University of Novi Sad,
Technical Faculty
"Mihajlo Pupin",
Zrenjanin, Republic of Serbia

International Conference on Physical Aspects of Environment ICPAE2022

Proceedings

Zrenjanin, 31st March – 2nd April 2022

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Conference Organizer:
Technical Faculty "Mihajlo Pupin", Zrenjanin, University of Novi Sad, Serbia

Conference Co-Organizer:
Faculty of Sciences and Mathematics, Nis, University of Nis, Serbia

Publisher:
Technical Faculty "Mihajlo Pupin", Zrenjanin, University of Novi Sad, Đure Đakovića bb, Zrenjanin, Serbia

For Publisher:
Dragica Radosav, Dean of Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia

Editor:
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Technical Support:
Milan Marković,Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia

CIP - Каталогизација у публикацији
Библиотеке Матице српске, Нови Сад

502(082)

INTERNATIONAL Conference on Physical Aspects of Environment ICPAE2022 (1 ; 2022 ; Zrenjanin)
Proceedings [Elektronski izvor] / First International Conference on Physical Aspects of Environment ICPAE2022, Zrenjanin, 31st March – 2nd April 2022 ; [editor Darko Radovančević]. - Zrenjanin : Technical Faculty "Mihajlo Pupin", 2022

Način pristupa (URL):
http://www.tfzr.uns.ac.rs/icpae/conference%20program/ICPAE2022.pdf. - Opis zasnovan na stanju na dan 21.6.2022. - Nasl. sa naslovnog ekrana. - Bibliografija uz svaki rad.

ISBN 978-86-7672-354-6

a) Животна средина -- Заштита -- Зборници

COBISS.SR-ID 69366025

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INTRODUCTION

The first International Conference on Physical Aspects of the Environment ICPAE2022, took place from March 31 to April 2, 2022. It was organized by the Technical Faculty "Mihajlo Pupin" from Zrenjanin. The co-organizer was the Faculty of Sciences and Mathematics from Nis. Members of the scientific-program, advisory and organizational committee of the conference were prominent professors and researchers from the University of Novi Sad, University of Nis, Institute of Physics in Zemun, University of Maribor, Josip Juraj Strossmayer University of Osijek, University of Montenegro, Ss. Cyril and Methodius University from Skopje, University of Banja Luka and University of Sarajevo.

The conference was attended by a large number of renowned participants sharing the results of their research, ideas and achievements related to the burning issues in the field of geophysics, environmental modeling, air pollution, greenhouse effect, global warming, climate change, radiation and the environment, energy efficiency and sustainable development, environmental physics and education.

There were 32 papers for the presentation at the conference: 17 papers from abroad and 15 from Serbia.

Plenary presentations were given by:

- Slavoljub Mijović, University of Montenegro, Faculty of Science and Mathematics, Podgorica, Montenegro;
- Lambe Barandovski, Ss. Cyril and Methodius University, Faculty of Natural Sciences and Mathematics, Skopje, North Macedonia;
- Vanja Radolić, Josip Juraj Strossmayer University of Osijek, Department of Physics, Osijek, Croatia;
- Robert Repnik, University of Maribor, Faculty of Natural Sciences and Mathematics, Maribor, Slovenia;
- Abdulah Akšamović, University of Sarajevo, Faculty of Electrical engineering, Sarajevo, Bosnia and Herzegovina;
- Zoran Mijić, Institute of Physics, Belgrade, Serbia;
- Diana Mance, University of Rijeka, Department of Physics, Rijeka, Croatia;
- Tatjana Ivošević, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia.

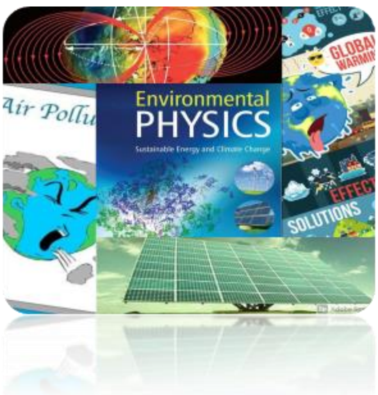
Zrenjanin, June 2022

President of the Scientific Program Committee
Darko Radovančević

CONTENTS

INVITED LECTURES

LECTURES



First International Conference on Physical Aspects of Environment

Technical Faculty “Mihajlo Pupin”, University of Novi Sad, Zrenjanin, Serbia

Faculty of Sciences and Mathematics, University of Nis, Nis, Serbia

31st March – 2nd April 2022

Invited Lectures

Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
Technical Faculty "Mihajlo Pupin", Zrenjanin & Faculty of Sciences and Mathematics, Nis

Greenhouse Effect: Background, Experiments and Modelling

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Abstract. Understanding the Earth's climate and predicting its future behavior is, first and formost a problem in Physics. A historical overview of the main ideas and views on the greenhouse effect and its impact on the climate system is given. Those fondations of our understanding is almost two centuries old. Modern interpretation of the climate change and its antropogenic contribution is reviewed with its key ingredient-the greenhouse effect. Accuracy, uncertenities, boudaries and sensitivity of models, from basics to complex one are analysed. New basic experiments for more quanitaive estimation of greenhous effect is proposed.

Keywords: greenhouse effect, modelling, sensitivity, climate changes, experiments

INTRODUCTION

Nowadays, society and scientists face two basic problems: the problem of energy and the problem of the environment. Both problems are highly interdisciplinary and multidisciplinary. Physics, as a basic science, occupies a central place, especially when it comes to climate change and global warming. Underlining that, The Intergovernmental Panel on Climate Change (IPCC), the United Nations body for assessing the science related to climate change, changed the title of their reports from 'Scientific Assessment' to 'Physical Science Basis' in 2007 [1].

The knowledge about the composition and structure of the atmosphere and ocean and their coupled behavior, together with new global measurement systems like remote sensing, and numerical computer models, make possible quantitative studies and predictions of issues such as global warming and climate change. For example, only IPCC Sixth Report-Climate Change 2021 was based on an assessment of over 14,000 scientific publications and in IPCC Fifth Report stated, with high confidence, that human-induced warming reached approximately 1°C (likely between 0.8°C and 1.2°C) above pre-industrial levels in 2017, increasing at 0.2°C (likely between 0.1°C and 0.3°C) per decade [2].

The main tasks for physicists are to calculate the state of the climate from an understanding of the physical laws that govern it, knowing some basic boundary conditions. We need to understand how stable it is, and how it may change in response to external or internal forcing, like solar variability as an example of external forcing or changes in the minor constituent concentration in the atmosphere, popularly named 'greenhouse' effect, as internal one [3].

In this work is analyzed increasing greenhouse effect due to increasing 'greenhouse' gases in the atmosphere as the consequences of volcanism, or to pollution by industrial and other human activities. The anticipated global warming has generated a strong demand for development of improved techniques for the early detection of the predicted climate change signal. Accuracy, uncertenities, boudaries and sensitivity of models, which describe greenhouse effect, from basics to complex one, are reviwed in a sense of historical development and the current state.

A SHORT HISTORY OF CLIMATE PHYSICS

To date, it has become clear which works were the main ones in reaching today's level of understanding of such a complex system as the Earth's climate and its main process - the greenhouse effect [4-9]. Usually, the starting point is connected to J. Fourier's study of the Earth's energy budget (1827), with an important conclusion that prevailing Earth's energy source is solar radiation. Also, he noted that the existence of the atmosphere must raise the temperature of the Earth's surface, and called it *'un effet de verre'*.

The experimental foundations for future studies of greenhouse effect was done by J. Tyndall (1861), measuring the absorption of infra-red (IR) radiation by the cool gas, and the emission of IR by the gas when it is heated. Gases in his study that absorb also emit a principal now known as Kirkhoff's law. The most impressive implication of his study was that essentially all of the greenhouse activity of the atmosphere is due to a few trace gases such as water vapor and carbon dioxide. Tyndall realized an easy way to change the climate of the Earth through time. Instead of waiting for the entire size or mass of the atmosphere to change, all that needs to change is the concentration of a few trace gases.

S. Arrhenius, (Nobel Laureate in chemistry 1903), made major advance in understanding greenhouse effect in his paper, published 1896, and practically started modern climate physics. Having the data in that time, Arrhenius calculated the warming that would result from doubling the CO_2 concentration of the atmosphere, a quantity that modern climate scientists call the climate sensitivity. The result he's gotten was 6°C (modern estimation is in the range of $(2.5 \div 4°C)$), but more important was his approach. Basically, what Arrhenius had to do was invent the field of climate modeling, which had never before been done quantitatively for planets with atmospheres. About Arrhenius one-layer model of the greenhouse effect we will discus in more details in next section.

Modelling

Models are simplified representations of reality, usually very complex phenomena like our climate system. Mathematical formulation of a model reduces system under investigation to one of more set of time dependent differential equations that can be solved either analytically or numerically, thus giving a chance to see time-evolution and prediction of the system behavior. Simple models provide useful insight into the physics involved, while complex models are necessary to obtain the greatest possible accuracy and to attempt to incorporate all of the feedback process. All models are based on energy balance budget between heating the Earth with solar shortwave radiation and the Earth's cooling with long-wave IR radiation:

$$F_{in} = F_{out}, \tag{1}$$

where are F_{in} −incoming energy flux and F_{out} −outgoing energy flux.

The zeroth order model

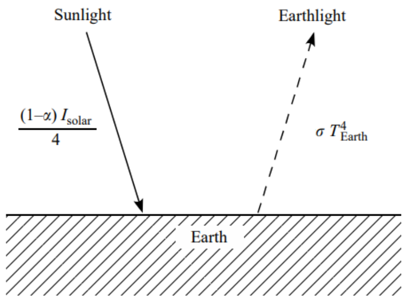

Figure 1. Energy diagram for Earth with no atmosphere

In equilibrium of incoming and outgoing fluxes, one can easily calculate the mean temperature of Earth surface as:

$$T_{Earth} = \sqrt[4]{\frac{(1-\alpha)S}{4\sigma}} \approx 255K = -18℃, \tag{2}$$

where are $S = 1.361kW/m^2$ −solar constant, $\sigma = 5.67 \cdot 10^{-8}Wm^{-2}K^{-4}$ −Stefan-Boltzmann constant, and $\alpha \approx 0.3$ −Earth's albedo. This temperature we named as effective or sometimes radiometric and is of course far away from the real Earth's temperature, so emphasizes the role of the atmosphere in the one-layer model.

Arrhenius one-layer model

In this model a single pane of glass is taken for the atmosphere, simulating a case of transparency of solar radiation and trapping of IR (Fig. 2.). Detailed calculation is given in [10]. If we mark the temperature of Earth without atmosphere with T_{BP} , BP −'bare planet' then the calculated new Earth's temperature is increased $2^{1/4}T_{BP} \approx 303K = 30℃$. The overestimated temperature ($15℃$ −is approx., the average Earth's temperature) is due to great simplification of the model.

Generalizing this to an N-layer atmosphere one can find that the Earth's temperature increases following the relation $(N+1)^{1/4}T_{BP}$ with the top of the atmosphere radiating to space at T_{BP}, with the clear implication of a runaway greenhouse effect.This is a pioneering study of how absorption by CO_2 would influence the temperature of Earth's surface and how Arrhenius built the scientific framework central to the atmospheric column models used in successively more complex treatments that have developed since then. This was done by Manabe and Wetherlad in their groundbreaking work 1967 [11].

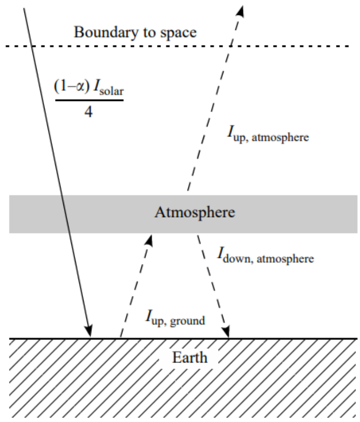

Figure 2. Energy diagram for Earth with atmosphere

Manabe's climate model (convection in the layer model)

Syukuro Manabe was the first scientist who used the state of energy balance when both radiation and convection are taking place, that is, the so-called radiative–convective equilibrium.

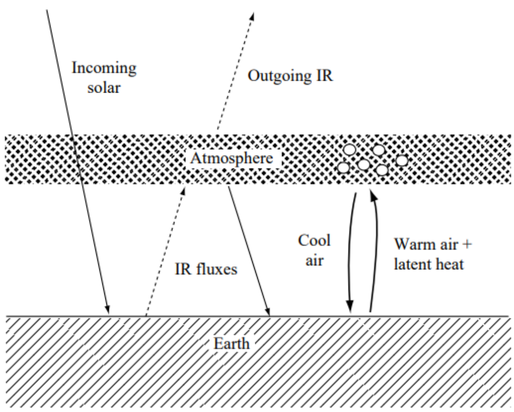

Figure 3. Schematically representation of Manabe's climate model

In this model, the entire atmosphere is treated as a single one-dimensional column with a given profile of relative humidity and greenhouse gas concentration. Convection carries heat vertically in the atmosphere, supplementing the heat carried by radiation. This process constitutes a parameterization of the vertical dynamics as follows. If a column evolves solely from radiative transfer, the lapse rate is ~ - 15 ◦C /km, far greater than observed.

Now, the adiabatic lapse rate is ~ - 10 ◦C /km, but as air rises in a real atmosphere the condensation of water releases latent heat, which is largely responsible for the observed, or "moist", lapse rate of ~ - 6 ◦C /km.

To understand how it influence the ground temperature (Earth's surface temperature), imagine increasing the concentration of CO2 in an atmosphere. This has the effect of raising the altitude in the atmosphere where light on average escapes to space (Fig.4). Let's call that altitude the skin altitude.

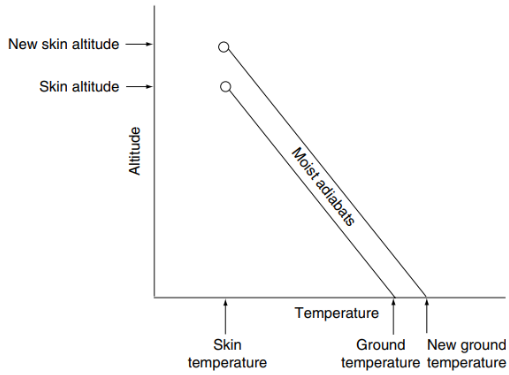

Figure 4. A demonstration of the effect of the lapse rate on the strength of the greenhouse effect

To be in equilibrium with incoming radiation, the outermost part of the atmosphere, the part that radiates directly to space, always had the same temperature in all of those different model configurations. We called that the skin temperature, and it was always 255 K as we calculated it earlier. To meet that requirement and constant 'moist' adiabat the ground temperature must arise (see Fig. 4). To understand such a complex system S. Manabe got Nobel Prize in Physics in 2021.

General Circulation Model

The most sophisticated numerical climate models are known as general circulation models (GCMs). It including the fluid dynamical equations that represent the circulation of the atmosphere in a realistic way. Nowadays we have ocean GCMs as well, and advanced climate models include atmospheric and oceanic GCMs that are coupled together. They consist of a large number of inter-related, time-dependent mathematical equations requiring a massive supercomputer to run.

DISCUSSION

Usually the extensive work with a model leads to renewed extensions, which turn simple models into complex ones almost as a rule. Not all models are improved by doing this. Jørgensen (1994) [12] envisages the connection between model complexity and knowledge, gained by the model, as shown in Fig. 6. Simple models can be improved by extensions, but there is a certain peak position after which further extensions do not add to the knowledge – rather quite the contrary. An improved model design increases the quality of the model (let's take gained knowledge as a quality measure), but further extensions of the improved model may finally lead to a situation in which the increase of model complexity is counter-productive.

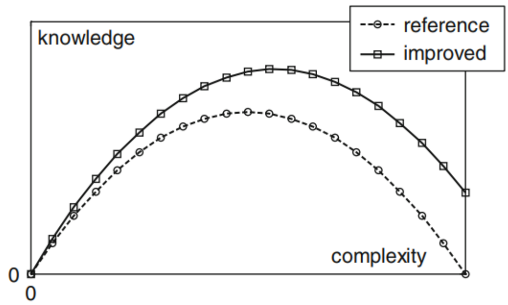

Figure 5. Model evaluation: knowledge gained vs. complexity

The major drawback of complex models is the increased number of parameters, sometimes to a drastical extend. The situation may be worsened by the fact that many new parameters are usually difficult to obtain or have to be determined by parameter estimation runs with the model. Another drawback may appear, if the model becomes very sensitive to one or more parameters, i.e. that relatively small changes of a parameter induce a tremendous effect on the output results. A complex model which depends sensitively on numerous unknown parameters can surely not be used as a predictive tool. However, complex models have their justification.

It is not the aim of modeling to set up complex models. The opposite of that statement is a more suitable goal: the aim of modeling is to find simple models that explain some aspects of a real system. Moreover, if a system is complex, a simple model can explain a few aspects at the most and that may not be enough to solve a real problem.

Instability and nonlinearity underlie multiscale complexity and stochasticity The emergence of disorder from order, and with it multiple scales in space and time, is a characteristic of complex systems. Understanding the nature of that disorder presents an enormous scientific challenge.

Despite of the problems listed above the scientific level of understanding climate system is impressive. In order to assess whether climate models are faithfully reproducing the signal from the natural variability, Klaus Hasselmann (Nobel Laureate in Physics 2021) paid attention in stochastic climate dynamics and made a framework to systematically compare climate models and observations. He found statistically the optimal detector of climate change, clearly prooving how to separate stohastic weather as „noise", from the climate change signal. This is variable that has the maximal signal-to-noice ratio, and consist of a weighted linear combination (the „fingerprint") of all variables.

CONCLUSION

If we take it as facts that the Earth is heating up and densities of "greenhouse" gases in the atmosphere increase, claims that these are not natural phenomena but due to anthropogenic influence can be taken only with high probabilities. The reason for above statement lies in the fact that each model is only a representative of reality and not proof. It means that basic physical processes which govern the climate system must be proved experimentally. Hope that we are now in better position relating to experimental equipment than J. Tyndall in nineteen century.

As second open question, as Hasselmann stated, is a task of identifying the most sensitive climate index, from a large set of potentialy available indices, for which the anticipated antropogenic climate signal can be most readily distingwished from the natural climate noise. Global mean surface temperature, vertical temperature differences, sea ice extent , sea level change, and integrated deep ocean temperatures are examples of indices. Whether the global mean surface temperature is really the most suitable variable for detection of climate change?

I will try to answer this question on the example of the temperature of a moon that has neither an atmosphere nor is inhabited. It is at the same distance from the Sun as the Earth, so solar constant is the same. Its albedo is 0.12, thus the average temperature can be easily calculated using the zeroth order model: $T_{moon} = 270K$. Now, taking into account that the average daytime moon's temperaure is 380K and the average nighttime moon's temperaure is 120K, surprisingly, we get that the outgoing flux corresponds to a uniformly warmed moon at a temperature of 320K! I call it „Pardox of mean temperaure". With this non-uniform distribution of moon's temperature we got that outgoing flux is almost two times higher than in a case of uniform temperature distribution. Such big discrepancy we got due to non-linear effect, because the outgoing flux is prportional to forth power of the temperaure. Something is very wrong!

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Air Pollution Study in Macedonia Using Moss Biomonitoring Technique, NAA, ICP-AES and AAS

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Abstract. In the framework of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops under the spices of the United Nations Economic Commission for Europe (UNECE-ICP Vegetation) Convention on Long-Range Transboundary Air Pollution (LRTAP), in 2002, 2005, 2010, 2015 and 2020 a moss biomonitoring technique was applied to air pollution studies in Macedonia. In every survey year 72 samples of the terrestrial moss samples were collected over the territory of Macedonia, using the same sampling network grid. Using Neutroin activation analysis (NAA), inductively coupled plasma - atomic emission spectrometry (ICP-AES) and atomic absorption spectrometry (AAS), contents of more than 40 elements in the moss semples were determinedtra. To reveal hidden multivariate data structures and to identify and characterize different pollution sources Multivariate analysis was used. Distributional maps were prepared to point out the regions that were the most affected by the pollution and to be related to known sources of contamination. The largest anthropogenic impact of air pollution with heavy metals was establish nearby a smelter for ferronickel near Kavadarci (with Ni and Cr) and lead and zinc mines in the vicinity of Probistip, Makedonska Kamenica and Kriva Palanka (with Cd, Pb and Zn).

Keywords: Moss; biomonitoring; air pollution; potentially toxic metals; Macedonia

Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
Technical Faculty "Mihajlo Pupin", Zrenjanin & Faculty of Sciences and Mathematics, Nis

Radon Levels in Caves of Croatia – a Review

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Abstract. From 2004, radon measurements are being performed in more than 20 caves of Croatia, simultaneously with other geochemical and geophysical parameters and are still going on. Track etched radon detectors were exposed mostly during speleological expeditions in the Velebit and the Žumberak regions. The obtained results are presented and significant difference in radon concentrations between those two regions are discussed. The correlation between radon and partial pressure of carbon dioxide, which is an important factor in the variety of geochemical processes occurring in caves, are presented in the case of Modrič Cave. Continuous monitoring of radon variations was performed in several touristic caves in southern Velebit mountain (Manita peć and Modrič Caves) as well as in the Dubrovnik region (Đurovića Cave) and risk assessments for touristic guides and visitors were conducted. The obtained results are discussed regarding the implementation of new ICRP dose conversion factors.

