the upcoming period it will significantly contribute to the sustainable development and achievement of social, environmental, and economic benefits. Owing to the interpolation of greenery as well as the simultaneous development of pedestrian and reduction of traffic areas, air quality is improved, i.e. urban vegetation contributes to air quality by absorbing CO_2 from the atmosphere, trees retain and filter pollutants so that cities with large urban vegetation areas have lower levels of dust particles than the cities without vegetation. The positive impact of vegetation is also demonstrated by a decrease in wind strength and speed regardless of whether it is an individual or a group of trees, which can provide significant protection for cities on the coast where wind gusts can be extreme. Green infrastructure is crucial in achieving adequate temperature and reducing the effect of urban heat islands, helps efficiently collect stormwater, reduces noise, encourages movement and spending time outdoors. The function of green spaces is also manifested through the improvement of human health because it has been proved that time spent in nature has positive impacts on mental and physical health.

The Environmental Protection and Energy Efficiency Fund financially supports projects for implementing the Green Infrastructure concepts with the aim of increasing the resilience of local and regional communities and reducing the vulnerability of natural systems to the adverse impacts of climate change, which will consequently contribute to the development of a green and climate-neutral Croatia. This paper considers the mechanism of funding green infrastructure projects and presents the best practice examples.

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Poster presentation

Magdalena Vincetić, Silva Žužul, Jasmina Rinkovec

TOTAL DEPOSITED MATTER AND ITS METAL CONTENT – A COMPARISON OF RESULTS OBTAINED IN RURAL AND URBAN SITES IN CENTRAL CROATIA

Keywords: *air monitoring, Bergerhoff method, heavy metals*

Levels of total deposited matter (TDM) as well as the content of five metals (nickel, arsenic, cadmium, lead and thallium) in TDM have to be regularly monitored as a part of the routine air quality monitoring required by EU and Croatian legislation. The aim of this work was to compare the levels of TDM and its metal content at one rural background station located within the Šumbar Research Area in Karlovac County and two urban locations in the city of Zagreb, one described as urban with high traffic density and the other as urban industrial. The Šumbar Research Area is a unique ecosystem monitored and managed by the Institute for Medical Research and Occupational Health which performs activities of safeguarding, improvement and control of habitat stability.

Twelve samples of total deposited matter at each sampling site were collected during 2022 from January to December, using the Bergerhoff method. Every sample was exposed over a period of 30 ± 2 days. Collected total deposited matter was determined gravimetrically, while metal concentrations in TDM were determined by inductively coupled plasma mass spectrometry after microwave digestion in nitric acid under high pressure and temperature.

Results showed that levels of total deposited matter varied between 9 mg/m^{2}d and 323 mg/m^{2}d at the rural site and 17 mg/m^{2}d and 134 mg/m^{2}d at the urban sites. The annual average value was higher at the Šumbar Research Area than at the two other urban sites but the difference was not statistically significant. Maximum values were found in April and June at all three of the measuring sites. A statistically significant difference was found for nickel concentrations between all sampling sites in contrast to thallium concentrations, where no statistically significant difference was found. Metal concentrations as well as levels of TDM at all three sites were below limit values according to the Regulation on the level of pollutants in the air issued by the Government of the Republic of Croatia (Official Gazette 77/2020).

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Oral presentation

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OLIVE POLLEN (*Olea* spp.) DYNAMICS ALONG THE EASTERN ADRIATIC COAST

Keywords: *aerobiology, pollen, olive, Dalmatia, allergy risk*

Adriatic Croatia (Istria, Dalmatia, coasts, and islands) is a climatically and geographically favorable area for growing olives and developing olive farming. Olive is an important agricultural crop in numerous Mediterranean countries but also, but olive pollen as a cause of respiratory allergies represents a potential public health problem in the Mediterranean area. Concentration dynamics of olive pollen have been well-researched in most Mediterranean countries, while in Croatia, research data on olive pollen concentrations are rare and insufficient. This research is an upgrade of existing research and data, as it covers the entire eastern part of the Adriatic for the first time. In the research, which included nine aerobiological measuring stations (Pazin, Poreč, Labin, Pula, Rijeka, Zadar, Šibenik, Split, and Dubrovnik), the main olive pollen seasons were analyzed in the five-year period (2018-2022). Aerobiological data were collected using the Hirst methodology, and pollen classes were determined according to thresholds for the occurrence of allergic reactions as recommended by the Spanish Aerobiological Network (REA), adapted to local conditions. The main pollen season is defined as the period in which 95% of the total annual pollen was collected. The beginning, end, and duration of the main pollen season, the date of the peak concentration values, and the class of olive pollen were determined. Pollen calendars were created for the researched location. The results show that olive pollen seasons are relatively short and last 30 days on average. The main pollen season in Istria and northern Dalmatia started on average in the middle of May, and in southern Dalmatia at the beginning of May. An earlier start of the pollen season was recorded in the last year of research in Pazin, Labin, Pula and Rijeka. Pollen seasons ended at the beginning or middle of June, depending on the location. The longest pollen seasons were in Šibenik and Split, and the highest peak olive pollen concentration values were in Poreč and Split. Peak concentrations in most locations were reached in the second half of May, except in Poreč, Pula, and Rijeka where they were reached in June. In the last year of research, the highest total annual concentrations, the highest daily concentrations, and an increase in the number of days with moderate and high concentrations were recorded in most locations. The results obtained from this research are of great importance for people allergic to olive pollen and are the basis for further research, especially those that deal with climate change, and can be used in different disciplines (aerobiology, allergology, agronomy).