Keywords: radon, cave, Croatia

INTRODUCTION

Radon is produced by the radioactive decay of radium (^{226}Ra) along with the emission of α particle inside mineral grains that contain uranium. Although most of radon never leaves the mineral crystal lattice in which it is created until its own radioactive decay (half-life of radon is $\tau_{1/2}$ = 3.825 days), smaller amounts of radon manage to escape and travel through the Earth`s crust guided by various transport mechanisms (by diffusion, advection, convection or trapped by geogases (CO_2, CH_4, …) [1].

Caves in a karstic area are formed by a special chemical dissolution process due to infiltrated water is taking place in the carbonaceous rock matrix. The result of this chemical process is the formation of an interconnected set of larger openings and fractures which further leads to the collapse of large volume rocks. The consequence of these processes is a cave formation [2]. Carbonate rocks (dolomites, limestones, and their impurities) usually have a low level of ^{238}U (16 - 31 Bq/kg) [3,4]. However, in surrounding rocks, occasionally feldspar and mica, uranium can be found in structural positions. Radon generated in these rocks may migrate in the subsoil penetrating this carbonate due to its greater permeability causing high radon concentration inside caves. In general, radon concentration in caves depend on different parameters and the dominant ones are: radon exhalation from the cave surfaces, shape and size of the cave, air flow and air exchange rate from inside to outside the cave and vice versa (mixing governed by meteorological parameters inside and outside the cave). The temperature difference between the air inside and the air outside of the cave is the principal mechanism of air exchange in horizontally structured caves, while in vertical caves the same mechanism is governed by the pressure difference between the upper and lower part of the cave [5]. According to this, in horizontal caves maximum radon concentrations are expected during summer period because of the constant air temperature in the cave during the year; during winter the air temperature in the cave is higher than the outside temperature and due to this temperature gradient, air from the cave is extracted and fresh air flows into the cave reducing the radon concentration.

During the last fifty years, radon concentrations were measured in caves throughout the world [6-11], as well as in our neighboring countries [12-19]. Hakl et al. [4] systematized radon concentrations in more than 330 caves in Hungary, Italy, Slovakia, Luxembourg, England, Mexico and the United States of America. They took into consideration Only radon measurements that covered a full year were taken into consideration by them. The distribution of analysed data was log-normal, with arithmetic mean of 2.8 kBq m^{-3} and values were in range of 0.1 and 20 kBq m^{-3}.

MATERIALS AND METHODS

Radon measurements

The measurement of radon concentration is performed by a passive method by using the solid state nuclear track-etched detectors LR 115 type II (manufacturer Dosirad, France). The top of the cylindrical plastic vessel (cup with 11 cm in diameter and height of 7 cm) is covered with filter paper (surface density 0.078 kg/m^2). Inside the vessel, on the bottom, a LR115 type II detector (with dimensions 2.4x3 cm^2), that is called diffusion detector, is placed. The diffusion detector records only tracks left by alpha particles emitted from radon, because radon progeny cannot penetrate through the filter paper [20]. After being exposed, LR115 type II detectors were chemically etched in 10% aqueous solution of NaOH at a temperature of 60 °C for 120 minutes. Tracks were counted visually (when track densities were rather low) and automatically by using the optical microscope Olympus BX51, digital camera Olympus c5050 and software for image analysis. Radon concentrations were determined as the product of track densities on the diffuse detector and sensitivity coefficient (30.0 ± 2.0 (visually counted) or 31.7 ± 3.2 Bq m^{-3} / tr cm^{-2} d^{-1} for automatically counting) which was determined during the calibration process at reference radon chambers (NRPB in England, PTP BEV in Austria and Bureau of Metrology in Montenegro in 2021). The quality control of detectors has been continuously monitored in the radon chamber of the Physics Department in Osijek, Croatia.

Continuous measurements of radon and its short-lived progeny concentrations, as well as certain meteorological parameters (air temperature, barometric pressure, relative humidity) were performed by the AlphaGUARD measuring unit (manufacturer: Genitron Instruments GmbH, Germany). The central part of this measurement system is the

AlphaGUARD PQ 2000 PRO which detector is a radon pulse ionization chamber with active volume 0.56 dm^3. The instrument was working in the diffusion mode with the measurement time interval of 60 minutes. Determination of equilibrium equivalent concentrations of radon progenies as well as equilibrium factors were performed by the Radon WL Meter TN-WL-02 (manufacturer: Thomson Nielsen, Canada) which is connected to the AlphaGUARD measuring system and uses its internal memory to store recorded data. Since 2018, the TSR3 detectors (manufacturer: Tesla company, Czech Republic) have been used for continuous measurements in radon monitoring of caves. Radon diffuses into the detection chamber with a semiconductor detector inside. The measurement interval is 60 minutes.

Location of caves and local geomorphology

Since 2004, radon has been extensively measured in pits and caves in the Republic of Croatia. Detectors were set up during speleological research expeditions with the purpose of exploring physical and chemical properties of the karst underground. Until today, radon concentrations have been measured in more than twenty caves and pits in the Velebit and Žumberak mountains (Figure 1.).

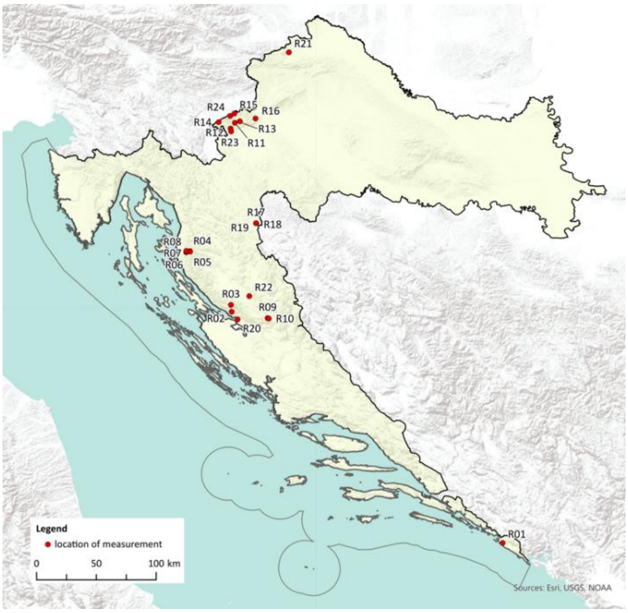

Figure 1. Location of the selected caves in Croatia in which radon measurements were performed.

Velebit is a mountainous region in Croatia between the Adriatic Sea and Ličko-Gacko polje. This karst area is conducive to the formation of deep pits, three of them are deeper than 1 km - Lukina jama Cave (-1392 m, #R04 in Fig.1), Slovačka jama (-1320 m) , and recently discovered Velebita (-1026 m, #R06 in Fig.1). So far, 259 pits have been discovered in the Northern Velebit area that covers some 25 square kilometers [21]. This area is composed of lithostratigraphic units ranging from Middle Triassic to Paleogene Age.

The largest part of Northern Velebit is composed of Jurassic sediments which contain carbonate rocks only. Limestone prevails in the composition of deposits, but dolomites are also present. Jurassic deposits are approximately 2,850 m thick. However, speleological explorations have revealed a more complex geology of Northern Velebit. [22]. Žumberak and Samobor mountain area is a mountainous region in western part of Croatia near the border with Slovenia. Geological and lithological maps of this area show that limestone (from Upper Cretaceous to Jurassic), dolomites (from Upper Cretaceous to Upper Triassic) and flysch-like series of rocks from Upper Cretaceous dominate [23].

RESULTS AND DISCUSSION

The obtained results of radon measurements are presented in Table 1. The highest radon concentration among the deep pits of Velebit mountain was measured in Lubuška pit (3.8 kBq m^{-3}) [24]. In the Žumberak mountains the highest radon concentration was measured in the Dolača cave (21.8 kBq m^{-3}), 250 meters from the entrance during summer period [25]. Furthermore, a radon monitoring was performed in three caves (R01, R02, R20 from Table 1). The highest radon levels were measured in Đurovića cave, located near the control tower of Dubrovnik airport, which makes it very interesting for tourists. Detectors were exposed in late autumn 2008 and during spring and summer 2009, and the obtained average radon concentrations were 9.5, 17.9 and 25.0 kBq m^{-3}, respectively [26]. These preliminary data, according to dose conversion factors based on epidemiological approach and valid at that time [27] (radon exposure of 1 Bq h m^{-3} is equivalent to the effective dose of $3.108 \cdot 10^{-6}$ mSv) gave dose rate in Đurovića cave of 28 μSv/h. Radon monitoring in Manita peć Cave (R02, located in NP Paklenica) as well as in Modrič Cave (R20) also showed that visitors received the highest doses from radon and its short-lived progenies during summer months. For the Manita peć Cave, dose rates were 3.7 μSv/h in 2010 and 3.4 μSv/h in 2011 while for the Modrič Cave they were 11.4 and 14.1 μSv/h in 2020 and 2021, respectively when the epidemiological approach and dose conversion factors was applied. By applying dose conversion factors derived from biokinetic model [28] the dose rates were 4.17 times higher. Continuous radon measurements in the Modrič Cave are still going on as a part of an extensive project with the goal to determine ventilation patterns of the cave, which governs the carbon dioxide concentration as a key factor in calcite corrosion/precipitation in the cave. The obtained results so far, showed a similar spatial and temporal pattern between radon and CO_2 and a strong linear correlation has been found.

Table 1. Average radon concentrations with its standard deviations (c ± σc / kBq/m^3), number of detectors exposed (N), information of year, seasons, and duration of measurements (in days) in selected caves in Croatia where radon measurements were performed.

Label	Cave	Location	Year	Duration / days	Season // Months	N	c ± sc / kBq/m^3
R01	Đurovića špilja	Cavtat	2008	55	Autumn // Oct – Dec	11	9.5 ± 1.7
			2009	63	Spring // Apr - Jun	11	17.9 ± 1.9

			2009	73	Summer // Jun - Aug	13	25.0 ± 2.8
R02	Manita Peć	NP Paklenica	2010	91	Summer // Jun - Aug	24	1.11 ± 0.19
			2010	91	Autumn // Sep - Nov	16	0.26 ± 0.07
			2010 / 2011	91	Winter // Dec - Feb	16	0.03 ± 0.01
			2011	91	Spring // Mar - May	16	0.14 ± 0.03
			2011	91	Summer // Jun - Aug	26	1.07 ± 0.13
R03	Špilja pod Zubom Buljme	NP Paklenica	2009	99	Summer // Jun - Oct	2	2.20 ± 0.29
			2009 / 2010	245	Autumn - Spring // Oct - Jun	2	1.17 ± 0.07
R04	Jamski sustav Lukina jama - Trojama	NP Sjeverni Velebit	2010	11	Summer // Jun - Aug	7	0.59 ± 0.08
			2011	7	Summer // Jun - Aug	14	0.63 ± 0.28
R05	Lubuška jama	NP Sjeverni Velebit	2006	11	Summer // Aug	5	0.67 ± 0.34
			2009	5	Summer // Jul - Aug	3	0.94 ± 0.05
R06	Jamski sustav Velebita	NP Sjeverni Velebit	2004	9	Summer // Aug	10	0.26 ± 0.15
			2007	11	Summer // Aug	13	0.61 ± 0.38
			2011 / 2012	210	Autumn - Spring // Oct - May	5	0.45 ± 0.19
			2012	161	Spring - Autumn // May - Oct	6	0.27 ± 0.07
			2012	7	Summer // Aug	10	1.06 ± 0.38
R07	Jama Varnjača	NP Sjeverni Velebit	2014 / 2015	360	All seasons	3	0.7 ± 0.4
R08	Jama Sirena	NP Sjeverni Velebit	2013 / 2014	360	All seasons	8	0.52 ± 0.25
R09	Jamski sustav Kita Gaćešina - Draženova puhaljka	PP Velebit	2006	120	Summer - Autumn // Jun - Oct	3	0.91 ± 0.02
			2013 / 2014	350	All seasons	6	0.87 ± 0.15
R10	Špilja Munižaba	PP Velebit	2004	7	Summer // Jul	9	1.39 ± 0.23
R11	Špilja Dolača	PP Žumberak -	2004	49	Autumn // Oct - Dec	5	4.4 ± 1.3

		Samoborsko gorje	2006	120	Summer - Autumn // Jun - Oct	5	14.2 ± 4.4
R12	Špilja Provala	PP Žumberak - Samoborsko gorje	2004	49	Autumn // Oct - Dec	7	7.6 ± 3.3
			2006	105	Summer // Jun - Sep	6	8.7 ± 1.5
R13	Jama Bedara	PP Žumberak - Samoborsko gorje	2004 / 2005	161	Winter - Spring // Dec - May	3	0.27 ± 0.05
			2007 / 2008	210	Summer – Winter // Jun -Jan	3	0.71 ± 0.21
R14	Dakina jama	PP Žumberak-Samoborsko gorje	2009	139	Summer - Autumn // Jul -Nov	1	2.93 ± 0.30
			2009 / 2010	239	Autumn - Summer // Nov - Jul	1	0.73 ± 0.08
R15	Židovske kuće	PP Žumberak-Samoborsko gorje	2009	143	Summer - Autumn // Jul -Nov	1	2.07 ± 0.22
			2009 / 2010	234	Autumn - Summer // Nov - Jul	1	0.58 ± 0.06
R16	Vugrinova špilja	PP Žumberak-Samoborsko gorje	2009	141	Summer - Autumn // Jul -Nov	1	6.67 ± 0.68
			2009/ 10	234	Autumn - Summer // Nov - Jul	1	2.95 ± 0.31
R17	Gornja Baraćeva špilja	Rakovica	2014	143	Summer - Autumn // Jun -Nov	5	2.0 ± 1.1
			2014 / 2015	217	Autumn - Summer // Nov - Jun	5	0.90 ± 0.39
R18	Donja Baraćeva špilja	Rakovica	2014	143	Summer - Autumn // Jun -Nov	2	14.04 ± 0.31
			2014 / 2015	217	Autumn - Summer // Nov - Jun	2	4.2 ± 1.3
R19	Nova Baraćeva špilja	Rakovica	2014 / 2015	360	All seasons	1	4.59 ± 0.49
			2014 / 2015	217	Autumn - Summer // Nov - Jun	1	2.11 ± 0.23
R20	Špilja Modrič	Rovanjska	2009	101	Summer - Autumn // Jun -Oct	2	2.00 ± 0.20

			2009 / 2010	245	Autumn - Spring // Oct - Jun	2	0.63 ± 0.06
			2018-	Integrated and continuous radon measurements are ongoing			
R21	Cerjanska špilja	Ravna gora, Kralji	2012 / 2013	377	All seasons	1	2.59 ± 0.28
R22	Špilja Debeljača	Kamenolom Lovinac	2009 / 2010	532	May 2009 - Oct 2010	2	4.4 ± 1.2
R23	Špilja Rogovac	PP Žumberak-Samoborsko gorje	2004	48	Autumn // Oct -Dec	3	0.43 ± 0.47
			2006	105	Summer // Jun – Sep	2	0.9 ± 1.1
			2007 / 2008	210	Summer - Winter // Jun - Jan	3	0.95 ± 0.30
R24	Pogana jama	PP Žumberak-Samoborsko gorje	2007	187	Spring - Autumn // May - Nov	3	0.68 ± 0.36

ACKNOWLEDGEMENTS

This work was financially supported by the National Park Sjeverni Velebit, Croatian waters, National Park Paklenica, Natura Jadera, University of Zadar (project IP.01.2021.17 VENTSPIS). The authors would also like to thank to the members of Speleological section Velebit, Samobor and Zagreb as well as to touristic guides for field work support.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
Technical Faculty "Mihajlo Pupin", Zrenjanin & Faculty of Sciences and Mathematics, Nis

Phase Change Materials in Teaching Physics

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Abstract. The largest share of households' energy consumption presents heating and cooling of houses to maintain certain thermal comfort. Therefore, it is of importance to optimize the thermal balance of buildings. One possibility is using phase change materials (PCMs) to decrease room temperature oscillation. PCMs accumulate or release the latent heat accompanying the phase transition. Given the growing energy requirements, it is sensible to address the topic of PCMs in schools within the science subject. In this contribution, we first present the basic properties of PCMs and requirements for their use as heat and cooling storage in different applications. With a focus on introducing PCMs in teaching Physics, we present the basics of PCMs thermodynamics. Based on the analysis of the high school Physics curriculum, we propose how to implement PCMs in the physics classroom.

Keywords: phase change materials, thermal stabilization, physics teaching

INTRODUCTION

Economic development, population growth, and consumer habits lead to an increase in energy demands. Countries strive to rationalize energy consumption, not only from an economic but also from an environmental point of view. According to Eurostat [1], almost two thirds of all energy consumed in the households sector is for space heating (63,6 %) and cooling(0,4 %) purposes. Therefore, improvements in the energy balance of buildings are of constant interest to researchers. To improve the energy balance of buildings, one needs to understand the mechanisms of heat transfer and the thermal properties of materials. Concerning the rising demand for energy-efficient, passive and sustainable buildings, the development of new methods and innovative materials is needed.

Recently, many studies [2-9] suggest phase change materials (PCMs) could be efficient as innovative insulation materials. PCMs undergo the phase transition, during which the latent heat accumulates or releases to the surroundings. The ability to store or release the latent heat means PCMs can minimize day-night room temperature fluctuations and improve the energy balance of buildings. Experimental studies confirm the incorporation of PCMs into lightweight building materials compensates for small heat storage capacity. The optimal properties of PCMs vary depending on the intended use. In this contribution, we focus on the thermal stabilization of buildings, which reduces the need for additional heating or cooling. However, PCMs are of interest in the textile and medical sectors [10-12].

Despite the novelty of PCMs and challenges in the research and development of such materials, concepts of PCMs can be introduced in physics class. It is necessary children become aware of the impact of their actions on the environment and the contribution of science in solving such problems. Introducing real-life problems can also increase their interest in science. One of the goals of education should be to educate and raise competent people that will be able to solve challenges they will face in the future.

In this contribution, we first present the theoretical background of phase change materials on the level suitable for secondary education. Next, we analyze curricula in primary and secondary schools in Slovenia. We use a qualitative documentary method to find possibilities to introduce PCMs within formal education. Then, we present the experimental approach to introduce PCMs in physics classroom. The experiment is simple but illustrative to understand the concept of incorporation of PCMs in building composites.

THEORY BEHIND PHASE CHANGE MATERIALS

Phase change materials (PCMs) are materials that undergo a first-order discontinuous phase transition at the phase transition temperature T_c or in the narrow temperature range $[T_c, T_c + \Delta T_c]$. During the first-order phase transition, PCM accumulates the latent heat (L) from its surroundings or releases it. Therefore, PCMs can store additional heat, which is the reason they are also known as latent heat storage materials. The most common PCM is water. To change the phase from liquid water to solid ice at the phase transition temperature 0 °C, latent heat (334 kJ/kg) is released to its surroundings (Figure 1a). When melting ice into water, the same amount of latent heat is absorbed (Figure 1b).

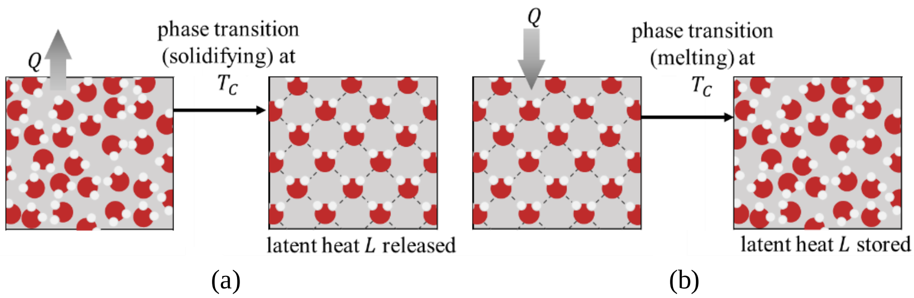


Figure 1. Schematic representation of PCMs (water) during phase transition when the latent heat is a) released and b) stored.

The efficiency of PCMs strongly depends on the phase transition temperature T_c and large latent heat. At temperatures much higher or lower than the phase transition temperature, PCMs are inefficient. The optimal value of T_c varies for different applications. In the application of PCMs for the thermal stabilization of buildings, the phase transition should occur near the desired room temperature. Therefore, water is not suitable for such use, despite the large latent heat. Other physical properties are also important in the optimization of energy balance. In the case of conventional thermal insulators, we want low thermal conductivity λ to reduce heat conduction. On the other hand, we want to store or release as much latent heat as possible during one period of outdoor temperature fluctuations. For that reason, the system needs to be responsive, which means the higher thermal diffusivity $\alpha = \lambda/(\rho\, c)$ is required. Here, ρ stands for the density and c for the specific heat of the PCM. In general, λ, ρ, c and α are temperature dependent. These are all problems that researchers and engineers face in the development of new PCMs and incorporation of them in building composite materials. In addition, PCMs must be chemically stable with sufficiently long service life, affordable and cost-effective, as well as recyclable. We can already find building composites with PCMs on the market from various manufacturers [13-15]. Table 1 presents essential parameters of representatives of organic and inorganic PCMs that could be used for the thermal stabilization of buildings. We focus on the solid-liquid phase transitions due to smaller volume changes.

Table 1. Phase transition temperature and latent heat of PCMs

PCM	Phase transition temperature (melting) [°C]	Latent heat [kJ/kg]
Mirabilite - hydrous sodium sulfate mineral (inorganic)	18	286
Paraffin C-17 (organic)	22	215
Polyethylene glycol 600 (organic)	20	146
Glycerol (organic)	18	191

We can describe the contribution of PCMs to the energy balance of buildings mathematically using different methods. In one dimension, the heat equation in terms of enthalpy $h = c\, T$ is expressed as [16]:

$$\rho \frac{\partial h}{\partial t} = \lambda\, \frac{\partial^2 T}{\partial x^2}. \qquad (1)$$

Here, we assume specific heat is constant in this temperature range. During hot days, heat transfers from the outside through the wall (Figure 2a), and the room temperature (T_r) increases. Next, let us see what happens if PCMs are incorporated in the wall composites. As the heat transfers from the outside through the wall, some heat is stored due to the thermal capacity. If the wall temperature increases to T_c, PCMs undergo the phase transition. The used for the phase transition is stored inside the composite (Figure 2b).

We calculate the enthalpy as:

$$h = c\, T + \, \omega\, r\, L, \qquad (2)$$

where ω is the relative amount of PCMs in the building composite and r describes the proportion of the disordered (liquid) phase. It equals zero in the solid phase, and equals one in the liquid phase. Usually linear approximation is used to determine value of $r(T)$:

$$r(T) = \frac{T - T_c}{\Delta T_c}. \qquad (3)$$

When all PCMs change phase to liquid, additional heat is stored within walls. By combining Eq. (1), Eq. (2), and Eq. (3), heat equation in the presence of PCMs is:

$$\rho\, c \frac{\partial T}{\partial t} + \rho\, \omega\, L\, \frac{\partial r}{\partial T}\frac{\partial T}{\partial t} = \lambda\, \frac{\partial^2 T}{\partial x^2}. \quad (4)$$

We obtain the additional term, which indicates the contribution of PCMs.

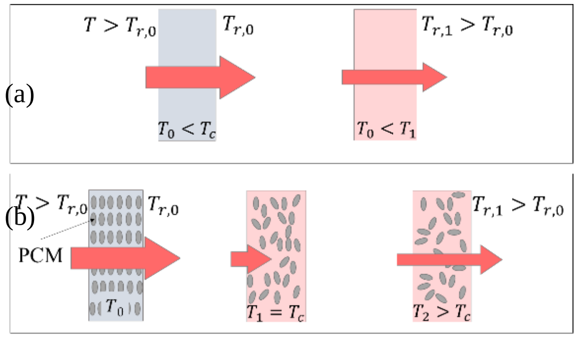


Figure 2. The schematic representation of the heat transfer through the planar wall. a) Due to the thermal capacity, heat is stored within a "classic" wall, and the room temperature increases in time. b) For composites with PCMs, PCMs undergo the phase transition, during which latent heat is absorbed. Consequently, room temperature remains constant. When all PCMs are in the disordered (liquefied) phase, the room temperature increases.

INTRODUCTION OF PHASE CHANGE MATERIALS IN SCHOOLS

We analyze curricula of primary and secondary education of Slovenia school systems to find opportunities to introduce the concept of PCMs from an environmental aspect. Concerning the theory behind PCMs, science-related subjects are of focus. It is desired students have preliminary knowledge of heat transfer, aggregate states, phase transitions, and thermal properties of materials.

In primary education, students first learn about those qualitatively. In the Natural science and technology curriculum [17], related learning outcomes are: students 1) describe states of water and describe their properties, 2) prove heat transfers from warmer to colder, 3) show heat transfer differs for different materials, 4) describe types of insulation materials, their use and importance. In last two years of primary school, students have the subjects Physics. Based on the curriculum [18], students learn about the structure of solids, liquids and gases, temperature and heat, and heat conduction. One of the learning content section is Physics and environment. Teachers can freely choose interesting topics to show students how physics can make our life easier. Students also have two elective subjects: Environmental education and Projects in physics and ecology. The latter [19] acquaints students with basic laws of physics, explains phenomena in nature, and presents some environmental problems we face today. The curriculum includes ideas for simple experiments aiming to increase students' interest in science and raise their awareness of the human impact on the environment. In our opinion, this course is suitable to introduce novelty materials such as PCMs and their potential to improve the energy balance. Based on the elementary education's curricula analysis, we can conclude students have some basic knowledge about phase transitions and heat transfer.

In secondary education, we focus on Physics curriculum [20]. Students learn about different states of matter on the microscopic level and describe the phase transitions. They know that temperature difference leads to the heat transfer between bodies (conduction) or between the body and its surroundings (emission and convection). Convection is introduced only qualitatively. They calculate the conduction heat flux through the planar surface area S with thickness d: $P = \lambda\, S\, \Delta T / d$. They understand that some materials are thermal insulators, and some are thermal conductors. Students also know thermal properties such as specific heat, heat capacity, thermal conductivity, thermal resistance, and latent heat (melting, evaporating, and combustion). Therefore, we believe introducing PCMs in secondary education is possible, especially on the qualitative level. In the following section, we present the idea to introduce the concept of PCMs in Physics using an experimental approach.

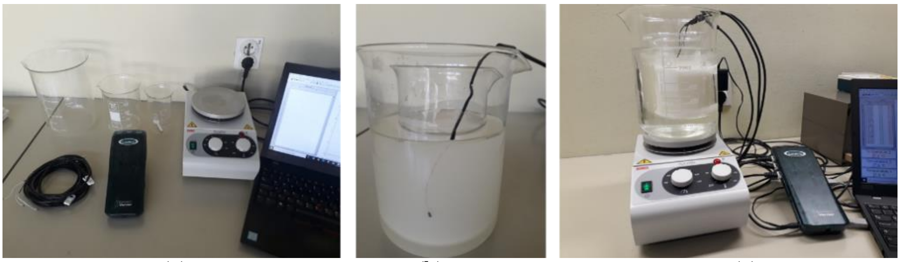
Experimental approach

The goal of the experiment is to illustrate application of PCMs for the thermal stabilization of buildings. The best way to perform this experiment is in small groups of 3 to 5 students. However, a demonstration by a teacher is also possible regarding the material constraints and students' competencies.

We need three glass containers of different sizes, an electric heater with a magnetic stirrer, three temperature sensors, a computer with an interface and software to collect data, water, and paraffin wax (Figure 3a). In our case, we use Vernier temperature sensors, LabPro interface, and collect data in LoggerPro software. Paraffin wax is affordable PCM that is widely available on the market. We use paraffin wax with the melting temperature between 54 °C and 56 °C. The container filled with paraffin represents building walls, the inner container is indoors (room), and the outer container is outdoors.

Measurements

First, we melt paraffin wax in the middle-sized container using a water bath. When paraffin is liquid, we insert a smaller container filled with water. In this stage, we have to insert one temperature sensor in the paraffin (Figure 3b). When the paraffin becomes solid, we set both containers in a larger container filled with water, set the temperature sensors, and start heating. We monitor and collect temperature data until all paraffin liquefies. Then, we turn off the heating but leave on the stirring and wait until paraffin is in a solid state. The experiment setup is shown in Figure 3c. For reference, we repeat the experiment using water in all three containers.



(a) (b) (c)

Figure 3. a) Experiment equipment, b) Paraffin wax preparation, and c) Experiment setup.

Results

First, we present reference results when all three containers are filled with water (Figure 4). The indoor temperature (blue curve) increases in time following the outdoor temperature (red curve). Similarly, when heating is turned off, the indoor temperature decreases in time with respect to the decrease of the outdoor temperature.

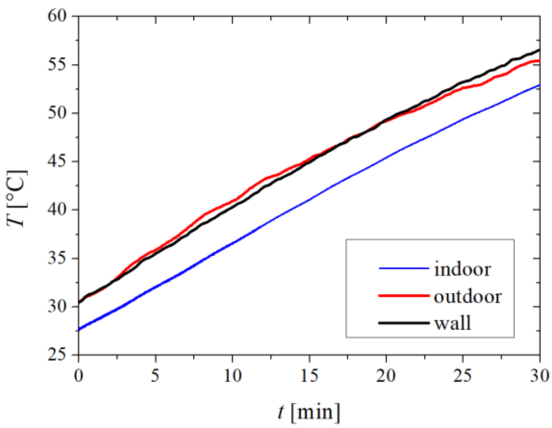


Figure 4. Temperature time dependency for heating. All three containers are filled with water.

Next, we present results with paraffin as PCM in the middle container. Figure 5 shows the time variation of temperature in the outer, middle, and inner container. We can see temperature increases with time in all three containers. For the middle container with paraffin wax (black curve), we notice regions where the temperature is more or less constant. The latter is the result of paraffin's phase transition, during which the latent heat is stored. When paraffin is in the liquid phase, heat transfer to the inner container continues, increasing room temperature. If we look closely at slopes of temperature increase (blue curve) and compare them for solid and liquid phases of paraffin, we see differences. When paraffin is in the solid phase, heat conduction is present. However, for the liquid state of paraffin, heat transfers mainly by convection. It is prominent heat transfer is more efficient for convection than conduction, which results in the change of the slope of the room temperature.

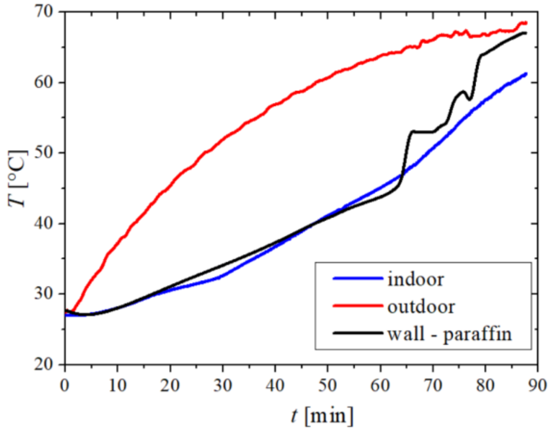


Figure 5. Temperature time dependency for heating. Middle container is filled with paraffin wax with phase transition temperature between 54°C-56°C.

By comparing our experimental results with theoretical expectations, we find differences. Theoretically, we expect the temperature at the inner container to be constant during the paraffin's phase transition. Furthermore, we expect a linear increase in temperature until the melting point is reached. In our case, we notice a jump in temperature, followed by the phase transition of paraffin. We suspect a few reasons behind these differences. In the experiment, we used only one compartment of paraffin. In addition, paraffin is not melting uniformly throughout the volume and has phase transition within the temperature range and not at a single temperature, which is in accordance with the specification with the tested material. However, other experimental studies [21-23] found similar results. Still, we believe that the suggested experiment can successfully show the principle of PMCs. In the future, some modifications are necessary to improve the conduction of the experiment in terms of clarity.

CONCLUSION

Nowadays, we face different environmental problems, for example, global warming, deforestation, exploitation of non-renewable energy sources, and increased energy consumption. From our experience, students show interest in such problems, so it is sensible to use them as a basis for acquiring knowledge and skills. The main disadvantage is the complexity and time demand of authentic problems, which result in avoiding them in informal education. Nevertheless, to raise responsible and competent individuals, it is crucial to provide opportunities to students to learn about real-life problems and methods for problem-solving.

One opportunity to include real-life problems related to the environment presents PCMs. PCMs are relatively new materials that are also used to improve the energy balance of buildings. Unlike conventional insulation materials, PCMs reduce heat transfer by storing (or releasing) latent heat, which contributes to the thermal stabilization of buildings. Consequently, the energy balance of buildings is improved, which helps in reducing energy consumption in space heating and cooling. Based on the qualitative analysis of Slovenian's elementary and secondary education curricula, we can conclude the concept of PCMs can be introduced in physics at secondary schools. We present a simple, illustrative experiment, using paraffin wax as PCMs. The suggested experiment indicates how PCMs reduce temperature fluctuations in the room.

For further investigation, we could test different modifications and conduction of the experiment to gain good agreement with theoretical expectations. In addition, it would be reasonable to conduct empirical research to test students' prior knowledge and the effectiveness of the suggested experimental approach.

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Digital Transformation: Causes, Consequences, Expectations

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Abstract. The last decade is characterized by the term "digital transformation" or "Industry 4.0", which is announced as the 4th phase in the industrial economy. Lack of clear boundary between the virtual and the real, comprehensive networking, and artificial intelligence are just some of the determinants of digital transformation. The paper analyzes the technological assumptions that enabled this transformation. Contrary to the first three phases, the fourth one is unrelated to some specific invention. Based on the definition of Industry 4.0 adopted by the European Parliament, its specific technological innovations have been detected. Thus, the WWW (World Wide Web), IoT (Internet of Things), AI (Artificial Intelligence), and 5G are marked as the main technological inventions responsible for digital transformation. The previous three revolutions have enabled significant productivity increase and higher standards and have produced many problems. These problems are reflected in excessive electricity consumption and excessive CO_2 emissions, generating enormous waste. As the fastest growing waste, electrical and electronic waste (ee-waste) is of particular concern. The paper gives a brief analysis of the problem of disposal of ee-waste in Bosnia and Herzegovina (B&H).

Keywords: digital transformation, Industry 4.0, IoT, ee-waste, decarbonisation

INTRODUCTION

The development of science and technology in the last 300 years has enabled the accelerated development of humanity in all aspects: GDP growth, population growth, democratization, public access to education, general health care, liberalization, all of which resulted in a better quality of life. In addition to evident and significant scientific discoveries that are the basic premise of this progress, the achieved standard of modern civilization is due to the excessive use of natural resources: energy, minerals, and the natural environment. Excessive use of natural resources has led to many ecological, economic, and political problems.

CO_2 is considered the main culprit for increasing the average temperature on Earth [1]. Excessive emissions of this gas are due to excessive combustion of fossil fuels, burning forests, and organic matter. All this leads to the greenhouse effect that causes the temperature on Earth to rise. In the last 70 years, there has been: an increase in annual CO_2

emissions of approximately six times (from 6 billion tons to 34.8 billion tons), an increase in energy consumption six times (from 28516 TWh to 173340 TWh), an increase in population three times from 2.54 billion to 7.79 billion), an increase in the average temperature of the Earth's surface by close to 1°C. Of concern is the linear trend of rising temperatures over the last 50 years, which, if not stopped, could lead to a 4°C rise in temperature in 2100 [2]. These black climate change forecasts have led to a series of concrete steps in international agreements to limit CO_2 emissions. The goal is to complete the decarbonisation of industry in the EU by 2050 [3].

Table 1 shows the trends: the number of inhabitants on Earth, CO_2 emissions, changes in the average annual surface temperature of the Earth, the annual gross domestic product on Earth (GDP), and total energy consumption. The period 1950 to 2020 is covered based on the Our World in Data database [2]. The 12.2-fold increase in GDP results from an increase in population (3.06 times) and energy consumption (6.07 times). The rise in energy consumption twice as much as the increase in the number of inhabitants is a consequence of the use of energy to operate machines in business processes and an increase in consumption per capita.

Table 1. Population trends, CO2 emissions, temperature rising, GDP and energy consumption on Earth from 1950-2020.

Year	Number of citizens, x 10^9	CO_2 emissions, x 10^6 tons	Temperature rising, °C	GDP, x 10^{12}\$	Energy consumption, x 10^3 TWh
1950	2.54	6.00	-0.21	9.80	28.516
1960	3.03	9.39	-0.15	14.62	41.713
1970	3.70	14.90	0.01	23.87	66.378
1980	4.46	19.49	0.35	37.73	87.599
1990	5.33	22.75	0.38	47.04	106.161
2000	6.14	25.23	0.56	63.10	122.073
2010	6.96	33.34	0.63	91.33	152.249
2020	7.79	34.81	0.89	119.56	173.340

PHASES OF INDUSTRIAL ECONOMY

The terms Industry 1.0, 2.0, and 3.0 treat changes in industrial production that have led to leaps in productivity. The steam-powered loom reduced the required number of workers and increased production. The conveyor belt in the meat industry, and later in the automotive industry, enabled skilled workers who performed only one operation, making them more productive and cheaper due to the lower demand for expertise. The programmable logic controller (PLC) enabled flexibility in the production phases, which allowed the production of several different products on the same production line in a way that only changed the program in the PLC. Hence, 1784 (Loom), 1870 (Meat Production Line), and 1969 (Programmable Logic Controller, PLC) are used for zero years in these terms [4]. The terms Industrial Revolution 1, 2, and 3 denote the impact of industrial change on the radical changes of society as a whole. These changes did happen, but a change in industrial production did not just cause them. There are a lot of important events that have led to these changes. The terms Industry 4 and Industrial Revolution 4 have been used in the last ten years. Neither the zero date nor the basic technological invention is mentioned.

Instead, there is a need to make a radical change in industrial production to become more productive (fewer workers, less energy consumption, fewer materials, etc.), denoted by Industry 4.0. On the other hand, the term Industrial Revolution 4 includes apparent changes that have taken place in the last 20 years in the whole society for which causes are still being sought, and the possible consequences are being discussed.

DIGITAL TRANSFORMATION

Digital transformation is the process of introducing new digital techniques in all social flows (economy, administration, education, health, etc.) with the aim of more efficient action, all with the aim of improving the quality of life [5]. This process is characterized by infrastructure, regulation, implementation, and consumption. The infrastructure relies on communication and information technologies that enable the creation, collection, storage, and transmission of data. Given that telecommunications and the Internet, due to their primary purposes, are at a desirable infrastructural level, we are currently working on the part of the system in terms of developing an efficient way to collect data (for example, Internet of Things (IoT), automated scanners, etc.). The level of the regulation defines the rules for the use of data in terms of legal assumptions about the meaning, use, and generation of data (public disclosure, protection of personal data, digital signature, electronic payment, etc.). Implementation is a process by which appropriate software solutions enable the use of data by end-users (information systems, e-commerce, electronic diary, etc.). Consumption is the process of using the services of implemented software solutions. Consumers based on these services save time, energy, resources and increase efficiency in their core businesses.

The European Parliament, 2015, accepts the definition of the term Industry 4.0 as follows: Industry 4.0 is a digital industrial transformation with an emphasis on automation, data exchange, cyber-physical systems, robots, artificial intelligence, Internet of Things (IoT), 3D printing, nanotechnology, biotechnology, materials science, energy storage, autonomous vehicles and autonomous industrial techniques to achieve smart industry and production goals [6].

Based on quantitative indicators that determine the 4th phase of business, an analysis of global economic entities emerged due to the application of business models characteristic of the period of digital transformation. Figure 1 shows the analyzed financial entities. Selected global economic systems represent dominant domains: search engines, social networks, internet sales.

Figure 2 shows the financial achievements of global economic systems characteristic of the 4 phases of the business: railway and steel industry (phase I), automotive industry, oil industry, electronics industry (phase II), semiconductor industry, software industry (phase III), search engines, social networks, internet sales, the solar industry, electric cars (phase IV). The available data are based on financial operations given in [7].

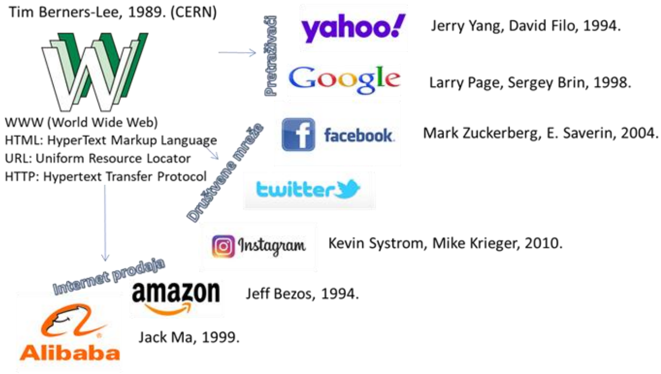

Figure 1. The most important global economic systems emerged on the wave of digital transformation

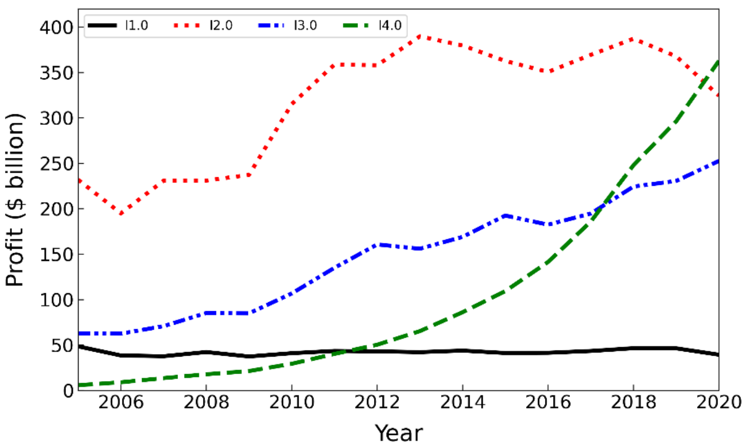

Figure 2. Trends in financial achievements of global economic systems for the period 2005-2020.

In the profit analysis, the following companies were analyzed: Union Pacific (84), Canadian Pacific Railway, Siemens (90) for I1.0, Diamler General Motors, Ford, China Petroleum & Chemical PetroChina, IBM, Philips, Sony Group (96), Texas Instrument (64) for I2.0, Apple, Microsoft, Intel, Microchip, Analog Devices for I3.0 and Alphabet (Google), Amazon, Alibaba, Meta platforms (Facebook), Tesla, Twitter, JinkoSolar Holding, Canadian Solar for I4.0. The diagram shows that the financial share of phase IV economic entities is approaching the lead in an exponential trend. When analyzing the technological assumptions that have enabled the positioning of phase IV economic entities at the global financial level, they are WWW, IoT, AI, 5G.

WWW (World Wide Web)

The WWW was initiated by Tim Berners-Lee in 1989, who proposed and later demonstrated the use of hypertext documents via the Internet while working for CERN [8].

Unlike a standard text document, a hypertext document contains text, diagrams, images, sound, video, etc. Such a document becomes dynamic by changing its content according to new data or user requirements. Also, various software tools are used to create and use these documents.