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Poster presentation

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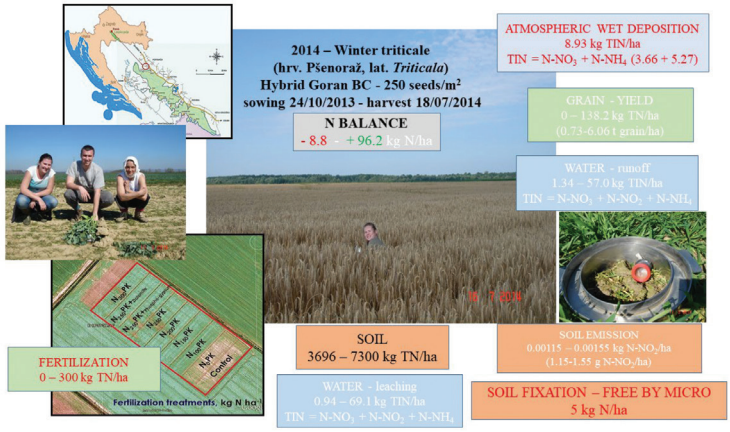
NITROGEN BALANCE IN AGROECOSYSTEM - CASE STUDY POTOK, CONTINENTAL CROATIA

Keywords: *fertilization, leaching, runoff, soil content, soil emission, yield, wet deposition*

Agricultural production is an open-air factory. The balance of inflows and outflows of macro and micro elements in the agroecosystem is one of the most important issues today. Therefore, sustainable management of agroecosystem requires control of water, nitrogen, carbon, phosphorus, etc. In this work, we focused on nitrogen and analysed one production year (2014) in a real agroecosystem. We tested triticale, a small-grain cereal, a cross between wheat (*Triticum*) and rye (*Secale*), which has a slightly better amino acid composition than rye (a significant amount of the enzyme phytase) and a better source of available phosphorus. The aim of the work was to determine the nitrogen balance in the conventional agroecosystem of continental production in Croatia, and to define possible strengths and weaknesses, in terms of risk and management. On the experimental field in Potok near Popovača, winter triticale (*hrv. Pšenoraž*, variety Goran BC) was sown on October 24th, 2013 with 250 grains/m^2 and harvested on July 18th, 2014. On the experimental field, in addition to different fertilizer treatments (10 variants from 0 to 300 kg N/ha), lysimeter and drainage pipes were installed to analyse the amounts of nutrients (N-NO_2, N-NH_4 and N-NO_3) leached, i.e. entering the surrounding aquatic ecosystems as leachate (groundwater) and surface water (runoff). The analysis also included: atmospheric wet deposition (N-NH_4 and N-NO_3), emissions from soil (N-NO_2), and removal by crop yields (cereals, TN). Soil as a N reservoir was also analysed. The results showed that the N balance ranged from negative (-8.8 kg N/ha in a control treatment) to positive (+ 96.2 kg N/ha in a 300 kg N/ha treatment). The highest leaching (69.1 kg N/ha), runoff (57.0 kg N/ha) and yield removal (138.2 kg N/ha) were observed in the treatment with 250 kg N/ha and Phosfogypsum. In the treatment with the highest fertilization (300 kg N/ha), the highest soil N contents (7 300 kg N/ha) were observed in the arable horizon (0-30 cm).



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Oral presentation

Sabina Žero, Amina Balićevac, Amar Karadža, Jasna Huremović

THE CASE OF SARAJEVO: MOSS, HERBACEOUS PLANTS AND CONIFER NEEDLES AS BIOMONITORS FOR ATMOSPHERIC HEAVY METALS

Keywords: *biomonitoring, air pollution, metals, urban environment, Bosnia and Herzegovina*

Moss are mostly used as biomonitor organisms for atmospheric trace elements, along with lichens. Moss take chemical substances mainly from the dry and wet deposition since they have no roots comparable with higher plants. Nevertheless, some plants, especially conifers are considered to be an effective tool for heavy metal pollution biomonitoring.

Since Sarajevo, the capital of Bosnia and Herzegovina, is affected by high levels of air pollution during the winter and domestic heating period of the year, the main focus of this study was to assess the content of selected heavy metals in this period. For this purpose, moss, herbaceous plants and conifer needles samples were collected from two urban locations in Sarajevo during January 2023.

In the present study, the concentration of heavy metals (Cd, Co, Cu, Fe, Mn, Ni, Pb and Zn) was determined by flame atomic absorption spectrometry. The samples were dissolved (~100°C) in HNO_3 (65%) and H_2O_2 (30%). The mean values ranged from not detected (for Cd, Co and Ni in most samples) to 1049 mg/kg in herbaceous plants. The average metal values exhibited the following trend in moss and herbaceous plants at location 1: Fe>Mn>Zn>Pb>Cu>Cd>Co>Ni, in moss at location 2: Fe>Mn>Zn>Pb>Cd>Cu>Co>Ni, in herbaceous plants at location 2: Fe>Mn>Zn>Cu>Pb>Cd>Co>Ni and in conifer needles at both locations: Fe>Zn>Mn>Cu>Pb. Soil samples were collected at both sampling sites in order to calculate the enrichment factor (EF) and provide possible sources of heavy metals in investigated biomonitors. The EF values of the metals estimated were predominantly <1 which indicates that the crust soil is the predominant source at the sampling sites.

The results suggest that moss, herbaceous plants and conifer needles are suitable biomonitors for assessing atmospheric heavy metals in urban environments.

University of Sarajevo-Faculty of Science, Zmaja od Bosne 33-35, 71000 Sarajevo, Bosnia and Herzegovina

EFCA SESSION: NEW REGIME ON AIR PROTECTION IN EUROPE

Oral presentation

Nadine Allemand, Grégoire Bongrand[1]

GUIDANCE DOCUMENT ON TECHNICAL MEASURES FOR REDUCTION OF EMISSIONS FROM SHIPPING (CLRTAP)

Keywords: *maritime traffic, SO_2, PM and NO_X emissions, reduction techniques, costs*

The Amended Gothenburg Protocol of 2012, of the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP), requires that Parties reduce their pollutant emissions between 2005 and 2020 (sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOC), particulate matter (PM) and ammonia (NH_3)). To help Parties to achieve their commitments, several technical annexes of the Protocol implement mandatory limit values for a selection of sources of emissions and a series of guidance documents presenting best available techniques for different sources, such as mobile sources and stationary sources, have been developed and are associated to the Protocol. The guidance that will be presented aims to provide Parties to the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP) and other stakeholders with the most updated information on effective means to reduce maritime shipping emissions and related impact on human health and the environment. This Guidance has been developed by the Task Force of Techno Economic Issues in 2022 and should be published by end of 2023 by the Convention.

This new guidance document presents pollution control techniques applicable to ships, both during navigation and at berth, to limit their atmospheric emissions of sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOC) and particulate matter (PM), total suspended particles (TSP), PM_{10} and $PM_{2.5}$, including black carbon (BC) and polyaromatic hydrocarbons (PAH)).

Recommended techniques are presented as guidance in the possible implementation of emission reduction techniques for the shipping sector, although the list is not exhaustive of all existing and/or promising future measures. In general, all techniques assessed provide measurable emission reductions, over a reference technology, at a cost that is proportional to the achieved reductions, and they are technically implementable under some specific conditions, depending on the techniques. Reduction techniques will be presented. There are all reduction techniques that can be implement in a short-term period.

TFTEI techno scientific secretariat, Citepa, 42 Rue Paradis, 75010 Paris, Framce

Oral presentation

Maria I. Gini[1], Evangelia Diapouli[1], Eleftheria Chalvatzaki[2], Mihalis Lazaridis[2], Vania Martins[3], Tiago Faria[3], Susana Marta Almeida[3], **Konstantinos Eleftheriadis[1]**

THE EFFECT OF SIZE DISTRIBUTION METRICS OF AEROSOL COMPONENTS ON THE INHALED DEPOSITED DOSE. A CASE STUDY IN URBAN AREAS AT LISBON

Keywords: *indoor air quality, aerosol size distribution, aerosol penetration rate, inhaled dose*

Particulate matter (PM) is of major concern, due to its adverse impact on human health and climate. PM consists of a complex mixture of different chemical components including water-soluble ions, trace metals and organic compounds. The modal structure of PM and its components size distributions is directly linked to the potential inhaled dose and adverse health effects caused by ambient PM exposure. However, highly-resolved size distributions typically require a lot of effort that could be avoided in some cases, when it comes to the dose estimates of specific chemical components. The present study aims to investigate the extent of the variability of the size distribution patterns of specific chemical components and its influence to the inhaled dose estimated from $PM_{2.5}$ and PM_{10} mass concentration levels or/and PM mass size distribution measurements under certain assumptions.