IoT (Internet of Things)

IoT (Internet of Things) first appeared as a term in 1985 by Peter T. Lewis [9], where a new concept of connecting consumer devices to the Internet is defined. These devices perform their existing function, and with the connection to the Internet, the possibilities of application are expanding, and new appliances with entirely new functions also appear. Unlike pre-existing devices with an Internet connection (PC and mobile phone), these devices can communicate via the Internet without operator intervention, consume much less energy and are cheaper. These three features have imposed the definition of entirely new design concepts for such devices and the development of new protocols. The complete concept is based on the need to automate data input from the environment in real-time. This data can be used efficiently, which are the basic assumptions of digital transformation. However, the concept of IoT itself is not reduced exclusively to the parameters of physical systems that are automatically collected through sensors and made available to users via the Internet. Currently, the architecture where sensors are the data source is predominantly considered. Figure 3 shows the concept of IoT. It relies on the rapidly evolving Internet infrastructure and enables data exchange between devices located in a wide area of human activity via wireless communication.

To allow the connection of many new devices, the existing IPv4 IP address format has been extended to IPv6 [10]. IoT draws its beginnings from Radio Frequency Identification (RFID) technology as automatic identification of products in production or sale by radio. The RFID identifier consists of memory, processor, and wireless communication system. The memory capacities of RFID identifiers can be different: from 20 bits to 32KB. In terms of communication, low and medium frequency bands (50-500kHz and 13.5MHz) with a range of 2.5cm to 72.5cm and a microwave band (0.9 to 2.5GHz) are used. Active RFID can have a range of up to several hundred meters [11]. Historically, the principle of radio identification dates back to before World War II, when used in aviation, and modern RFID is linked to Mario Cardullo's 1973 patent [12]. The number of devices connected to the Internet in 2020 exceeded 50×10^9.

AI (Artificial Intelligence)

Large amounts of data collected in digital transformation are becoming a problem in terms of algorithms for processing such data and access to information that will increase the system's efficiency. Expert systems based on artificial intelligence (AI) are used as one of the solutions [13]. AI bases its algorithms on imitating biological systems. Basically, instead of standard data processing methods in AI, the outputs are formed by iterative adjustment of the system coefficients. In doing so, the outputs are closer to the solutions offered in the existing practice (learning) to offer outcomes based on new input data, which we assume are in the domain of desirable (application).

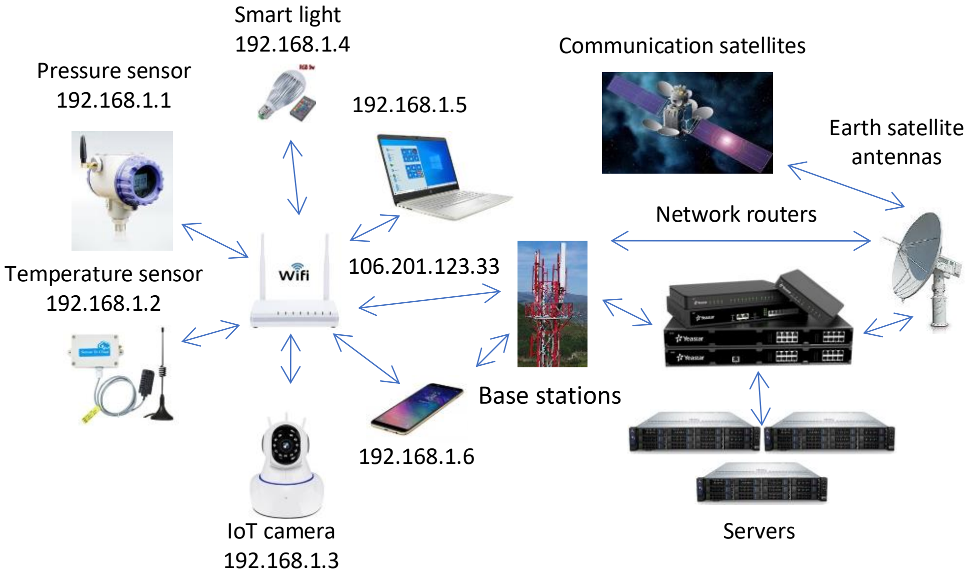

Figure 3. The concept of IoT

5G

Many different sources simultaneously generate large amounts of data due to the application of the IoT concept, which imposes the need for significant improvements in the communication system. This improvement is implemented in higher transmission speeds, lower transmission delays, and greater space coverage. The development of mobile communications from analog (G1) through digital transmission (G2, G3, G4) leads to the G5 being the fastest transmission in the mobile network. The G5 uses frequencies up to 30GHz, allowing real-time systems applications to require minor delays. A particular application of the G5 is expected in terms of the development and application of autonomous vehicles. The first installations of the G5 network were performed in 2019 in the USA (Chicago and Minneapolis) [14]. In some applications, the G5 is used only locally (WiFi), while the connection to the Internet is based on the infrastructure for the G3 or the G4.

ELECTRONIC WASTE

The development of the electronics industry (phase 2 and phase 3), the semiconductor industry (phase 3), and the mass application of devices for the collection, transmission, storage, and use of digital data (phase 4) have led to enormous amounts of electronic devices in use. Due to technological obsolescence, these devices are quickly put out of use, producing large amounts of electronic waste. It is the fastest-growing waste [15]. Such waste contains over a hundred different substances, some of which are very harmful to the environment (mercury, lead, chromium, beryllium, etc.), and some are important raw materials (aluminum, copper, gold, etc.) [16]. Based on the research on the problem of electronic waste disposal for the Sarajevo Canton (KS) presented in [17], an estimate of the quantities and composition of this waste for B&H was made. This waste comes from industry, the public sector, and households. This analysis covers only consumer e-waste generated by households. Due to the lack of initial data for applying some of the methods used to estimate the amount of e-waste, the method used here is based on population data and the assessment of habits and survey results regarding the time of use of the device. According to the 2013 census, there are 3166570 inhabitants in B&H, in 1143329 households, with 1508981 declaring themselves computer literate [18]. We can assume with sufficient reliability that all residents from the first grade of primary school onwards have a mobile phone, that every household has a TV, and that every resident who declared himself computer literate has a PC. It provides 2570012 mobile devices, 1143329 TV sets and 1508981 PCs. Technological progress requires that TV be changed after 12 years, PC after five years, mobile device after three years. Here are the average values obtained by surveying a sample of 350 students and high school students in KS. The values are slightly higher than the world average because the standard is such that it conditions the stated amounts.

Based on the above data, we can calculate the annual decommissioning of the following devices: 95270 TVs, 301585 PCs, and 856665 mobile devices. Up to 30% of the stated amount ends in second-hand use (on the second-hand goods market, gifts, etc.). Ultimately, we have: 66685 TVs, 211253 PCs, 599662 mobile devices. If we take the average mass of the TV, PC, and mobile device: 25kg, 20kg, 135g, respectively, we get 5967 tons of spent e-waste per year in B&H. By recycling, this amount of e-waste can be obtained: 1,612 tons of glass (27%), 1612 tons of plastic (27%), 1367 tons of mild steel (23%), 476 tons of hard steel (8%), 176 tons of copper (3%), 176 tons of aluminum (3%), 476 tons of other materials (8%) and 53 tons of toxic substance (1%). These data were obtained by mapping the results for KS to the whole B&H with a scaling factor of 0.9. This factor is due to the higher standard in the Sarajevo region than the rest of B&H.

CONCLUSION

Given the realized development trend and the fact that we are approaching the extreme limits of available natural resources, there is a change in the basic paradigm of modern business. Instead of increasing the exploitation of mineral resources, increasing energy production, market growth, increasing industrial production, which in the previous period were the main features of development, now the central paradigm can be represented by the following features: energy efficiency, energy transition, environmental protection, decarbonisation, sustainable development, optimization, smart cities, circular economy. The technological basis of all these features is digital transformation.

The impossibility of further raising the standards at the expense of the use of natural resources has imposed the need for more rational use of existing ones. Therefore, digital transformation cannot be seen as a new paradigm that will enable progress in new technology but as a necessity to overcome the problems of lack of energy, lack of raw materials, environmental and climate issues.

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Remote Sensing of Tropospheric Aerosols: Experience from Belgrade Raman Lidar Station

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Abstract. Atmospheric aerosols are considered as one of the major uncertainties in climate forcing and atmospheric processes due to their short lifetime and the large variability. Lidar (LIght Detection And Ranging), an active remote sensing technique, represents the optimal tool to provide range-resolved aerosol optical parameters and information on the atmospheric structure and its dynamics. In order to create a quantitative, comprehensive, and statistically significant database for the horizontal, vertical, and temporal distribution of aerosols on a continental scale the European Aerosol Research Lidar Network (EARLINET) has been established. In this study the capacity of Belgrade Raman lidar system and the activities of lidar station within EARLINET will be presented together with the experience from measurement campaigns aiming to provide near real time (NRT) data products and study the changes in the atmosphere during the COVID-19 lockdown period.

Keywords: atmospheric aerosol, optical properties, remote sensing, lidar, air quality

INTRODUCTION

Aerosols in the atmosphere play an important role in numerous atmospheric processes. Despite being a minor component of the atmosphere, they have a significant impact on the Earth's radiation budget, the water cycle and atmospheric chemistry, playing a crucial role in climate change and air quality. Due to their short lifetime and the large variability in space and time atmospheric aerosols are considered one of the major uncertainties in atmospheric processes [1]. As a result, vertically resolved studies of particle physical and optical parameters such as particle surface area concentration, volume and mass concentrations, mean particle size, and volume extinction coefficient are of particular interest. Long-term height-resolved measurements of atmospheric aerosol optical parameters can be carried out using lidar (Light Detection And Ranging), an active remote sensing technique. The observational lidar stations network called EARLINET (the European Aerosol Research Lidar Network) [2] was founded in 2000 to provide the long-term measurement series needed to build a climatology of aerosol optical properties at the continental scale. The main objectives of EARLINET are the establishment of a comprehensive and quantitative statistical data base of the horizontal and vertical distribution of aerosols at the European scale using a network of advanced laser remote sensing stations, and the use of these data for studies related to the impact of aerosols on a variety of environmental problems. In this paper the characteristics of Raman lidar system at the Institute of Physics Belgrade (IPB) [3], an EARLINET joining lidar station, is presented together with several quality tests in order to demonstrate the performance of a lidar system. In addition, preliminary findings and experience from a dedicated EARLINET measurement campaign organized in May 2020 in order to monitor the atmosphere's structure during the COVID-19 lockdown period in Europe is discussed.

Methodolgy

Raman lidar

Raman lidar system at the IPB (44.860 N, 20.390 E) is bi-axial lidar system with combined elastic and Raman detection designed to perform continuous measurements of aerosols in the planetary boundary layer and the lower free troposphere (Figure 1). Transmitter unit is based on the third harmonic frequency of a water cooled, pulsed Nd:YAG laser, emitting pulses of 65 mJ output energy at 355 nm with a 20 Hz repetition rate. The optical receiving unit consists of two sub-units, a receiving telescope and wavelength separation unit. The optical receiver is a Cassegrain reflecting telescope with a primary mirror of 250 mm diameter and a focal length of 1250 mm. Photomultiplier tubes are used to detect elastic backscatter lidar signal at 355 nm and Raman signal at 387 nm (nitrogen vibrational scattering). The detectors are operating both in the analog and photon-counting mode and the spatial raw resolution of the detected signals is 7.5 m. Averaging time of the lidar profiles is of the order of 1 min corresponding to 1200 laser shots. The Licel transient recorder comprises a fast transient digitizer with on board signal averaging, a discriminator for single photon detection and a multichannel scaler combined with preamplifiers for both systems. For analog detection, the signal is amplified according to the input range selected and digitized by a 12-Bit-20 MHz A/D converter. At the same time the signal part in the high frequency domain is amplified and a 250 MHz fast discriminator detects single photon events above the selected threshold voltage.

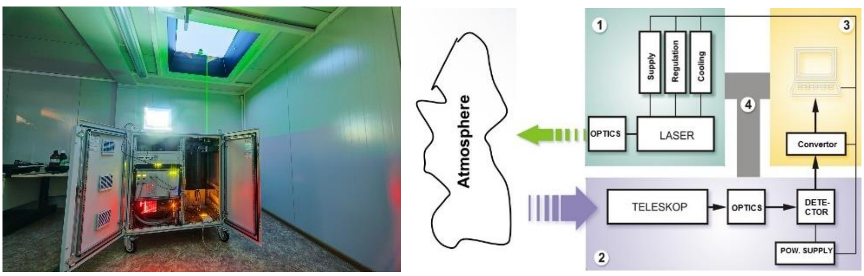

Figure 1. Raman lidar at IPB (left) and components of a lidar system (right)

COVID-19 Campaign

The lockdown period provided a unique opportunity to examine the effects of reduced anthropogenic activities on changes in the atmospheric environment. As a part of the ACTRIS initiative for studying the changes in the atmosphere during the COVID-19 lockdown period in May 2020 a dedicated EARLINET measurement campaign was organized in order to monitor the atmosphere's structure and to identify possible changes due to decreased emissions by comparison to the aerosol climatology in Europe. During the campaign the near real time (NRT) operation of the EARLINET was demonstrated. The Belgrade lidar station participated in the campaign together with 21 EARLINET stations providing vertical aerosol profiles twice per day (minimum two hours measurements at noon, and minimum two hours after sunset). The measurements were submitted and processed by the Single Calculus Chain (SCC) in the near-real time. The SCC is a tool for the automatic analysis of aerosol lidar measurements developed within EARLINET network [4,5]. The main aim of SCC is to provide a data processing chain that allows all EARLINET stations to retrieve, in a fully automatic way, the aerosol backscatter and extinction profiles (measures of the aerosol load) together with other aerosol products. The first analysis was based on the data processed by the SCC and directly published on the THREDDS server in NRT.

RESULTS AND DISCUSSION

A quality assurance scheme for both hardware and retrieval methods has been built within the lidar network. System alignment is one of the fundamental setup tests because the incomplete overlap between the laser beam and the receiver field of view has a substantial impact on lidar observations of particle optical characteristics. Thus, quality assurance of lidar measurements needs testing the lidar system's alignment following Freudenthaler's procedure [6]. It consists of a series of measurements with a partly covered telescope (four sectors labeled N, E, W, and S), such that each measurement represents a collection of backscattered light at a specific sector of the telescope. The variation of each sector signal from the average of all signals of less than 10% is required.

The Rayleigh fit method, which is based on normalizing of the lidar signal to the calculated Rayleigh backscatter coefficient in a range where we assume clean environment and where the calculated signal matches the lidar signal sufficiently well, can be used to ensure lidar alignment in the far range. As seen in Figure 2. IPB lidar system was accurately aligned up to 14 km. Once properly aligned, the device could be utilized for systematic aerosol measurements.

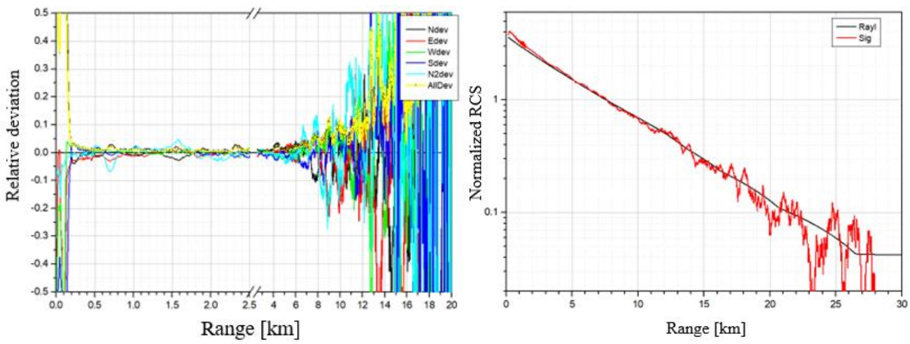

Figure 2. Deviations of signals collected with four telescope sectors compared to the mean signal (left) and Rayleigh fit for 355 nm elastic channel, Raman lidar at IPB, May 8th, 2020

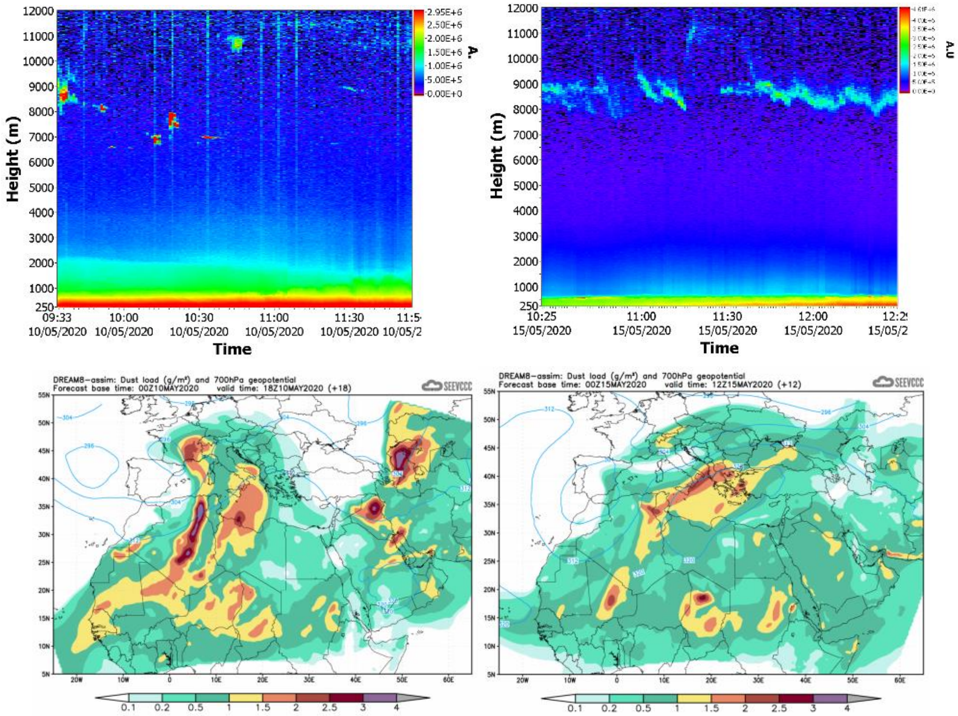

Figure 3.LIDAR range corrected signal (above) and dust load over South Europe estimated by the DREAM model (below) on 10th and 15th May, 2020

The preliminary analysis made on aerosol lidar data shows that by simply comparing the observed backscatter values with the climatological values from 2000-2015 was not sufficient to extract a clear conclusion on how much the COVID-19 lock-down has impacted the aerosols over Europe, but a certain effect for low troposphere was observed [7]. Generally, during the week of 15 – 21 May 2020, the aerosol backscatter coefficient values in both upper and lower troposphere were very close to the climatological values. On 15th of May, a certain tendency of higher than climatological values is observed because of the dust intrusion over the Southern Europe. Aerosol backscatter was significantly higher than in North and Central Europe, both in the low and high troposphere. Clear skies and high temperatures were observed in southern Europe accompanied with Saharan dust in the Balkans. In Figure 3 time evolution of lidar range-corrected signal at IPB, Belgrade on May 10th and 15th is shown indicating the presence of Saharan dust in lower troposphere that was also confirmed by the forecast of Dust Regional Atmospheric Model (DREAM) [8].

CONCLUSION

Basic characteristics of Raman lidar system at IPB together with the results of few quality checks are presented showing the capacity for detection and monitoring aerosol layers' intrusion in Serbia. The action organized by EARLINET/ACTRIS (NRT delivery of the data and fast analysis of the data products) proved that aerosol lidars are useful for providing information not only for climatological purposes, but also in emergency situations. A more quantitative analysis based on re-analyzing additional data products is expected to be availabe soon in order to consolidate the conclusions on how much the COVID-19 lock-down has impacted the aerosols in the atmosphere.

ACKNOWLEDGEMENTS

The authors acknowledge funding provided by the Institute of Physics Belgrade, through the grant by the Ministry of Educations, Science, and Technological Development of the Republic of Serbia. The financial support for EARLINET in the ACTRIS Research Infrastructure Project by the European Union's Horizon 2020 research and innovation programme under grant agreement no 654109 and previously under the grants no. 262254 in the 7th Framework Programme (FP7/2007-2013) and no 025991 in the 6th Framework Programme (FP6/2002-2006) is gratefully acknowledged.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
Technical Faculty "Mihajlo Pupin", Zrenjanin & Faculty of Sciences and Mathematics, Nis

Development of Graduate Studies in Environmental Physics in Croatia

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Abstract. We are witnessing major changes in the environment due to anthropogenic factors. Global climate change, extreme weather events, pollution of the atmosphere and drinking water sources, decline in biodiversity, radioactive waste storage, and exposure to ionizing radiation are some examples of these changes and the problems they cause. Developed countries have recognized the role of physics and physicists in reducing negative anthropogenic impacts on the environment and in mitigating and adapting to climate change. The training of physicists specializing in environmental studies includes the study of physical laws, the application of quantitative models, their testing, and their use in predicting environmental impacts. The study of the environment requires an interdisciplinary approach, and therefore it is necessary to supplement traditional training in physics with specific skills and knowledge. The environmental physicist should be trained in the fundamentals of ecology, should understand the environmental impacts for which prediction methods are being developed, should have a basic knowledge of the management of the commons, must be familiar with environmental regulations, and must have the ability to communicate effectively with the public. Over the past three years, physicists from four Croatian universities have worked together on a project aimed at modernizing physics curricula and adapting them to the needs of the labour market. One of the outcomes of the project was the development of an occupational standard for graduate engineers in environmental physics. In this paper I will discuss the results of the project in the context of the development of the standard and present the study program in Physics and environmental science at the Department of Physics of the University of Rijeka.

Keywords: anthropogenic impact, environmental changes, environmental physics, occupational standard, study programs

INTRODUCTION

The ability to actively participate in the development and implementation of new technologies is critical for the effective and sustainable development of modern society. This is particularly evident in the increasing challenges of environmental protection. Climate change, pollution of water, air and soil, as well as the expansion and construction of new roads/highways are just some of the elements that have made environmental protection one of the world's leading problems and a topic of scientific and professional debate.

Environmental research, climate change mitigation, and the green and blue economy are among main European Union's research goals. Horizon Europe until 2027, for example, deals directly with environmental issues in Pillar II clusters 5 and 6. Cluster 5: Climate, Energy, and Mobility, in particular, aims to combat climate change by improving "understanding of its causes, evolution, risks, impacts, and opportunities, and by making the energy and transport sectors more climate and environment-friendly, more efficient and competitive, smarter, safer, and more resilient" [1]. Cluster 6: Food, Bioeconomy, Natural Resources, Agriculture, and Environment, on the other hand, aims to reduce environmental degradation, halt and reverse biodiversity loss, and better manage natural resources through transformative economic and societal changes. Through knowledge, innovation, and digitalisation in agriculture, fisheries, aquaculture, and food systems, it aims to ensure food and nutrition security, as well as "steer and accelerate the transition to a low-carbon, resource-efficient circular economy and sustainable bioeconomy" [2].

The University of Rijeka demonstrates its understanding of the importance of nature protection and environmental issues not only through the funding of scientific projects addressing environmental research, but also through its educational component. The University of Rijeka, in particular, provides a physics degree with a focus on environmental physics. The University of Split is the only other university in Croatia that offers graduate studies in environmental physics.

Furthermore, the European Social Fund financed the project "Development of physics studies with the implementation of the Croatian Qualifications Framework - FizKO" at the University of Rijeka [3]. The project brought together physicists from four Croatian universities: the University of Rijeka, the University of Zagreb, the University of Split, and the University of Osijek, as well as representatives from potential employers. One of the project's goals was to create an occupational standard for graduates in environmental physics.

Graduates in environmental physics

Graduates in environmental physics are expected to apply the knowledge from physics in general, as well as from classical and quantum mechanics, electromagnetism, thermodynamics, optics, electrodynamics, and statistical, atomic, and nuclear physics to the analysis and modelling of atmospheric and oceanographic processes, processes in inland waters and soil, as well as processes in urban areas. They plan and conduct environmental monitoring and analysis, create and use new, environmentally friendly materials and innovative technologies, and participate in the processes of planning sustainable natural resource management and assessing the environmental impact of planned actions. An environmental physicist should not only have basic technical knowledge, but also basic managerial and economic as well as legal skills in order to successfully fit into an interdisciplinary team.

Several policy documents of the Republic of Croatia, as well as the European Union, highlight the necessity for graduate courses in environmental sciences. In the 2014 Croatian Education, Science, and Technology Strategy, for example, the relevance of education and science in overcoming challenges such as the application of new technologies and environmental protection was underlined [4]. According to the Strategy, priority occupational standards and qualifications, as well as corresponding education programs, should be defined and developed in new areas of economic activity, such as the acquisition of skills and technologies for environmental protection, recycling, and biodiversity conservation.

The Republic of Croatia's Nature Preservation Strategy and Action Plan for the years 2017 to 2025 emphasizes the development of technical knowledge and skills in order to effectively implement nature protection. It also promotes better understanding as well as an increase in the number of issues connected to environmental protection in the educational system, as well as stronger collaboration with the education sector [5].

In the strategy document “Healthy and sustainable environment for future generations”, the European Commission envisages the creation of 400,000 jobs for the full implementation of existing EU regulations in the field of environmental protection, indicating a considerable need for experts in this field [6].

Three priority areas in the Danube Region Strategy deal with environmental challenges (Water Quality, Environmental Risks, and Biodiversity, Landscapes, and Air & Soil Quality) and two deal with knowledge society and people and skills [7]. The EU Strategy for the Adriatic and Ionian Region highlights environmental quality and a sustainable economy as key challenges and potential [8]. Croatia belongs to both regions, and significant parts of the mentioned strategies relate to environmental quality, water protection, biodiversity conservation, risk management and sustainable economy. As a conclusion, we can infer that the aforementioned action plans also necessitate the involvement of environmental experts.

By developing occupational standard for graduates in environmental physics that is tailored to the needs of employers, we aimed to improve the quality and attractiveness of physics study programs, as well as their relevance to the labour market.

Competencies of graduates in environmental physics

Graduates in environmental physics should be able to plan, organize, and carry out environmental monitoring, as well as analyse the state of various environmental components. They may be involved in working in areas such as environmental research, development, and innovation, quality assurance, health and environmental protection, various administrative and commercial engagements, education, and so on.

Graduates in environmental physics can expect to work in interdisciplinary and international teams. Students must obtain basic competencies through graduate degree programs in order to be well prepared for the labour market, i.e. to be productive members of such teams. With this in mind, the following sets of competencies have been identified as necessary for this specific profile of physics graduates.

Knowledge, analysis and modelling of atmospheric processes

This group of competencies includes: knowledge, formulation and application of laws, models and theories of atmospheric physics. The graduate is expected to know the composition of the atmosphere and climatic processes, the processes of cloud formation and precipitation, as well as the basics of dynamic meteorology. After completing the study, the student should know the basic structures of numerical models of weather and climate, know the basic forms of motion at the synoptic and global scale and understand the laws of transport and dispersion of atmospheric pollutants. An environmental physicist should know and use basic experimental equipment in meteorology, as well as to encode and execute computer programs for research, simulation or modelling of physical phenomena in the atmosphere.

Knowledge, analysis and modelling of oceanographic processes

Environmental physicists should be able to understand, formulate, and apply laws, models, and theories of marine physics. The fundamentals of dynamic oceanography must be understood, as well as the various types of wave motion in the sea. This set of competences includes the formulation of simple mathematical models of tides, understanding of marine transport systems and pollutant dispersion mechanisms, as well as understanding of marine climatic dynamics. In addition, after finishing the graduate study in environmental physics, the student should know and utilize basic oceanographic experimental equipment, as well as encode and execute computer programs for research, simulation, or modelling of physical events in the sea.

Knowledge, analysis and modelling of soil processes

Students should be trained in the formulation and application of soil physics laws, models, and theories. They should be able to apply their knowledge of fluid mechanics and thermodynamics to soil processes and understand the physical properties of soil and the methods used in their research. They should be able to explain how climate change affects soil and soil processes, as well as be familiar with the basic experimental equipment used in soil physics. They are expected to apply soil characteristics research findings to environmental protection and the sustainable use of natural resources. They should also be able to encode and execute computer programs written in a programming language in order to investigate, simulate, or model physical phenomena in the soil.

Knowledge, analysis and modelling of processes in the urban environment

During their studies, students should be introduced to the fundamentals of data science, network models, machine learning, and artificial intelligence. Graduates should be able to calculate the microclimatic parameters of thermal comfort in residential and commercial buildings, as well as the fundamentals of noise and vibration protection. They should also be able to apply their knowledge of environmental radioactivity, dosimetry, and radiation protection against both ionizing and non-ionizing radiation. This set of competencies could also include topics like traffic analysis and optimization using network models, explanations of the effects of external electromagnetic fields on human health, fundamentals of epidemiological modelling and social physics, and models of competition and human cooperation.

The use and maintenance of environmental monitoring equipment

Students should learn how to plan, organize, and carry out fieldwork in order to collect samples and data. They should be involved in the planning and execution of instrumental analyses as well. It would be preferable if they knew how to maintain and optimize the use of experimental equipment for environmental sample analysis. They should be able to use measuring equipment and assess the quality, accuracy, and reliability of measurement results. Students should become acquainted with standard laboratory instruments used in experimental physics during their studies, as well as conduct and evaluate measurements of various physical quantities. A graduate in environmental physics should be able to read manuals and understand laboratory equipment specifications. He or she should be familiar with the standard methods of recording laboratory activities and storing data, as well as the safety principles and the equipment and regulations of a standard physics laboratory.

Processing of environmental data

Graduates of environmental physics should be familiar with scientific research methodology as well as how to maintain project documentation, records, and data storage. They should be able to perform statistical analyses on environmental data and interpret the results. They ought to be able to interpret the cause-and-effect relationships on a given piece of content, as well as understand the physical laws associated with specific measurements and measurement results. Physicists must be able to analyse and express conclusions from observations and experiments using physics concepts and mathematical formalism, as well as solve multidisciplinary problems that link physics to other scientific disciplines.

Health and environmental protection

Students should understand the fundamentals of both ionizing and non-ionizing radiation protection, as well as noise and vibration protection. Environmental physicists who have completed their studies should be able to monitor the state of the environment, as well as apply physical and mathematical models for public health protection and occupational safety rules. They should also be able to contribute to the development of policies that aim to prevent or mitigate the negative effects of waste on human health and the environment.

Dissemination of project results in environmental physics

Students should be taught how to analyze the interaction of physics and society, as well as the impact of physics and modern technological development on the environment. Graduate in environmental physics should be able to demonstrate improvements in living standards as a result of physics work and discoveries, describe and explain the role of physics in modern technology, and analyze the major factors influencing physics' historical development in the context of society and technological development. They should also be capable of applying physical laws to explain everyday life phenomena, describing various examples of physicists' actions affecting health, the environment, and/or society, and explaining the effects of climate change on people and the environment. Students should be concerned with the application and promotion of socially responsible behavior, as well as the organization and implementation of scientific, professional, and popularization activities in the field of environmental physics (from early childhood to lifelong learning).

Scientific communication

Knowledge of the main features of the information and communication process, knowledge of scientific communication methods, and knowledge of science popularization are all part of this set of competencies. A graduate physicist should use standard criteria to select reliable scientific information and communicate using a variety of methods (scientific and professional journals, books, newspapers, video, web, etc.). He or she must be able to organize and present ideas using words, mathematical equations, tables, graphs, pictures, animations, diagrams, and other visual aids. Graduate physicists should be able to present scientific and technical concepts both orally and in writing, in standard Croatian and English, in a concise and comprehensive manner.

Addressing environmental issues by applying fundamental knowledge from the natural, technical, and social sciences

Environmental research necessitates an interdisciplinary approach. As a result, students should be taught how to apply fundamental chemistry knowledge to environmental problems, with a focus on pollutant structure and chemical and photochemical reactions. They should also be able to apply basic biology and ecology knowledge to environmental problems, with a focus on environmental migration methods and pollutant effects on humans and wildlife. Knowledge of the fundamentals of geology and seismology, as well as the fundamentals of waste management, is preferable. Students should also be familiar with the fundamentals of managing common goods, analyzing economic and social environmental impacts, and comprehending basic environmental laws, regulations, and ordinances.

Personal and professional development

A graduate in environmental physics is expected to understand the opportunities for pursuing a career in environmental physics at the regional, national, and global levels. He / she must be able to plan and manage his / her own career, as well as encourage, advise, and supervise subordinate employees' careers. This set of competencies also includes the ability to evaluate the impact of technological and broader social changes on one's own career while keeping one's own abilities and competencies in mind. A graduate physicist should be able to create a personal portfolio, network within the profession, participate in lifelong learning programs, and understand the standards for effective presentation of their knowledge and skills relevant to the job via appropriate CV, job interview, and professional appearance and behavior. He / she should be aware of the relevant competencies and qualifications required to continue academic / professional development, as well as his / her own strengths and weaknesses, knowledge, skills, and attitudes, and their impact on future career opportunities.

Graduate studies in Physics and environmental sciences

Incorporating all of the aforementioned competencies into the study program is a major challenge. We live in a world that is constantly changing and moving onward incredibly fast. On a daily basis, we are enthralled by innovations, but also shocked by irresponsible and negative actions toward the environment and society. Under these conditions, an education program that adequately prepares students for the labour market must be adaptable while also providing a clearly defined set of competencies.

At the University of Rijeka's Faculty of Physics, we decided that, in addition to traditional physics courses, compulsory courses in our graduate study in Physics and environmental sciences would focus on physics of three basic components of the environment: atmosphere, oceans and soil. In the courses Physics of the atmosphere, Marine physics, and Soil physics, students acquire the outcomes of knowledge required to achieve the competencies from the first three sets of competencies listed in the previous section.

Students gain other competencies through a series of elective courses led by professors from the Faculty of Physics, associates from other faculties and departments of the University of Rijeka, and professors from other Croatian and international universities. A large number of elective courses allow students to pursue competencies based on their personal interests.

At the University of Rijeka, we understand that education does not end with a diploma. It is permanent and lasts for the rest of a person's life. In this ever-changing world, there is a constant need to learn new things and improve one's skills. Micro-qualifications (or micro-credentials) have emerged as a new route in open personalized education. The Faculty of Physics, in collaboration with the Faculty of Economics at the University of Rijeka, is currently developing a joint micro-qualification "Recognition of environmental changes and risk management," which will provide students with solid economic knowledge, specifically on the management of common goods that include natural resources. The micro-qualification will be delivered in English, allowing for interdisciplinarity and internationalization.

CONCLUSION

The environment and society are undergoing significant transformations. In such challenging times, there is a need for a graduate study profile that allows for the study of environmental and social phenomena from the standpoint of natural sciences. This type of profile is ideal for a physicist whose competencies are supplemented by skills from other disciplines. Environmental physicist education should be designed to ensure the acquisition of traditional physicist competencies while also presenting open and personalized digital age education. This was the driving force behind the creation of the graduate program in Physics and environmental sciences at the University of Rijeka's Faculty of Physics.

ACKNOWLEDGEMENTS

This work was partially supported by the European Social Fund under the grant UP.03.1.1.03.0046 and by the University of Rijeka under the grants: uniri-pr-prirod-19-24, uniri-class-A1-21-8 and uniri-class-A2-21-2. Mladen Petravić, Nataša Erceg, Žarko Kovač, Dalibor Paar, Ivana Jelovica Badovinac, Robert Peter, Sandra Pavičić Žeželj, and Aleksandar Bulog contributed to the development of the occupational standard of graduate in environmental physics. Special thanks go to Darko Koračin, Jadranka Šepić, Tarzan Legović, Marko Jusup, Leonardo Marušić and Davor Mance for their valuable inputs.

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Multi-Elemental Analysis and Characterization of Fine Particulate Matter ($PM_{2.5}$)

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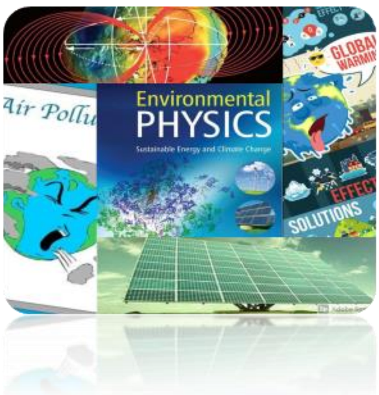
Abstract. Fine particulate pollution ($PM_{2.5}$) has been a subject of intense research, due to its strong negative impact on the human health. Epidemiological links have been established between the concentrations of $PM_{2.5}$ fraction and increase of morbidity and mortality in urban areas. The samples of $PM_{2.5}$ fraction in Rijeka (Croatia), collected on stretched Teflon filters, were analysed by X ray fluorescence and Ion Beam Analysis techniques and concentrations of 22 elements were determined from Na to Pb. Concentrations of black carbon (BC) were determined by Laser Integrated Plate Method. The concentrations of $PM_{2.5}$ fraction in the air were statistically evaluated by means of Positive Matrix Factorization. Results show that during calm periods in Rijeka when air pollution is steadily increasing, from all anthropogenic sources such as vehicles, secondary sulphates, smoke, heavy oil combustion, road dust, industry Fe and port activities only secondary sulphates from thermal power plant and heavy oil combustion from oil refinery were significantly higher, 40% and 50%, respectively.

Keywords: $PM_{2.5}$ fraction, Ion Beam Analysis, Positive Matrix Factorization, calm weather



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ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
Technical Faculty "Mihajlo Pupin", Zrenjanin & Faculty of Sciences and Mathematics, Nis

Greenhouse Effect in Physics Teaching

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Abstract. The greenhouse effect is a vital phenomenon for the living world on Earth because, without it, the planet's temperature would be about 39 K lower. It is often identified with "global warming" in everyday life, although these are not the same terms. The greenhouse effect is complex and is related to the absorption and emission of infrared radiation by greenhouse effect gases and heat transfer processes at the fundamental level, and as such, it needs to be included in school and university physics curricula. The paper presents the basics of the mechanism of the greenhouse effect, which can be modelled, and dealt with at different complexity levels depending on whether it is primary, secondary, or university education level.

Keywords: environmental physics, greenhouse effect, global warming, physics education

INTRODUCTION

It is believed that the Irish physicist John Tindall was the first to demonstrate experimentally in 1859 that carbon dioxide and water vapour can absorb and emit heat transmitted by infrared radiation, which is the physical basis of the greenhouse effect. Gases with this feature are called greenhouse gases. Due to their presence in the Earth's atmosphere, the average temperature on the surface of our planet is about 39 K higher than it would be if there were no greenhouse gases in the atmosphere [1–4]. Several years before Tyndall, an American called Eunice Foote was the first to carry out such measurements. However, she did not differentiate between the energy transmitted by solar radiation from the entire spectrum and infrared radiation, nor did she manage to explain the phenomenon observed. On the other hand, not only did Tyndall notice that the focus was on infrared radiation, but he also took specific measurements and explained them. Our present understanding of the greenhouse effect is also based on the work of Joseph Fourier, who named the effect in 1820, and Svante Arrhenius, who in 1896 calculated how much the Earth's temperature would change if the concentration of carbon dioxide in the atmosphere doubled. In 1938, Gui Callendar highlighted that human activities could increase the concentration of carbon dioxide. Today, many scientists in the world deal with this fundamental issue. The Nobel Prize in Physics 2021 was awarded jointly to Syukuro Manabe and Klaus Hasselmann "for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming."

THE GREENHOUSE EFFECT AND GLOBAL WARMING

The very wording of *the greenhouse effect* is a metaphor indicating that both the Earth's atmosphere and a greenhouse let radiation go through and then trap some of the heat. However, the mechanisms of heat transfer or its retention are different. Inside the greenhouse, heat is transferred by convection, and the mere existence of a physical barrier, i.e., the side of the greenhouse, prevents the heat from escaping (Fig. 1. a) [5]. Infrared radiation is retained in the Earth's atmosphere due to its absorption by greenhouse effect gases (Fig. 1. b), which can be found in the atmosphere (carbon dioxide, water vapour, methane, nitrous oxide, ozone…) [6]. If we imagine the atmosphere (greenhouse gases) divided into layers, each absorbs infrared radiation from the lower layer and then re-emits it both up and down. As will be said below, this effect leads to an increase in the average surface temperature of our planet. The speed at which the Earth loses heat is determined by the median temperature of the highest layer of the atmosphere participating in these processes as it gives off the heat into the universe.

On the other hand, global warming increases the Earth's temperature due to the greenhouse effect, increasing the concentration of greenhouse effect gases in the atmosphere *due to human activities* (predominantly burning fossil fuels). Long-term changes of this type in the Earth's climate system have been observed since the pre-industrial period (between 1850 and 1900).

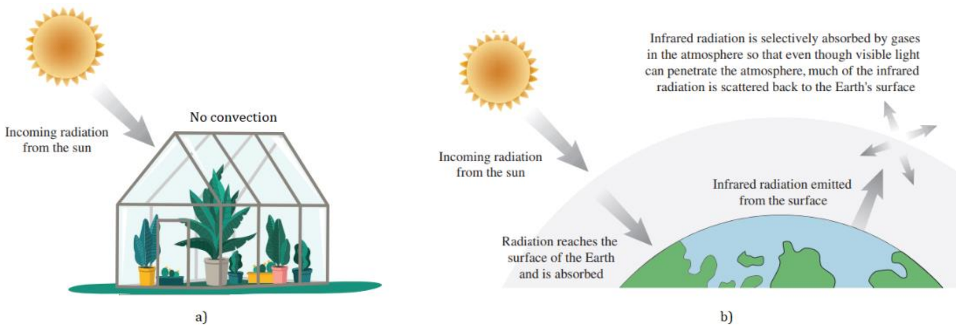

Figure 1. a) A greenhouse does not allow heat transfer by convection; b) Atmospheric greenhouse effect [5]

GREENHOUSE EFFECT MECHANISM

Greenhouse gases absorb and emit radiation energy within the thermal infrared range causing the greenhouse effect. The primary greenhouse gases in the Earth's atmosphere are carbon dioxide, water vapour, methane, nitrous oxide, and ozone. Interestingly, the gases that mostly make up the Earth's atmosphere, i.e., nitrogen (78%), oxygen (21%), and argon (0.9%), are not greenhouse gases. How come?

To answer this question, one should start from the general structure of energy levels in molecules. Namely, considering the structure, molecules being polyatomic systems allow for oscillations of atomic nuclei. The energy of these oscillations is quantized. Molecules can also rotate, and this energy of rotation is quantized too. In that sense, the energy levels in molecules can be: electronic, vibrational and rotational (Fig. 2).

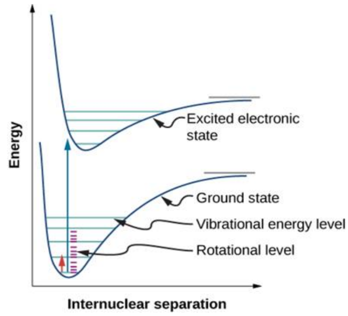

Figure 2. A general outline of the energy scale of vibrational and rotational levels of molecules [2]

Rotational levels are about a thousand times denser than vibrational levels on the energy scale, and vibrational levels are about a thousand times denser than electronic ones. Simple diatomic molecules (N_2, O_2…) can only change the chemical bond length established between two atoms. More complex molecules with more bonds (H_2O, CH_4…) have more possibilities of changing both shape and size. Therefore, they have a more complex structure of vibrational and rotational energy levels in the part of the thermal infrared range, which allows them to absorb and emit IR radiation.