In the framework of the Life Index-Air project, a measurement campaign was performed in schools and households in Lisbon, Portugal (October 2017 - January 2018). During these campaigns simultaneous indoor and outdoor sampling was performed at 4 households and 4 schools, by means of a 4-stage Personal Cascade Impactor Sampler (PCIS). Major and trace elements were determined by means of XRF (X-Ray Fluorescence) and AAS (Atomic Absorption Spectroscopy). The elemental (EC) and organic carbon (OC) concentrations were determined by the thermal-optical method. The initial size distributions (step function) were inverted into smoothed and corrected size distributions, taking into account the collection efficiency curves of each impaction stage. The inverted size distributions were fitted by a sum of log-normal distributions, described by a characteristic Mass Median Aerodynamic Diameter (MMAD), a Geometric Standard Deviation (GSD) and mass concentration (input parameters for dosimetry calculations). Then, the ExDoM2 dosimetry model was applied for the quantification of the deposited dose of particle mass and major components. The human experienced dose rate, through inhalation, was determined as the product of inhalation rate, concentration of exposure and deposited fraction in the respiratory tract.

The results are scaled with respect to the over or under predicted inhaled dose and associated risk when the overall mass size distribution structure is selected, instead of that of the individual major components.

Acknowledgements: *This work was supported by the European Union's LIFE Programme in the framework of the LIFE Index-Air project (LIFE15 ENV/PT/000674). This work reflects only the authors' view and EASME is not responsible for any use that may be made of the information it contains.*

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Oral presentation

Andrzej Jagusiewicz

NEW AIR PROTECTION REGIME UNDER THE AIR CONVENTION

KEYWORDS: *Air Convention, emissions, Gothenburg Protocol, WGSR*

At its 61st session (6-8 September 2023) the Working Group on Strategies and Review (WGSR) is expected to accept the review of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (the Gothenburg Protocol as amended in 2012) prepared by the Gothenburg Protocol Review group (GPRG) and submit the agreed proposal for the new air protection regime to the incoming 43rd session (11-14 December 2023) of the Executive Body (EB) for adoption.

The review has been based on scientific and technical information involving all subsidiary bodies and task forces set under the Air Convention in order to propose new set of obligations under the reviewed instrument, including new emission ceilings for NOx, NMVOCs, SO_X, NH_3, $PM_{2.5}$ and BC (black carbon), stricter emission limit values (ELVs) for stationary and mobile sources contained in the annexes to the reviewed Protocol, timescales and facilitation mechanisms for ratification and a set of guidance documents e.g. for ships and shipping.

The author will attend the session of the WGSR, just before the Dubrovnik "Air Protection 2023" conference and bring to the audience the possible format and content of the reviewed instruments. The latter if adopted by the EB and ratified by the Parties to the Air Convention will shape new air protection regime in the ECE region, including the EU for at least a decade or even more.

President of EFCA (European Federation of Clean Air and Environmental Protection Associations)

Oral presentation

Gordana Pehnec

CURRENT AIR QUALITY LEGISLATION AND NEW WORLD HEALTH ORGANIZATION GUIDELINES – IMPACT ON AIR QUALITY ASSESSMENT IN ZAGREB, CROATIA

Keywords: *air pollutants, air quality objectives, EU Directive Proposal, limit value, WHO*

Air quality in Croatia is assessed annually according to the Air Pollution Act (OG No. 127/19, 57/22) and Regulation on Levels of Pollutants in Ambient Air (OG No. 72/20). Since 2011, Croatian legislation has been fully harmonized with EU legislation. In 2021, based on the last scientific evidence, the World Health Organization (WHO) published new global air quality guidelines, with stricter recommendations on guideline levels for the following pollutants: $PM_{2.5}$, PM_{10}, ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon monoxide (CO). In October 2022, the EU Commission proposed a revision of the Ambient Air Quality Directives. The EU Directive Proposal set air quality standards that are more closely aligned with the latest WHO recommendations and should be reached by 2030.