The primary source of IR and other electromagnetic radiation in our solar system is the Sun. The flux of energy of electromagnetic radiation that reaches the upper layers of the Earth's atmosphere from the Sun is called the solar constant and is: $F_s = 1380$ W/m^2. In *the zero-order model* (Fig. 3), which does not take into account the existence of the atmosphere, the total energy received by the Earth per second of time will be: $(1-a)F_s\pi r^2$ where a is the Earth's albedo (the ratio of the intensity of the reflected and the intensity of the incident radiation).

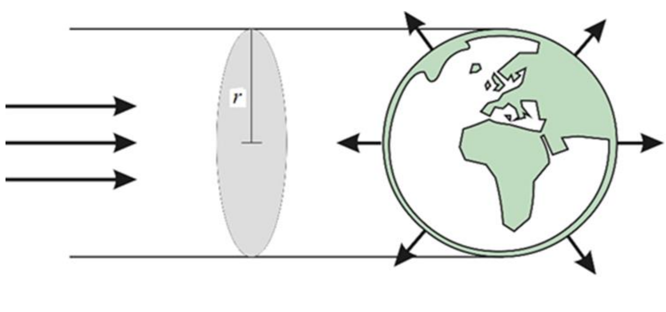

Figure 3. Zero-order model [2, 3]

By absorbing electromagnetic radiation, the Earth is heated to a temperature T_p and radiates, following this model as a black body, according to Stefan-Boltzmann's law, energy per second: $4\pi r^2\sigma T_p^4$. Starting from the fact that the absorbed energy is equal to the emitted, i.e., that $(1-a)F_s\pi r^2 = 4\pi r^2\sigma T_p^4$, the Earth's temperature (Planck's temperature) is

$$T_p = \left(\frac{Fs(1-a)}{4\sigma}\right)^{1/4} \approx 249\ \text{K} \sim -24\ ^\circ\text{C} \qquad (1)$$

According to Wien's displacement law, this temperature corresponds to the maximum emission of electromagnetic radiation at a wavelength of λ_{max} = 0.0029 K·m/249 K=11.6 µm, which corresponds to the IR part of the spectrum. In the absence of the Earth's atmosphere (zero-order model), the energy emitted by the Earth at a temperature of 249 K would go into space irreversibly. Thanks to the Earth's atmosphere, i.e., the greenhouse effect, the Earth's temperature is higher by an average of 39 K and is 288 K ~ 15 °C.

Arrhenius' one layer model provides a solid prediction of the measured average Earth temperature of 288 K. This model takes into account the Earth's rotation and takes into account the Earth's atmosphere as its single-layer "mantle" that absorbs, transmits and emits electromagnetic radiation. Taking into account the rotation of the Earth within this model, the flux of short-wave radiation coming from the Sun is: $F_0 = \frac{1}{4}(1-a)F_s$. The atmosphere absorbs part of the flux and the remaining part of $t_k F_0$ reaches the Earth's surface (Fig. 4). The t_k is the transmission coefficient of the Earth's atmosphere for short-wave IR radiation coming from the Sun. By absorbing this radiation, the Earth's surface is heated to a temperature of $T_{z.}$ According to Stefan-Boltzmann's law, it emits electromagnetic radiation of total flux: $F_z = \sigma T_z^4$. The atmosphere absorbs part of this flux while letting go the part $t_d F_z$. Here t_d is the coefficient of atmospheric transmission for long-wave IR radiation coming from the Earth's surface, the absorption of which heats the atmosphere to a temperature T_A, emitting radiation into space and towards the Earth (Fig. 4) with the flux of $F_A = \sigma T_A^4$, according to Stefan-Boltzmann's law.

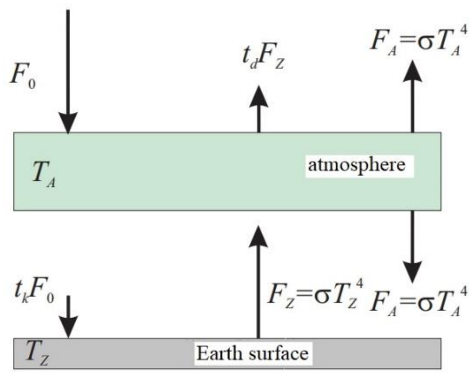

Figure 4. One layer model [2]

Obviously, in the state of thermal equilibrium, according to Fig. 4., $F_0 = F_A + t_d F_Z$ (for the atmosphere layer) and $F_z = F_A + t_k F_0$ (for the Earth's surface). Eliminating F_A results in $F_Z = F_0 \frac{1+t_k}{1+t_d}$, which combined with $F_0 = \frac{1}{4}(1-a)F_s$ gives the Earth's temperature within this model

$$T_z = \left(\frac{F_0(1 + t_k)}{\sigma(1 + t_d)}\right)^{1/4} \quad (2)$$

The absence of the atmospheric layer results in $t_k = t_d = 1$ (no absorption), so the result of the zero model is that $T_z = T_p = 249$ K.

The atmosphere transmits short-wave radiation from the Sun well. However, it is poorly permeable to long-wave IR radiation from the Earth's surface due to the greenhouse gases present. For the values of the transmission coefficients $t_k = 0.9$ and $t_d = 0.1$, (2) results in $T_z \approx 285$ K, which agrees with the measured average temperature of 285 K.

Thanks to the greenhouse effect, the temperature of our planet is, therefore, higher by 39 K and amounts to an average of 15 °C, which certainly makes our planet, generally speaking, a more pleasant place to live. In the same way, the greenhouse effect affects the increase of temperatures on other planets in the solar system that have an atmosphere and greenhouse gases (Table 1.).

Table 1. Greenhouse Effect on inner planets of the solar system

Mercury	Venus	Earth	Mars
No atmosphere	90 % CO_2	0.03 % CO_2; 1 % H_2O	90 % CO_2
0 K	497 K	39 K	5 K

GREENHOUSE EFFECT IN THE CLASSROOM

The process is very complex and challenging to thoroughly explain at the school level, which requires using models of various complexity levels. Before processing it, it is necessary to determine students' ideas about the greenhouse effect and their exactness [7]. Students' ideas about a phenomenon are the basis for further building on their knowledge and abilities. Since the greenhouse effect is closely related to radiation, it is also necessary to check what students already know about electromagnetic radiation (their preconceptions) [8, 9].

At the primary school level, a complete understanding of heat retention on the Earth cannot be achieved because students lack knowledge related to EM radiation, thermal processes and the carbon cycle. With this in mind, it is unnecessary to insist on the difference in heat transfer mechanism in a real greenhouse and the atmosphere at this level of education. The consequences of the existence of this effect can only be explained in principle by understanding its consequences and developing the correct terminology, which, at the following levels of education, shall serve as the basis for acquiring further knowledge in this area. An analysis of the greenhouse effect can begin with the questions such as: Have you heard of the greenhouse effect? Is it a good or a bad "thing"? Next, students can be shown how IR radiation can be "seen" by a mobile phone camera. The goals of processing these contents are: a) demonstration of the existence of the effect of the actual greenhouse and b) determination of the influence of greenhouse effect gases on the increase of air temperature.

Within grammar school education and in most other secondary school physics curricula (except for some profiles in secondary schools of economy, music schools…), students will be introduced to the properties of electromagnetic radiation, heat transfer mechanisms, black body radiation laws and basics of quantum mechanics. Therefore, at this level of education, students can be introduced to the greenhouse effect and its consequences satisfactorily, or at least at the level of the approach presented in this paper.

As far as higher education institutions are concerned, the possibilities are even more comprehensive and depend on the level of study at which this issue is studied. In bachelor's academic studies, it can be dealt with in a similar way as in high schools, while if taught in master's studies, then it is possible to do it in a much more comprehensive way. There has been an increased interest in presenting these topics in university-level Environmental Physics courses [1–3].

CONCLUSION

The paper offers a brief overview of the mechanism of the greenhouse effect and its consequences. Given the importance of the impact of this effect on life on Earth, introducing students to this topic is extremely important. The paper highlights the specifics of the approach in studying the greenhouse effect at education levels. Understanding the greenhouse effect and global warming also results in understanding their impact on the climate on our planet.

The greenhouse effect is a complex phenomenon, and this paper only deals with its basics. There are upgrades to the models for dealing with the greenhouse effect presented here. Namely, more elaborate models also consider non-radiative energy transfers from the Earth to the atmosphere (evapotranspiration, heat conduction, convection, etc.). Understanding the thermal effects in which the atmosphere participates will help shape the right attitude of students to the issues related to the pollution of the atmosphere and the change of its properties driven by human activities.

ACKNOWLEDGEMENTS

This work has been partially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia under the grant no. 451-03-68/2022-14/200124

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Conference Proceedings
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Increasing Uncertainty of the Time Series under the Influence of Nonlinear Force and Global Temperature Trend

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Abstract. This paper presents a new approach to the application of Newton 's second law to a non - mechanical system. A force that satisfies Newton's second law acts on a point in the data space. Artificial and real time series, which describe chaotic-stochastic oscillations, are transformed into time-dependent force parameters. A large nonlinear force, in a short time interval, causes a delayed increase in uncertainty time series, due to sensitivity to initial conditions. The length of the delay depends on the level of stochastics. By calculating the nonlinear force parameter, the increase in amplitude and frequency can be predicted. By applying this model it is possible better understanding of global temperature trend.

Keywords: Newton 's second law, real time series, global temperature trend

INTRODUCTION

It is not surprising that there has been a great interest of scientists in the application of the laws of physics in various spheres of life. There are many attempts to implement the laws of physics in explaining various phenomena in the field of climate sciences [1-6]. It is also a well-known fact that many laws of physics can explain phenomena in nature, so the environmental physics is expanding. Scientists are striving to develop as adequate models as possible with the increasing development and advancement of technology, which could serve as a possible prediction of climate change. This paper presents a new approach to the implementation of the Newton 's second law in the field of environmental physics, i.e. in the calculations related to the average annual temperature and the very current issue of global warming.

METHOD

The climate system is a very complex system that is out of thermodynamic equilibrium. We can say that it is also a nonlinear, heterogeneous system in which we have a combination of chaos and stochasticity. The system is affected by both internal and external forces, and its behavior depends on natural and anthropogenic factors.

We observe artificial and real series that describe chaotic-stochastic oscillations, and we transform them into time-dependent force parameters [7]. Force satisfies Newton's second law consists of the part representing the elastic force, the part representing the nonlinear part, damping and coercive force.

The force is given in the form (1):

$$F = a\left(x_{n+j} - S\right) + a_2\left(x_{n+j} - S\right)^2 + a_3\left(x_{n+j} - S\right)^3 + bv_{n+j} + \omega + \sum_{i=2}^{6} c_i \cos\frac{6.28(n+j)}{i} \tag{1}$$

The time series x_n $(n = 1,2,3, \dots)$ represents the value of the coordinate of particle unit mass, and the expression (2):

$$v_{n+j} = x_{n+j} - x_{n+j-1}; \qquad (n = 2,3,4, \dots ,12; j = 0,1,2, \dots) \tag{2}$$

the particle velocity. It is assumed that force affect a particle at the moment $n + j$.

The term *S* is co called sliding average value given by (3)

$$S = \frac{1}{12}\sum_{n=1}^{12} x_{n+j}; \qquad (j = 0, 1, 2, \dots) \tag{3}$$

In the case of data obtained from real systems, there is a generalization of the second Newton's law, that is, we have one mechanical picture in the data space.

As already mentioned, the oscillations of this system are nonlinear and occasionally damped, amplified and unstable.

The first term in the expression (1) represents the elastic force. In the general case expression for elastic force is $\vec{F} = -k\Delta\vec{y}$, where *k* is force constant (spring constant) and sign (-) present tendency of the elastic force to act in opposite direction to applied force (Δy is displacment).

In case $a < 0$, it is an elastic force, and it tends to return the system to equilibrium. However, when $a > 0$ then the amplitude increases and the system moves further and further away from equilibrium (equilibrium in *S* is not a stable). The second and third terms in (1) represent nonlinearity. It is known that in nonlinear systems the response of the system to the influence of force is not completely proportional to the magnitude of the force, and they show chaotic properties. In this paper, special attention will be focused on parameter a_3 and its impact on the behavior of the system at some delayed moment.

The fourth term represent a damping force, if $b < 0$. If $b > 0$ this is amplifying force. The force parameter ω is a constant in a short time interval. The sixth term represents driving force. If we include $n = 3, 4, \dots, 12$ in (1), we get a system of 10 linear equations, whose solution gives us the force parameters: $a, a_2, a_3, b, \omega, c_2, c_3, c_3, c_5, c_6$. By examining these parameters, something significant can be concluded about that system.

RESULTS

Artificial time series

In order to better understand the results obtained by including data from real systems, artificial time series have been created. Several examples of artificial time series are presented below. Figure 1 presents the results obtained by solving the equations (4):

$$\frac{d}{dt}x(t) = \frac{8.7x(t) - 26}{17.53 + 17.52sin\big(4.4y(t) + 4.9f(t)\big)}$$
$$\frac{d}{dt}y(t) = \frac{3 - 8.3y(t)}{18.15 + 18.14cos\big(4.7x(t) + 4.9f(t)\big)} \quad (4)$$
$$y(0) = -2.6;\ x(0) = 3.155201, 3.155202, \ldots, 3.155209$$

The parameter $a_3$was calculated using relations (1) and (3), and $x(t)$is obtained from (4). In Fig.1 in cases a) and b) different realizations of the fluctuating function $f(t)$ were used. It can be seen clearly here that high value of the parameter $|a_3|$ announces the large uncertainty of $x(t)$.That means that as the nonlinear force increases, the sensitivity to the initial conditions increases too.

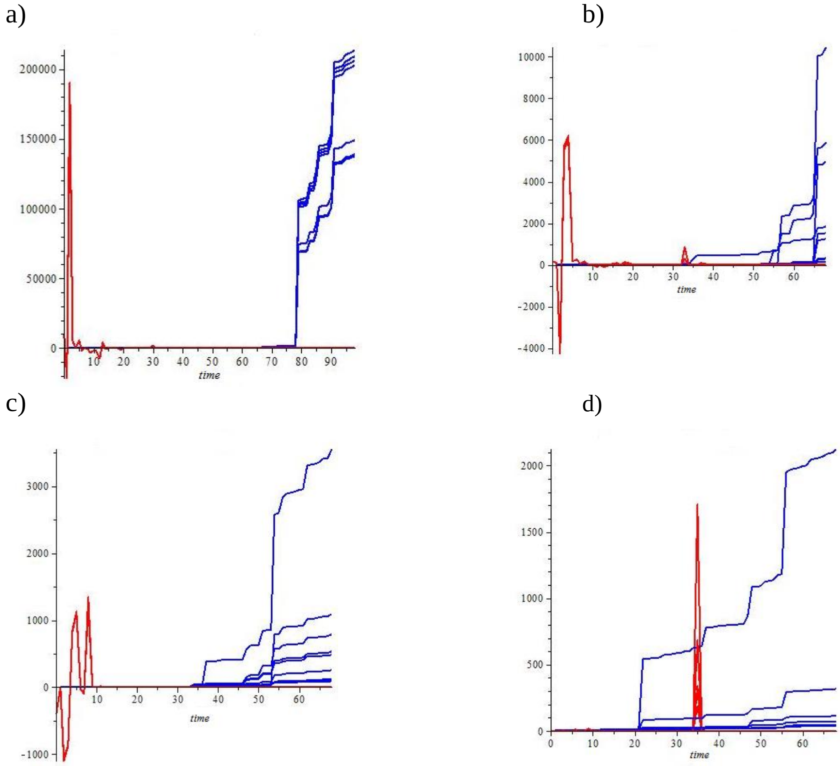

Figure 1. Force parameter a_3 (red) and $x(t)$ (blue) in two realization of fluctuatin function $f(t)$. In c) and d) time series generated by equations obtained by substitutions in (4): $4.9f(t) \to 3.5f(t)$ and $4.9f(t) \to 3.0f(t)$, respectively.

Another example of time series obtained from relations (5) is shown in Figure 2:

$$\frac{d}{dt}x(t) = \frac{23.6x(t) - 41}{128.63 + 128.62sin\big(1.3y(t) + 5.2f(t)\big)}$$
$$\frac{d}{dt}y(t) = \frac{9.7y(t) - 17}{249.35 + 249.34cos\big(1.8x(t) + 5.2f(t)\big)} \quad (5)$$
$$y(0) = 1.8;\ x(0) = -2.465231, -2.465232, \dots, -2.465239$$

a) b)

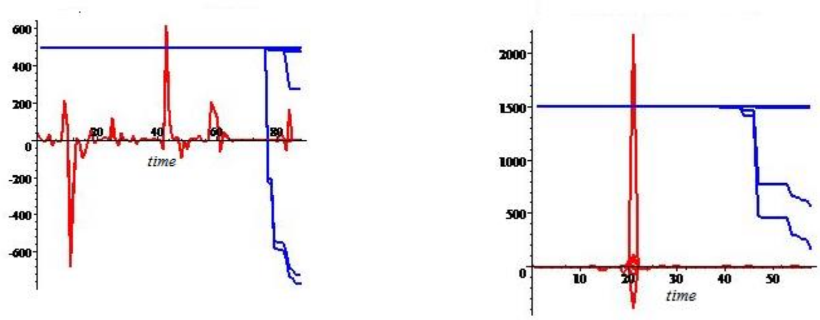

Figure 2. Force parameter a_3 (red) and $x(t)$ (blue); a) Time series generated by equations (5): b) Time series generated by equations (5) after substitution: $5.2f(t) \to 5.19f(t)$.

The previous examples illustrate the relationship between the high value of the parameter a_3 and the increase in uncertainty of $x(t)$. Now, look at an example without high maxima of parameter a_3 (Figure 3.).

a) b)

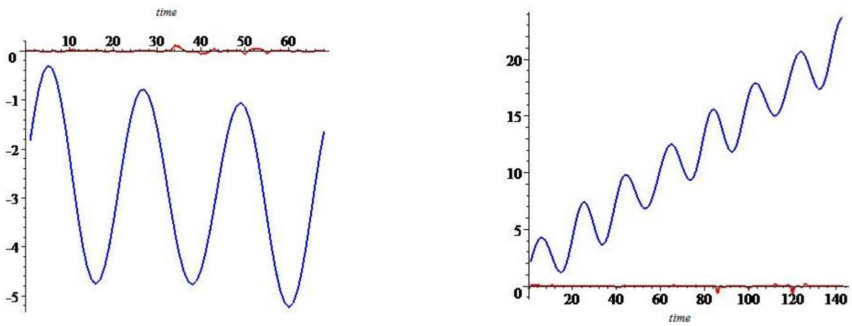

Figure 3. Force parameter a_3 (red) and $x(t)$ (blue); a) Time series generated by equations (6): b) Time series generated by equations (7).

$$\frac{d}{dt}x(t) = 0.3y(t) + 6\cos(2.9t + 0.001f(t)$$
$$\frac{d}{dt}y(t) = 0.05\cos\big(x(t)\big) - 8\sin(3.7t + 0.001f(t)$$
$$y(0) = 1.8;\ x(0) = -2.4651, -2.4652, \dots, -2.4659 \qquad (6)$$
$$\frac{d}{dt}x(t) = -0.75y(t) + 7.3\cos(3.2t + 0.002f(t)$$
$$\frac{d}{dt}y(t) = -0.06\cos\big(x(t)\big) - 4.4\sin(4.3t + 0.002f(t)$$

$$(0) = -0.4;\ x(0) = 1.4451, 1.4452, \dots, 1.4459 \qquad (7)$$

From the previous examples to conclude that there is a connection between the force parameter $a_3$which represents the nonlinearity and the delayed action of system (increase in uncertainty of $x(t)$).

Average annual global temperature

We observe data on the average annual temperature for the period from 1881 to 2020 [8]. We apply the same principle as in the previous paragraph for artificial time series. Values of average annual temperatures are observed as coordinates of the point of unit mass. We observe the parameter a_3 and the values of temperature over time (Figure 4.).

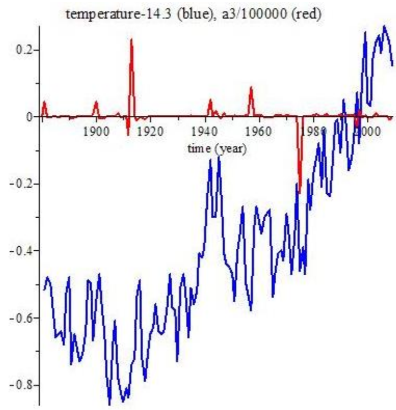

Figure 4. Force parameter a_3 (red) and temperature (blue);

It can be clearly seen in Figure 4 that there is an increase in uncertainty which was preceded by an increase in parameter a_3. As we have already stated transformation of the measured time series x_n $(n = 1,2,3, \dots)$ in time-dependent force parameters represent filtering of information. A sudden change in the value of nonlinear force parameter a_3 leads to a large increase in temperature uncertainty in the future. If we look at Figure 4 it can be seen that it is possible increase of the average annual temperature even more in the future, but there is a possibility of its reduction too.

CONCLUSION

During the last few decades there was an expansion of research and description of real systems using the laws of physics. In the 1960s, Lorenz dealt with the application of the laws of physics to the atmosphere [2-3]. He found that evolution of solution of a simple set of nonlinear equations could be changed by small perturbations of initial conditions. That means that after certain time there is no longer a single, deterministic solution of the nonlinear system of equations, and all forecast must be probabilistic treated. Considering artificial time series that are both stochastic and chaotic, it could be found that large perturbations in short time interval, causes large uncertainty of amplitude and frequency of oscillations in future. By applying the same principle to real time series we can conclude something about the behavior of the system itself. It is known that it annual average global temperature is higher now than it has been 1200 years ago [9, 10]. For many combinations of chaos and stochasticity, force associated with the first half of the time series allows rough, but relevant to the application, predicting the second half of the time series.

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Use of Renewable Energy Sources in Serbia

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Abstract. Serbia is dependent on imports of oil and crude gas as the main energy sources it uses, but an unstable market, rising prices and high environmental pollution are a big problem for the country. The solution to these problems is the use of renewable energy sources, which Serbia is rich in. However, the use of renewable energy sources in Serbia is at a low level, except when it comes to hydropower, while biomass and geothermal energy are almost neglected. This paper will present the potential of renewable energy sources and their utilization, as well as measures for the development of the use of renewable energy sources in Serbia.

Keywords: energy, renewable sources, potential, development.

INTRODUCTION

In recent years, the public in Serbia has been worried about the state of the environment in our country. Air pollution, rivers, the emergence of illegal landfills, uncontrolled deforestation, the growing need for energy are significant problems of our country. Such negative effects affect human health, their productivity, life expectancy, then soil fertility and finally climate change [1]. The need for energy is great and has a growing trend. Energy resources are classified into: non-renewable/conventional (coal, oil, gas, etc.) and non-renewable (wind, solar energy, wind energy, biomass, etc.). Due to restrictions on crude oil production, changes in prices, environmental pollution and the unstable situation in exporting countries, there is a growing interest in the use of renewable energy sources [2]. Renewable energy sources (RES) are the main driver and carrier of the energy transition to carbon neutral energy and economy. There is a crucial importance of the RES Paris Agreement from 2015. Global agreements are not just conventions and memoranda, but concrete actions, as shown by the fact that around 170 countries have set national targets for achieving the share of renewable energy sources in energy consumption. It is estimated that the use of RES, in addition to increasing energy efficiency and electrification of traffic, will lead to an effective impact on reducing global warming and environmental pollution.

The Republic of Serbia is characterized by an ever-growing energy deficit, so the country is energy dependent on energy exporting countries. The average annual consumption of all types of energy is higher than domestic production, so annual imports are estimated at about 40% [3]. At the same time, it is estimated that Serbia has the potential to produce 6 $Mtoe$ yearly from renewable energy sources. In this sense, renewable energy sources seem to be one of the most efficient and effective solutions for the development of clean and sustainable energy [4]. Some of the basic RES that Serbia can use are: wind energy, solar energy, water energy, biomass, biogas, geothermal energy, landfill gas. In March 2021, Serbia adopted a new Law on the Use of Renewable Energy Sources, which should modernize the incentive system by replacing the administratively allocated feed-in tariff model with market premiums and auctions, as a way of allocating incentives.

POTENTIALS OF RENEWABLE ENERGY SOURCES IN SERBIA

Renewable energy sources are often called clean energy, because they come from natural sources or processes that are fully or partially renewable, such as energy from watercourses, non-accumulated solar energy, wind energy, biomass, biogas, geothermal energy, landfill gas, etc. [5,6]. Unlike non-renewable energy sources, which are created in a process of several tens of millions of years, and which are depleted very quickly (several tens or hundreds of years), renewable energy sources are constantly or cyclically renewed and they are consumed at a speed that is less than the speed of their creation [6]. Renewable energy sources are used for the purpose of producing thermal, electrical, mechanical and chemical energy, and their most important characteristic is harmlessness for the environment.

The potentials of renewable energy sources available to the Republic of Serbia are as follows:

- Wind energy - Serbia is an area with significant wind energy potential. The estimated technically usable wind potential is 0.103 $Mtoe$. According to research and wind measurements conducted by the Hydrometeorological Institute of Serbia, areas particularly rich in wind are located in Vojvodina (southern Banat), as well as mountainous areas of southern and eastern Serbia. The largest areas with great wind energy potential are in the mountains such as: Jastrebac, Stara planina, Kopaonik, Juhor, Suva planina, Tupižnica, Vlasina [2]. Wind energy is a cost-effective option in locations where the average wind speed is greater than $4\frac{m}{s}$ during the weakest windy weather. Although there are doubts about wind stability, they can be solved by combining with some other renewable sources, such as solar energy and hydropower [7]. So far, eight wind farms with a total capacity of 398 MW have been connected to the Serbian power system. The construction of the largest wind farms in Serbia - Kovacica, Alibunar, Cibuk1 and Košava - were financed by loans from international institutions, which was a signal to many investors to come to Serbia and explore locations for future wind farms. The expansion of wind farms was mostly due to the reduction of technology prices and increased competitiveness among equipment manufacturers.
- Biomass is a renewable energy source that can be used as a substitute for fossil fuels in the production of heat and electricity. Unlike fossil fuels, combustion does not increase the amount of CO_2 in the atmosphere, and does not pollute the environment as when using non-renewable energy sources. Biomass includes: wood biomass (sawdust, wood residues); harvest residues (wheat straw, corn stalks); animal waste; biomass from waste (green fraction of household waste, sludge collectors, water purifiers) [8]. According to the data of the Energy Development Strategy of the Republic of Serbia until 2025, the

technically usable potential of biomass is 3,4 $Mtoe$, which is more than half of the defined national potential of RES [9]. Biomass can be used in plants for the production of heat and electricity, as well as raw materials for the production of biofuels, which can be used in the industry for the production of fibers and chemicals. According to the official register of the Ministry of Mining and Energy, only one biomass power plant has the status of a privileged producer of electricity, so it can be said that the potential of biomass is very poorly used. Several other relatively small capacity of biomass power plants are under development.

- Solar energy is responsible for the favorable climatic conditions and the existence of ecosystems on our planet. Most of the energy available on Earth actually comes from this source. With the right technology, we can use this free, ecological and eternal source of energy. The use of solar energy can be achieved in two ways: by converting solar energy into heat and by converting solar radiation into electricity [7]. The number of sunny days in Serbia is more than 2000 hours, which is a higher value than in most European Union countries. According to the data of the Energy Development Strategy of the Republic of Serbia until 2025, the technically usable potential of solar energy is 0,240 MW[9]. However, the solar potential is almost completely unused. In Serbia, 107 solar power plants with a capacity of 8,82 MWwere built, which received incentive prices (feed-in tariffs). These are low-power buildings on the roof and on the ground. In the coming years, investments in the field of solar energy are expected to increase and large investors to arrive.
- Hydropower is energy that comes from water. Hydropower potential is currently the most used renewable energy source for electricity production and is registered in the Energy Balance of Serbia [2]. The technically usable potential of water energy is 1,679 $Mtoe$. The largest part of the hydropower potential, of over 70%, is concentrated in the flows of the Danube, Drina, Velika Morava, Lima and Ibar with over 10000 GWh per year [10]. According to theoretical estimates, Serbia could build several hundred small hydropower plants, with an installed capacity estimated at 500 MW and an annual output of about 1600 GWh. Their construction would save about 400,000 m^3 of gas and 2,3 million lignites per year [2]. However, due to the impact of hydropower plants on the environment, the Law on the Use of RES envisages a ban on the construction of small hydropower plants in protected areas, unless the Government decides that the construction of hydropower plants is in the public interest.
- Geothermal energy is defined as heat from the Earth, ie it is energy that is mostly due to the slow natural decay of radioactive elements in the Earth's crust, so it can be called fossil nuclear energy [11, 12]. It is a clean, renewable resource, providing energy around the world in a variety of applications. It is estimated that the potential of geothermal energy in Serbia is about 2300 GWh, which is about 100 locations with geothermal sources [13]. Lands in Serbia are built of hard rocks and due to such favorable hydrogeological and geothermal characteristics, there are about 160 sources of geothermal water in Serbia (62 artificial geothermal springs in Vojvodina) with a temperature higher than 15°C. The hottest springs are in Vranjska Banja, where the temperature is around 96°C [8, 14]. In Serbia, only geothermal energy from geothermal and mineral water is used, mostly in the traditional way, mostly for spa and sports-recreational purposes. The use of geothermal energy for heating and other energy uses is at an early stage and is very modest compared to the potential of geothermal resources.

Legal regulations in the field of energy were changed in April 2021, when the Government of the Republic of Serbia adopted: the Law on the Use of Renewable Energy Sources (goal: to enable new investments in RES and increase the share of renewable sources in total energy produced) [15], Law on energy efficiency and rational use of energy (goal: achieving energy savings, reducing the impact of the energy sector on the environment and contributing to the sustainable use of natural and other resources) [16]. Also, amendments to the Law on Energy were made (goal: enabling harmonization of domestic legislation with the legal principles of the European Union, ensuring security of supply of energy and energy sources and enabling the introduction of new participants in the energy market) [17] and the Law on Mining and Geological research (goal: to create conditions for more efficient and sustainable management of mineral and other geological resources of Serbia, as well as increase investment in geological research and mining) [18].

MEASURES FOR THE DEVELOPMENT OF RES USE IN SERBIA

In order to improve the quality of life and environmental protection, as well as to establish the concept of sustainable development, Serbia should pay special attention to the development of the energy sector [19]. The main characteristic of the energy system of Serbia is the obsolescence of technology and low energy efficiency, as well as high environmental pollution. To overcome this situation, it is necessary to take coordinated actions in order to provide energy for further economic development of the country and preservation of the environment. This implies the transition from the current energy system to a sustainable clean energy system based on the use of renewable energy sources [4]. Measures to enable and encourage the development of the use of renewable energy sources are [9]:

- raising the capacity of financial organizations to finance energy efficiency measures, ie to finance and develop the production and placement of the best available technologies and energy equipment;
- development of innovative financing mechanisms for the energy services sector;
- encouraging the development of domestic industry to follow the development of the energy sector;
- analysis of the impact of climate change and making adaptation plans;
- Systematic capacity building of scientific and educational institutions for work in the energy sector;
- comprehensive and timely informing the public about the situation in the sector;
- education and raising awareness about the possibilities and benefits of using RES.

In addition to these measures, investments in activities and projects that would use RES, especially biomass, as an energy source that is mostly represented in Serbia, then geothermal energy, which is underutilized, would be of graet importance. The implementation of projects requires strong support from the Government of the Republic and local authorities, both in the legislative sense and in the financial sense. The introduction of a guaranteed minimum feed-in tariff for energy produced from RES and the exemption from taxes on the production of that energy are extremely positive for creating attractive conditions for the development of RES.

CONCLUSION

One of the key problems of many countries in the coming period will be energy security. Renewable energy sources should be the backbone of Serbia's energy independence in the future. The total potential of renewable energy can satisfy half of Serbia's annual energy needs. Currently, about 20% of the energy potential is used, mostly in the form of hydropower. Serbia is especially suitable for the use of biomass and geothermal energy as renewable energy sources. The government and all other institutions at the state level have set the production of energy from RES as a priority, which is regulated by law, as well as the allocation of subsidies to investors. The investments made so far are modest, but given the decent results, they can be considered as a positive example for all potential investors. Special attention should also be paid to raising people's awareness and investing in educational systems, which would emphasize the importance of using RES from both environmental and economic aspects.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
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Modern Teaching of Environmental Physics

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Abstract. Modern education aims at building environmental consciousness through general and interdisciplinary competencies that pupils and students should acquire after finishing secondary school or college. Physics is already an integral part of environmental studies of all sorts, that can be learned already in grammar schools. To facilitate that, interactive work with PHET simulations is introduced. Expertise in big data treatment is a second vital component needed for advances in environmental science. Physics and Modern technologies courses today offer an introduction to available tools for data handling.

Keywords: ecoinformatics, smart cities, climate change, global warming, the virtual physics laboratory, modern technologies

INTRODUCTION

The development of environmental conscience has recently gained more attention with transformations of high school [1] and college curriculums. Pupils and students get to learn about physical descriptions of complex phenomena [2-5] and IT solutions for the treatment of big data [6], while teachers and professors introduce new approaches to teaching [7]. One good example is global warming, which has triggered physicists to implement radiation laws to estimate the temperatures of the planets and to use scientific software to present a huge amount of data collected over decades daily [4,5]. For example, modeling of Earth's climate is taught at the Faculty of Physics, University of Belgrade, and research in this area is realized in collaborations with many partners in this country and worldwide. [8] In this paper, we will present how the elective subject *Modern technologies* offered in grammar schools can play a great role in the understanding of environmental actions and how *The Virtual Physics Laboratory* implemented in college offers much-needed tools for analysis and proper presentation of big data. In this case, big data will only symbolically be collected in the framework of project activities in the final year of a grammar school for the subject *Modern technologies* and then evaluated using *The Virtual Physics Laboratory* taught at college.

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MODERN TECHNOLOGIES IN GRAMMAR SCHOOLS

Electives in the Grammar school program

In the school year 2018/2019 a new reform of the school program for grammar schools has started in Serbia. Pupils enrolled in the first grade could choose one of six offered elective courses that span over the first two years of grammar school. After that, they are offered six new elective courses and they are meant to choose two that span over the last two years of grammar school. That is four additional classes per week.

There are several non-typical demands for the elective subjects. There is no traditional and certainly no ex-cathedra teaching, no textbook following the course, classes are held online and they do not have to last the entire 45 minutes.

The topics covered by the elective subjects are related to several different subjects from the regular school program, are contemporary, and especially useful for further schooling of the pupils.

Interdisciplinary and general competencies

One of the general goals for pupils who attend electives is the strengthening of interdisciplinary competencies. In the world of the 3Rs (reading, writing, and arithmetics), acquiring language and mathematical literacy was the main goal of primary and secondary education. We are living in the post-3Rs world and achieving soft skills starts being one of the top priorities.

General interdisciplinary competencies to be acquired are digital literacy, work with data and information, entrepreneurship, communication, collaboration, leadership, emotional intelligence, problem-solving, responsibility for the environment, responsibility for health, and responsible participation in the democratic society.

Respectful and responsible behavior towards the living environment is even among the general competencies that the pupils should acquire through the subjects physics and chemistry in grammar schools as well.

Elective subject Modern technologies

One of the offered electives for the 3rd and 4th-year pupils of grammar schools is *Modern technologies*. Topics covered in the 3rd year of *Modern technologies* are Cyber security and privacy, Smart cities, and Artificial intelligence. Within the framework of Smart cities, pupils are expected to notice problems in their environment and propose eco-friendly smart solutions involving the internet of things (IoT). This is done in a form of a project that is proposed by a team of 5-6 pupils with one of them acting as a team leader.

Topic Smart cities allows pupils to learn how physics is playing a vital role in most of the current technical and technological undertakings, giving a solid base for the development of our knowledge and understanding of climate change, energy efficiency, or pollution. Pupils appreciate the fact that exact science like physics builds the base of environmental sciences.

Topics covered in the 4th year of *Modern technologies* are IT innovations and entrepreneurship, 3D modeling and printing, Ecoinformatics, and Robotics/Mobile technology. In the classes of Ecoinformatics, high school pupils meet for the first time with the term “big data”. This time their project is to note consumption of plastic in their household over a given period, treat, interpret and present collected data and raise awareness about the time needed for certain types of plastic to disintegrate or costs needed to recycle them.

The ways that this type of task helps build environmental awareness are various. For some pupils, the trigger may be their important and leading role either within their household or within the team at school, which is necessary for the completion of this task.

The expected level of high school pupils' knowledge of data treatment is high. College students and university students are today offered numerous courses that help raise this skill to an even higher level, as we will show in the following text.

THE VIRTUAL PHYSICS LABORATORY IN COLLEGE

The project *Virtual Physics Laboratory* [6-11], was created in 2021. and is still active at the Technical College of Applied Sciences in Zrenjanin. It is an upgrade of a standard physics course aiming to provide students with the necessary skills for data treatment and presentation. At the core of this improvement is the use of different program packages like Excel for presenting and fitting experimental results and working with Descriptive Statistics tools, XLSTAT for professional statistical data analysis, and WolframAlpha for all types of online computations and information processing.

Information about the project as well as tutorials about the use of simulations and the above-mentioned software packages are available at the college website [9,10] and also in the project’s Google Classroom [11] (classroom code: wgfxx7r).

Excel

During laboratory exercises in physics, students learned to work in Excel, i.e. to present experimental data on a graph and to fit these data with linear, exponential, logarithmic, or polynomial functions. Instructions written for them are available on the college website [12,13]. Grammar school pupils used the same instructions for their data analysis within the Ecoinformatics project about plastics consumption.

Students were asked to compare the results obtained in Excel with results obtained by hand when plotting and fitting experimental data and they found numerous advantages when using Excel – the speed and the precision of the work were remarkably higher.

To introduce students to the field of statistics and probability in physics, some lectures on distributions and probability were given to them. After that, they were introduced to DataAnalysis (DescriptiveStatistics) package in Excel with which they learned to get parameters of the Gaussian distribution from experimental data.

Students have appreciated the vast field of implementation of this knowledge, recognizing that it may be very useful in all branches of engineering.

PHET Simulations

PHET interactive simulations are available on the website of the University of Colorado Boulder [14]. These simulations can be used online or can be downloaded and used locally offline. Among many different subjects, there are 44 simulations in physics.

These simulations are suitable for pupils and students of all ages, from primary school to university.

It is favorable to open an account because it takes just a valid email address to register and many teaching materials become available only for the registered users. There are teaching notes offered in different languages.

During physics lessons and exercises college students worked with 31 simulations that cover different physics topics like mechanics, elasticity, waves, fluids, thermodynamics, electrodynamics, optics, modern physics. Students found these simulations very interesting and instructive as they provide them with a better understanding of physics.

Grammar school pupils were instructed to use these simulations for better visualization of different phenomena in physics in the fields of electricity, states of matter, and oscillations. They found this to be a playful and interesting way of learning. Within the framework of subject *Modern technologies* in the field of Ecoinformatics, the fourth year pupils were offered more advanced simulations in Earth sciences, like the Greenhouse effect. They found this simulation to be content-rich and easy to understand.

CONCLUSION

We have shown in this paper that elective grammar school subject *Modern technologies* offers high school pupils insight into the role of physics in the treatment of current environmental problems. Furthermore, they are stimulated to plan their activities in environmental protection, implementing knowledge of entrepreneurship and data treatment. We have also shown that college can offer a vast set of tools that help cope with big data. They are easily accepted and used by the pupils and students who notice their numerous advantages. Both students and pupils were introduced to PHET simulations for a deeper understanding of physical phenomena, which they appreciated.

ACKNOWLEDGMENTS

This work was supported by the Provincial Secretary for Higher Education and Scientific Research.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
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Water Quality Analysis of Ibar River Through Rozaje (Montenegro) During the Period of 2010-2018

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Abstract: This paper aims to analyze the water quality in the river Ibar after passing through the Montenegrin municipality of Rožaje using the Water Quality Index (WQI). The method includes the use of ten physical, chemical and microbiological parameters (oxygen saturation, BOD5, ammonium, pH value, total nitrogen oxides, orthophosphates, suspended solids, temperature, electrical conductivity and coliform bacteria) and summarizes them in one index number based on which water quality is analyzed. For the purposes of obtaining parameters, the data of the Institute of Hydrometeorology and Seismology of Montenegro from the Annual Reports on Water Quality with two control stations (above Rožaje and Bać) in the period from 2010 to 2018 were used. The annual results of the research according to the WQI classification show that the water quality at the control station above Rožaje is mainly in the class of excellent quality. At the Bać station, which is located below Rožaje, the water quality is in good and bad classes. Due to the substantial anthropogenic impact and all in the function of protection of this vital water resource, an urgent local strategy for regulation, use, and protection is needed.

Keywords: water quality index, Ibar, Rožaje, water pollution classes

INTRODUCTION

Water quality is one of the most significant factors that have to be taken into account in evaluation of sustainability of a particular region [1]. The important aspects taken into consideration when examining the top-priority problems of water quality are the economic influence, the influence on human health, the influence on the ecosystem, the influence of the geographic area as well as the duration of the influence [2].

The study of the quality and pollution of watercourses in the world is most often based on various mathematical and statistical methods that use physical, chemical and microbiological parameters. The most commonly used mathematical-statistical method is the Water Quality Index (WQI). Authors from around the world use different WQI as indicators of river quality and pollution [3,4]. Various environmental departments or agencies develop many WQI methods: National Sanitary Foundation, British Columbia Water Quality Index, Oregon Water Quality Index, Malaysian Water Quality Index, Florida Water Quality Index, Columbia Water Quality Index, Canadian Water Quality

Index, Taiwan Water Quality Index, Washington State Water Quality Index, French Water Quality Index, Serbian Water Quality Index [5].

The Ibar River is one of the most polluted rivers in Montenegro. Like many other rivers in developing countries, it is polluted due to anthropogenic impacts in the municipality of Rožaje, primarily due to wastewater discharges from industrial and sewage systems landfills concentrated along the watercourse. There are no research works in Montenegro that deal with water quality analysis in the Montenegrin part of the river Ibar. Therefore, this paper aims to analyze the water quality of the river Ibar through Rožaje in the period 2010-2018 using WQI.

MATERIAL AND METHODS

Research Area

The subject of research in this paper is the Montenegrin part of the river Ibar after passing through Rožaje (Figure 1). The Ibar is a river in the northeastern part of Montenegro and the southwestern part of Serbia, with a total length of 276 km, and in the territory of the municipality of Rožaje, i.e. Montenegro, it flows in the length of 37 km. It springs on the northern side of the Hajla Mountain in Rožaje, and flows into the West Morava near Kraljevo in the Republic of Serbia. Due to the mountainous character of Rožaje, the Ibar receives a large number of tributaries on the right and left. In the middle of the 20th century, the quality of water in the Ibar after passing through Rožaje was endangered due to the process of urbanization, industrialization, agriculture, construction of transport infrastructure, unregulated landfills and wastewater. So today we have many general pressures that threaten this river [6].