Measurements of ambient air quality in Zagreb, Croatia, have been carried out continuously within the local air quality monitoring network funded by the City of Zagreb since the 1960s. Over the years, the number of monitoring stations has changed, as did the number of measured pollutants. Currently, the network consists of six stations, located in different parts of the town. Additionally, there are four monitoring stations of the national network for continuous air quality monitoring, as well as a few special purpose stations. In this study, data on air quality from the Zagreb local monitoring network for the period 2018-2022 were analysed. Levels of pollutants are discussed with regard to current air quality legislation, new EU Directive Proposal and WHO guidelines. Air quality with regard to SO_2, CO, benzene and metals (Pb, Cd, As, Ni) in PM_{10} was found to be satisfactory and in accordance with all of the aforementioned regulations and standards. Considering current legislation, during the observed five years, levels of PM_{10}, benzo[a]pyrene (BaP) in PM_{10}, NO_2 and O_3 exceeded limit values only at some monitoring stations. However, taking into account new EU Directive Proposal limit values, the air would be considered polluted at almost all of the stations regarding PM_{10}, BaP in PM_{10}, $PM_{2.5}$, NO_2 and O_3. Although decreasing trends of pollutant concentrations were observed at most of the stations, it seems difficult to achieve the new EU objectives before 2030. Regarding the recommended WHO guidelines values, the air quality was assessed as even worse for all of these pollutants.

Institute for Medical Research and Occupational Health, Zagreb, Croatia

IUAPPA SESSION:
AIR QUALITY STRATEGIES FOR LIVEABLE CITIES IN A CHANGING CLIMATE

Oral presentation

Beatriz Cardenas, Ana Cecilia Perales, Sandra Meneses

Bogota, Guadalajara Metro and Monterrey Metro: towards integrating air quality and climate change action plans

Keywords: *exposure to air pollutants, Latin America, action plans, premature deaths*

As in many cities in the world, air quality in Latin American cities is a health problem causing 320 000 premature deaths in the region. An overview of the air quality problem in Latin American cities will be presented followed by a more detailed description of the air pollution situation in the three cities in Latin America: Bogota, the capital city of Colombia home of 8 million habitants, Monterrey and Guadalajara metro, the second and third biggest metropolitan areas in Mexico hosting 5.3 and 5.2 million people respectively, is presented. These three cities have at least two decades of experiences in implementing strategies to improve air quality and at least a decade in actions to mitigate GHG to reduce global warming, however these strategies are not yet integrated missing some synergies and effectiveness. In this presentation we will use three projects developed in these cities to show the importance and opportunities in designing and implementing integrated strategies versus the usual silo approach. Vital neighborhood, a program implemented in Bogota over the last years by Bogota´s authorities has allowed to identify synergies among different strategies including better mobility, reducing exposure to air pollutants, while reducing CO_2 and SLCP emissions. By developing air quality impact indicators for vital neighborhood strategy, the challenge of being able to monitor and evaluate the impacts tactic urbanism strategies in air quality is solved. In Guadalajara Metro, an integrated emissions inventory (criteria pollutants and greenhouse gases) year based developed through a participatory process in which authorities from the three government levels participated is presented to show the importance of this tool to design, monitor and evaluate the impacts of strategies in both air quality and climate. As for Monterrey Metro, an integrated impact indicators framework that includes strategies for air quality action plan and climate action plan is presented. All these three examples will be discussed within the context of the strategies and challenges other Latin American cities are facing to improve the air people breath while contributing to reduce the GHG and SLCP.

World Resources Institute Mexico, Belisario Domínguez #8 P.A. Col. Villa Coyoacán 04000, Mexico City, Mexico

Oral presentation

Selahattin Incecik

POTENTIAL IMPACTS ON AIR POLLUTANTS FROM FUTURE REGIONAL CLIMATE PROJECTIONS

Keywords: *air quality, climate changes, health, ozone, particulate matter*

Both air pollution and climate change can have an impact on each other, and both can directly or indirectly affect health. While climate change may affect how primary pollutants are dispersed, particularly particulate matter, it can also exacerbate the production of secondary pollutants such as surface ozone. For example, a warming atmosphere and sunny days can result in higher surface ozone concentrations. Rising ozone levels cause serious health problems, especially in the summer, and may lead to difficulties in complying with ozone air quality standards in the future. $PM_{2.5}$ can also affect the climate. For example, black carbon can absorb heat, thereby increasing local temperatures. Sulfate particles and other secondary particles help aerosols interact with clouds. In addition, ozone, an important secondary pollutant in the troposphere, is a highly reactive gas that interacts with both shortwave and longwave radiation. Tropospheric ozone is also a greenhouse gas that contributes to climate change by trapping heat in the atmosphere.

Future changes in ozone precursor emissions will be the result of complex interactions between photochemistry, transport mechanisms, and climate change. Therefore, a gradual reduction of pollutant emissions will improve air quality while reducing the negative consequences of climate change in the future. Policies on the SLCPs are important in this regard. However, the consequences of climate change on air quality vary around the world, particularly in low- and middle-income countries where air pollution levels are already high. Because of this situation, regional analyses are required.

In this study, the links between climate change and air pollution and the effects of air pollution on health are discussed. The results are based on future regional climate forecasts employing the IPCC RCP 8.5 emission scenario.

Istanbul Technical University, Istanbul, Turkey

Oral presentation

Hanlie Liebenberg-Enslin[1], Kevin Hicks[2]

INTEGRATED ASSESSMENT OF AIR POLLUTION AND CLIMATE CHANGE FOR SUSTAINABLE DEVELOPMENT IN AFRICA – TOWARDS "THE AFRICA WE WANT"

Keywords: *regional air pollution under changing climate, air quality strategies for sustainable development, human health, greenhouse gas emissions, climate change*

Agenda 2063 outlines the vision of "the Africa we want" which emphasizes the importance of inclusive and sustainable economic growth and development for the continent. However, achieving this goal is challenging due to the rapid industrialization, urbanization, and motorization that is taking place, which is causing adverse impacts such as air pollution, ecosystem degradation, and biodiversity loss. To address these issues, the Integrated Assessment of Air Pollution and Climate Change for Sustainable Development in Africa was mandated by The African Ministerial Conference on Environment (AMCEN). The assessment analyzes the current state, trends, and outlook related to areas prioritized by countries under the United Nations Framework Convention on Climate Change (UNFCCC) and regional air quality agreements. Its aim is to support decision-making for progress towards improved health and well-being for the people of Africa and environmental protection through reducing air pollution, greenhouse gas (GHG), and short-lived climate pollutants (SLCP) emissions from Transport, Residential energy use, Energy production and use, Agriculture and Waste Management.

The current state of air pollution and climate change were assessed, as well as the near-term and long-term (out to 2063) trends and impacts on air quality, human health, and agricultural productivity linked to Africa's development. A baseline scenario was created reflecting a continuation of past trends in the evolution of fuel shares and energy intensities by sector, showing a gradual and incomplete shift from fossil fuels to cleaner energy sources. Two mitigation scenarios were then developed, one reducing SLCP emissions across the sectors and one reducing SLCP with more development and climate-focused mitigation measures, such as modal shifts in the transport sector and reducing food waste.

When working towards achieving "the Africa we want", the emphasis was on implementing policies and strategies that could be scaled up to achieve the goals set out in Agenda 2063. The Assessment showed that a package of 37 measures could improve air quality and contribute to mitigating climate change, preventing approximately 880,000 premature deaths per year by 2063 from air pollution, improving crop yields, and reducing desertification. The measures are also shown to have considerable benefits for the Sustainable Development Goals (SDGs) and Agenda 2030 in the short -term and Agenda 2063 in the long term.

The Assessment makes the case that without action, economic growth compounded by population growth, unplanned urbanization, and unsustainable lifestyles will exacerbate pressures on resources, the environment, and human health, and could increase inequalities and limit Africa's ability to achieve sustainable development.

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Oral presentation

John Murlis

STRATEGIES FOR URBAN AIR PROTECTION: WHY? WHAT? AND HOW?

Keywords: *climate and air quality strategies, urban areas, urban design*

The theme for this session speaks to the great difficulty found by municipalities and other urban authorities in designing and implementing effective and sustainable strategies for clean air and climate protection in towns and cities globally; particularly in the context of environmental change. On the mitigation side, this is partly a consequence of high levels of background pollution from sources outside their areas of control and partly through the relatively limited instruments for emission reduction available to them.

The difficulty in making strategies that address air quality by itself have led to the insight that integration of climate and air quality strategies is desirable and mutually beneficial to the two areas of action. Integrated measures that reduce both air pollutants and greenhouse certainly have the potential for greater cost effectiveness but in many cased also contribute to a larger "basket of benefits". Many such measures contribute, for example, to urban tranquillity and cleanliness which are tangible benefits. They may also contribute more broadly to the sense of well-being and "liveability" associated with the most attractive urban spaces.

The aim of this paper is to consider the value of an approach based on the "basket of benefits" in developing and assessing strategies for air protection in urban areas. The discussion will include considerations of why such strategies are needed , what elements they may contain and how they can best be implemented. Many of these ideas will be familiar to urban designers, including architects, but have yet fully to find a home within the air protection communities. It is hoped that this contribution will make them more accessible and promote their more complete incorporation in future.

Vice president of EFCA (European Federation of Clean Air and Environmental Protection Associations)

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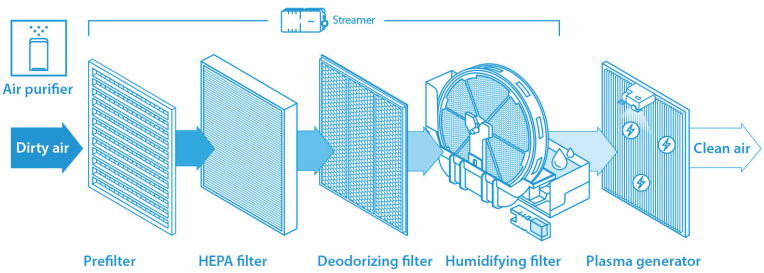

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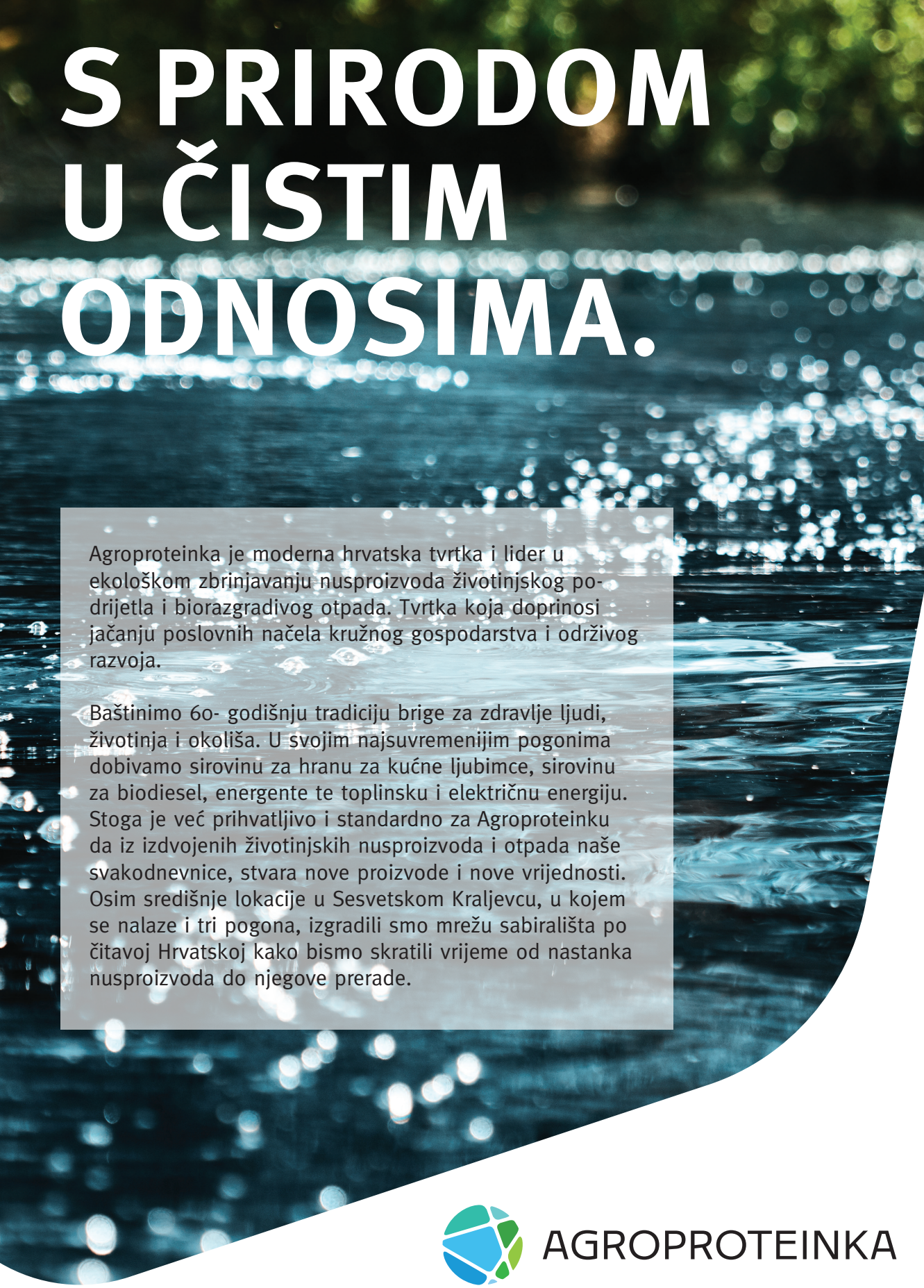

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Agroproteinka je moderna hrvatska tvrtka i lider u ekološkom zbrinjavanju nusproizvoda životinjskog podrijetla i biorazgradivog otpada. Tvrtka koja doprinosi jačanju poslovnih načela kružnog gospodarstva i održivog razvoja.

Baštinimo 6o- godišnju tradiciju brige za zdravlje ljudi, životinja i okoliša. U svojim najsuvremenijim pogonima dobivamo sirovinu za hranu za kućne ljubimce, sirovinu za biodiesel, energente te toplinsku i električnu energiju. Stoga je već prihvatljivo i standardno za Agroproteinku da iz izdvojenih životinjskih nusproizvoda i otpada naše svakodnevnice, stvara nove proizvode i nove vrijednosti. Osim središnje lokacije u Sesvetskom Kraljevcu, u kojem se nalaze i tri pogona, izgradili smo mrežu sabirališta po čitavoj Hrvatskoj kako bismo skratili vrijeme od nastanka nusproizvoda do njegove prerade.

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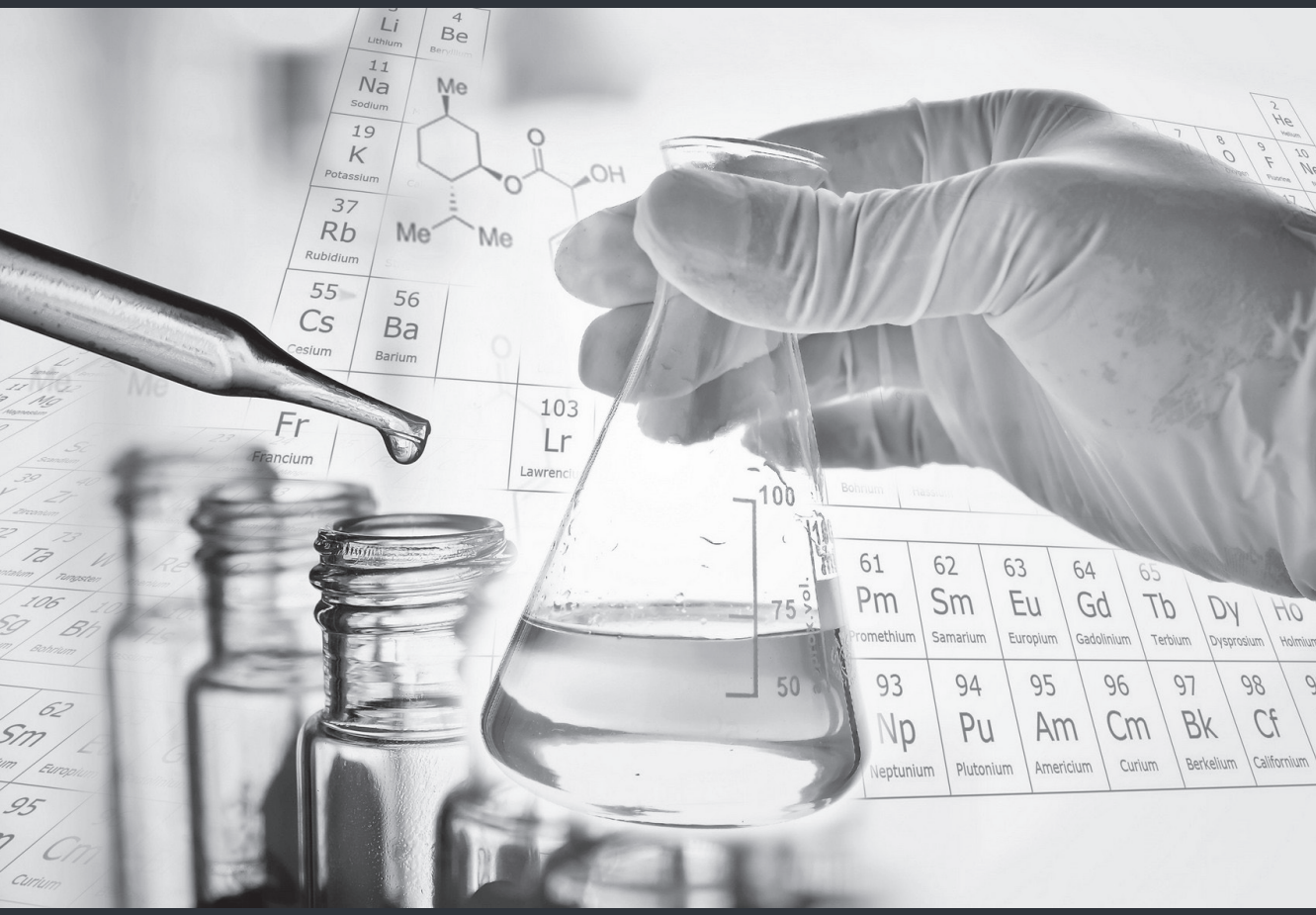

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