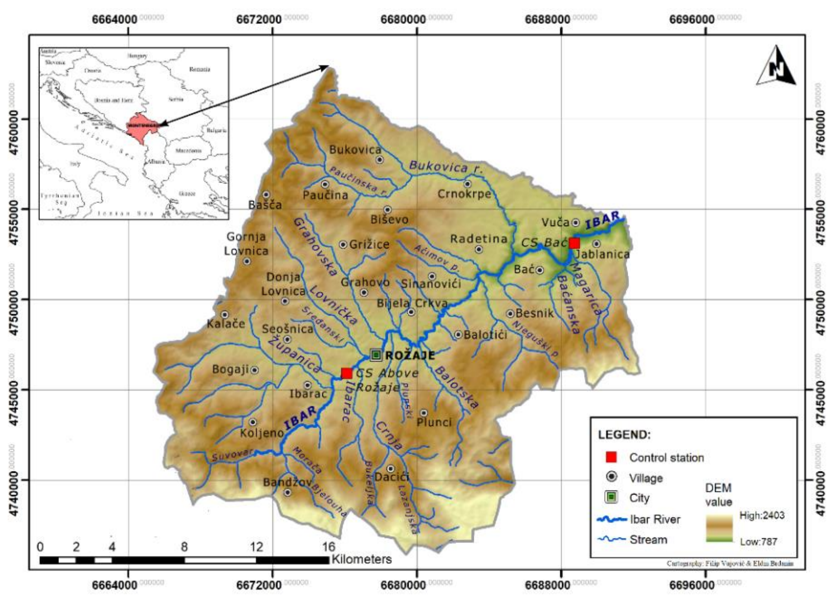

Figure 1. Map of the Montenegrin part of the river Ibar after passing through Rožaje

Data and methods

Data from the Institute of Hydrometeorology and Seismology of Montenegro (IHMS) from the Annual Reports on Water Quality were used to assess water quality [7]. Data from two water quality control stations were processed: above Rožaje and Bać (Figure 1) from 2010 to 2018 in Rožaje.

In order to calculate water quality, Water Quality Index (WQI) method was used. WQI is a numerical value that shows a complex impact of relevant physical, chemical and microbiological parameters on water quality. This is an efficient method to indicate the current water quality and its trend in the observed area. The European Union adopted the WQI as a water quality assessment tool. In order to reduce the risk for aquatic ecosystems, especially water quality, the experience of developed countries should be used [8].

WQI method combines standardized values (qi) of ten parameters, which specify the properties of surface waters to calculate a unique index value. This method uses ten physical, chemical, and microbiological parameters (temperature, pH value, electrical conductivity, oxygen saturation, BOD5, suspended solids, total nitrogen oxides, orthophosphates, ammonium, coliform bacteria) and summarizes them in a water quality index number. The impact of the ten listed physical, chemical, and microbiological parameters is not the same. Therefore, each has an assigned weight factor and an estimate of the number of points contributing to the water quality threat. By adding the products qi and wi, we come to the value of index 100 as the ideal sum of the values of all parameters [9].

The number and type of parameters and their weighting coefficients can vary (be adjusted) according to local or regional conditions [10]. In case we do not have the value of a parameter, the value of the arithmetically calculated WQI is corrected by multiplying the index by the value 1/k, where k is the sum of the arithmetically calculated weight factors of the available parameters [4].

The arithmetic sequence for the Water Quality Index (WQI) is calculated according to the following formula:

$$WQI = 1/100\left(\sum_{i=1}^{10} q_i \times w_i\right) \quad (1)$$

where WQI is the water quality index and the number on a continuous scale from 0 to 100, qi - water quality of the appropriate parameter, wi - weight prescribed by the appropriate parameter [4].

The final calculation of the WQI value was performed using a calculator available on the website of the Serbian Environmental Protection Agency (SEPA) [11]. The Serbian Water Quality Index (SWQI) is based on the primary method of the WQI Index and was developed by the SEPA.

Since the number and type of parameters, as well as their weighting coefficients, can be modified (adjusted) according to local or regional conditions [10], therefore there are differences in the intervals for quality classes water. According to the SEPA recommendations, the total nitrogen oxide parameter can be replaced with a set of parameters Nitrates + Nitrites. Therefore, the classification of surface water quality was performed according to WQI values, used by SEPA and the State Agency for Nature and Environmental Protection of Montenegro (ANEPM) (Table 1).

Table 1. Classification of surface water quality [12]

Water quality	Class intervals	Color symbol
Excellent	90-100	
Very good	84-89	
Good	72-83	
Bad	39-71	
Very bad	0-38	

RESULTS

The research results shown in Table 2 show the calculated annual values of the Water Quality Index (WQI) at two control stations in the Ibar River through Rožaje for the period from 2010 to 2018.

The water quality at the control station above Rožaje was classified as excellent (2010, 2011, 2012, 2014, 2015, 2016, 2017, 2018) and very good (2013). Values ranged from the lowest 85 (2013) to the highest 94 (2010, 2011). According to the average values during the entire research period, the water quality can be classified as excellent.

The water quality at the Bać control station below Rožaje is classified as bad (2010, 2013, 2017, 2018), good (2011, 2012, 2015, 2016) and very good (2014). Values ranged from the lowest 56 (2017) to the highest 86 (2014). According to the values during the entire research period, water quality can be classified as good, but it is on the value boundary between good and bad quality.

Table 2. Annual WQI at control stations in the Ibar River through Rožaje

CS	2010	2011	2012	2013	2014	2015	2016	2017	2018	AVE
AR	94	94	92	85	91	92	91	91	93	91
B	68	77	81	62	86	76	76	56	68	72

Note: Control station or CS, Above Rožaje or AR, Bać or B, Average or AVE

DISSCUSION AND CONCLUSION

In the case of the Ibar River through Rožaje, it should be said that the index is not adapted to a specific purpose but is a general index for determining the overall water quality.

Lower water quality in Ibar after passing through Rožaje at Bać control station is a consequence of unregulated temporary city landfill, illegal landfills concentrated along the watercourse, as well as general pressures of households, production and consumption of all forms of energy in stationary or mobile sources, industry, various mobile activities.

The water quality on the river is a limiting factor of development due to the negative anthropogenic impact and threats to human health and the sustainability of natural ecosystems. Keeping in mind the river's current state, several problems have been identified that are worrying and must be solved in the coming years. Also, coordinated action of all actors (local and national authorities, economic and non-governmental organizations, citizens) could contribute to the attitude towards water and the preservation of pollution in the Ibar. In order to implement this, integration of economic, social and environmental policies is needed. Priority tasks for water protection in the future for all actors should be: solving waste problems, introducing wastewater treatment technologies, building municipal and industrial wastewater treatment systems, revitalizing degraded watercourses and their shores and educating local people about water conservation. The situation is becoming worrying, so we conclude that there is an urgent need to develop a strategy for the regulation, use and protection of this essential water resource of particular importance.

Also in addition to the numerous advantages provided by this method, such as adaptability at the local and regional level and the combination of several parameters in one index number, this method still partially shows the ecological condition of the river. In order to achieve a more relevant result, it is necessary to develop and use the WQI method, which would include inorganic parameters (e.g., heavy metals). Therefore, in future research for better monitoring and relevant results, all to preserve this essential river resource, it would be desirable to use the Canadian Water Quality Index (CWQI), which uses more parameters and includes inorganic parameters.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
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Climate Change and "Debeli Namet" Glacier

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Abstract. Traces of glaciers can still be found in some Balkan mountains. Glacier Debeli Namet is relic of the largest glacier that ever existed in the Durmitor area. Nowadays, when climate changes are pronounced, the existence of this glacier is explained by the topology of the place where it exists, by the amount of precipitation in the colder period of the year and also by avalanches and wind-blown snow. The scientific predictions about further grow of the summer temperatures till the end of this century and the decreasing the amount of precipitation in the Mediterranean will probably lead to glacier retreat and their melting on the Balkan peninsula in the next few decades.

Keywords: climate change, glacier, Durmitor, Debeli Namet

INTRODUCTION

Climate change has accompanied mankind from its beginning to the present day. Science has determined the periodicity of alternating periods of favorable weather conditions and periods when weather conditions were much more unfavorable for the people and all beings on Earth. These periods are known as the ice age. Today, we are witnessing climate change, which, in addition to public controversy, has induced great interest and engagement of the scientific community. Measurements of the temperature and thickness of the ice sheet in various parts of the world are being carried out more accurately and diligently than ever before in the history of human civilization. These efforts are aimed at summarizing the results, statistical processing and drawing conclusions that would help us better align the development of modern civilization and our way of life with the natural rhythms of our planet. The great Serbian scientist Milutin Milankovitch published 81 years ago its capital publication “Canon of insolation”, where he explained mechanism of the ice ages generation [1]. His theory is based on Newton's laws of mechanics and on the laws of radiation. Milankovitch noticed that 65° north latitude is a critical area for the beginning of glaciation. He came to the essential conclusion that the insolation of the northern hemisphere has a predominant influence on climate fluctuations because 2/3 of the world's mainland is located on it. Ice ages in both hemispheres occur simultaneously because they are caused by the same force- insolation of the land areas in the northern hemisphere. The appearance of ice ages is not due to cold winters but cold summers.

Glaciation in the Balkans

The last ice age, which ended 11,000-12,000 years ago, left its mark on the Balkan Peninsula. Thanks to the research of Jovan Cvijitch, a contemporary of Milankovitch, traces of glaciation and interglaciation have been discovered in the Balkans. His discovery of an old glacial relief on Rila in Bulgaria, in 1896, then on Durmitor, Lovćen, Prokletije, Kopaonik and other high mountains, made him one of the greatest geographers of Europe at that time. Almost every mountain at an altitude of 1300 m shows traces of glaciation [2]. Mountains about the same heights had more glaciers if they were closer to the Adriatic Sea due to the larger amount of atmospheric precipitation. The largest glaciers on the peninsula were found in the highest Dinaric mountains- Prokletije, Komovi and Durmitor, whose highest peaks exceed 2500 m. Today, there are 16 glaciers on the Balkan Peninsula - 13 on Prokletije, 2 on the Pirin Mountain and 1 on Durmitor. Some of them represent the southernmost glacial masses of Europe, the only ones located south of 42° north latitude. Many of them exist below today's snow line thanks to favorable topology and local climate. They cover an area of 0.5-5 hectares, and their thickness is estimated at 10-20m. Snow line or height limit of eternal snow is determined, above all, by temperature and latitude. The temperature in the warmer half of the year plays very important role because it determines the height to which the snow is maintained during the summer as well. Alternating very warm summers and winters with low rainfall over several years would lead to the retreat of glaciers or their melting throughout the Balkans [3-6].

Glaciation of Durmitor

The northeastern part of Montenegro is the area of the most intense glaciation on the Balkan Peninsula. This glaciation covered an area of about 3000 km^2. As the area of Montenegro is 13812 km 2, it is about 22% of the total area of today's Montenegro. The most important glacier was the Jezera glacier in the east of the Durmitor massif. Glacier rivers descended from the Durmitor in all directions and overflowed on the area of Jezera, Dobri do, Žabljak and Međed. During the most intense glaciation, all glaciers on the Jezera area merged into one glacial cover of about 140 km^2, which received another glacier from the northern sides of Sinjajevina. At the point where the slopes of the Durmitor massif and the flat surface meet, glaciers have carved into the rock the deepest lake basin - Black Lake with a depth of 48m.

Traces of two glaciations have been observed on Durmitor - older (stronger) and younger (weaker). During the older phase of glaciation, almost the entire area of Durmitor was covered with ice. It is believed that 54% of the total surface of Durmitor was under ice cover, while during the phase of younger and weaker glaciation, 36% of this surface was under ice [7]. After these two phases of intense glaciation came the circus glaciation phase when glaciers lingered in circuses, erosive amphitheater depressions that they themselves made with their powerful action in previous glaciation phases. This phase is present to this day and its only representative on Durmitor is the Debeli namet glacier, Figure 1. This glacier was part of the once mighty valley glacier Velika Kalica and consisted of two smaller glaciers - Previja and Debeli Namet at 2030-2200 m above sea level. Rise in air temperature, from the so-called period of small ice ages (1300-1550, 1645-1715 and 1850-1860) to the present day, has caused the disappearance of glaciers in all parts of the world.

Figure 1. Glacier Debeli Namet, Durmitor, Montenegro.

The existence of a glacier Debeli Namet indicates that the glaciation process on Durmitor has not been interrupted. The northwestern exposure of the terrain, as well as the highest mountain peaks that surround this area, enabled the accumulation of significantly more snow through avalanches and blizzards than can happen to fall. That is why in this part of Durmitor, conditions are still maintained that enable the feeding of the existing glacier. The specific position of the Debeli Namet glacier is the reason why it is decreasing more slowly than other glaciers in Southern Europe during the last 50 years [8]. This glacier did not change its size much, length 300-320 m, width 110-135 m and thickness, regardless of the increase in temperature evident at the end of the 20th and the first decades of the 21th century [9]. Debeli Namet is located at an altitude of 2030-2200 m, which is much lower than the climatic snow line estimated at 2700 m in the west [10] and 3200 m in the eastern part of the Balkan Peninsula [11].

Debeli Namet glacier and climate change

Annual changes of glaciers are the consequences of different climatic factors in the cold and warm part of the year. Namely, in the cold part of the year, the period from November to April, the season of glacier accumulation begins. In the warmer part of the year, the period from May to October is the period of melting and shrinking glaciers. Therefore, the period from mid-September to the end of October is the best time to study glaciers and measure the balance of their accumulated and lost masses on an annual basis. This dynamics is an indicator of both short-term (annual) and long-term climate trends. Therefore, glaciers can be used as indicators for climate change. In the last 5 years, Debeli Namet has suffered a serious decrease, but it is still higher in respect to the size it had in the critical 1990s. Dynamic processes in glaciers are complex. There were years when the glacier was decreasing, but also years, e.g. 2005-2006. when it increased. In the period of intensive study of glaciers in the Balkans, from 2010-2014, the same, synchronized behavior of all glaciers was observed- their decrease in 2010-2011, 2011-2012, 2013-2014, and increase in 2012-2013. This increase coincides with minimum solar activity and with the development of the 24th solar cycle. The latest measurements show that the glaciers on the Pirin mountain are stagnating, ie. are in balance between accumulation and melting, while glaciers are on Prokletije and Durmitor are reduced. Thus, the Debeli Namet in 2016 was lower than in 2012. Recent results are currently unavailable.

In the Western Balkans, the existence of glaciers and perennial ice is made possible by high precipitations- annual data for most Durmitor areas are about 2600 mm [8]. In the colder part of the year, 2/3 of the total amount of precipitation falls. These precipitations enable the glaciers formation even at altitudes of about 2000 m in very shady places. The flat surfaces south of Debeli Namet serve as large reservoirs of snow, so that in the processes of avalanches and strong winds that carry snow, the actual amount of snow can become twice as much as quantities that fall in winter.

CONCLUSION

The projected climate change, according to the IPCC (The Intergovernmental Panel on Climate Change) scenario, refers to extreme rains around the world that will become stronger by 7% with each subsequent degree of Celsius. More tropical hurricanes will be of the highest categories 4 and 5. Monsoon rains in Asia will be stronger and will fall at different times compared to the usual rhythm. On the other hand, droughts that happened once in 10 years could now come 4 times in a decade. Heat waves, which are already more frequent than before the industrial revolution, will be ten times more likely and 5^0 C warmer. Critics of this study point out that astronomical and other natural factors are responsible for global warming (e.g. changes in the direction of warm and cold sea currents and winds), but also that, from the geological point of view, it is only "climate perturbations" and that the temperature drop is real trend. These scientists believe that today we are actually witnessing a transition period from warming to deep cooling of the Maunder type [12]. In this sense, the scenarios of these scientists and the IPCC team are very different. The modern glaciation process on Durmitor is monitored through the influence of extremely high summer temperatures. It has been found that these summer temperatures lead to a decrease in the Debeli namet glacier but not to its disappearance [13].

ACKNOWLEDGEMENTS

This work is done in the framework of Montenegrin National Project “Physics of Ionized Gases and Radiation”.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
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Physical Drivers of Climate Changes

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Abstract. Solar radiation is Earth's primary energy source. Changes in solar radiation directly impact the climate system. The total solar radiation during Sun's 11-year cycle vary in amount only 0,1% of the total solar input. Relative variations at specific wavelengths can be tens of percent. The spectral composition of the radiation is of crucial importance. Visible radiation reaches and warms the oceans and land surface, ultraviolet radiation is absorbed by atmospheric oxygen and ozone, while water vapor and carbon dioxide absorb infrared radiation. Therefore, variations in total and spectral solar radiation induce changes in atmospheric heating and circulation.

Keywords: solar radiation, solar cycle, ozone, carbon dioxide, climate change

INTRODUCTION

Energy of the Sun in the form of electromagnetic radiation is the fundamental driver for the Earth's climate system. Variations in the intensity and wavelength composition of incident solar radiation hitting the Earth may produce changes in the global and also regional climate. The idea of solar forcing of Earth's climate dates back to the early 19th century, but the role of solar variability as a forcing mechanism is still the matter of scientific debate. On average the Earth absorbs solar energy at the rate of $(1\text{-}A)I_{TS}/4$, where A is the Earth's albedo and I_{TS} is the total solar irradiance (TSI), i.e., the total electromagnetic power per unit area of cross section arriving at the mean distance of Earth from the Sun (about 150 million kilometers). Currently, TSI value is about 1365 W/m^2 [1]. Of this 30% is reflected away from Earth, back to the space, by bright surfaces like cloud and ice. Therefore albedo is A=0.3 [2]. The remain radiation is absorbed, warming the surface and the atmosphere. Much of the heat radiation emitted by Earth surface is trapped within the atmosphere by "greenhouse" gases, water vapour mainly, but enough heat is emitted to space to balance the incoming solar radiation and establish a climate equilibrium. While this balance is achieved globally, not every location on the Earth's surface is in energy balance. Therefore, distribution of the net radiation imbalances drives the global circulations of the atmosphere and oceans. Thus the distribution of solar irradiance over the globe is important in establishing both-the mean climate and its variability.

Milankovitch cycles

The total amount of solar energy flux reaching the top of the Earth's atmosphere depends on the distance between the Earth and the Sun. The Earth has an elliptical orbit but this orbit is not constant. The eccentricity of the Earth's orbit ranges from 0.000055 to 0.0679, where an eccentricity of zero would indicate a perfect circle. The eccentricity varies with two main periodicities of around 100.000 and 400.000 years, Figure 1. Besides, the Earth's equatorial plane is inclined with respect to the ecliptic plane. The angle of inclination is called obliquity or axial tilt. This angle oscillates every 41.000 years from 22.1^0 to 24.5^0 . Presently, the obliquity is at 23.44^0. Moreover, the Earth's rotation axis is not fixed in space but describes a cone with respect to the fixed stars, i.e., it precesses. It takes 26.000 years for the Earth's rotational axis to complete one full precession cycle. Moreover, the Earth's elliptical orbit also precesses around the Sun at the rate of 112.000 years, called the apsidial precession. These two precession rates lead to a combined period of ∼21.000 years. An astronomical influence of the Earth's key parameters eccentricity, tilt and precession on climate had already been postulated in the 19th century, but a qualitative relationship was only determined at the beginning of the 20th century, mainly by Milutin Milankovitch [3]. The theory that climate variations are forced by astronomical variations is therefore usually referred to as Milankovitch cycles, Figure 1. The effects of the Milankovitch cycles on Earth's climate are well known as orbital forcing.

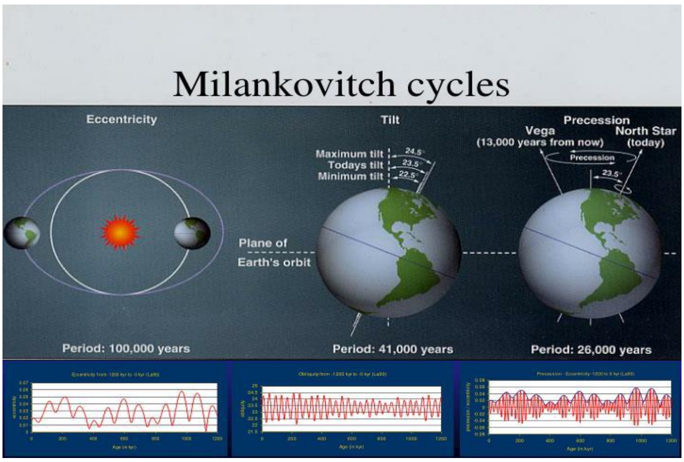

Figure 1. Milankovitch cycles. Eccentricity (departure from a circular orbit), obliquity (axial tilt) and precession (rotation of the Earth's axis).

Orbital forcing

Variations in eccentricity, obliquity and precession of the Earth's orbit determine climatic changes on the Earth. Simply, there are changes in the flow of solar energy reaching the Earth in a given time as a result of Earth-Sun geometry. On a Quaternary timescale (i.e. the last 2.6 million years), the combined effects of changing eccentricity, obliquity and precession have resulted in a dynamical climate change that is characterized by variations between long glacial periods and relatively short interglacials. Figure 2 shows how interglacial periods occur at intervals of approximately 100.000 years, corresponding to variations in eccentricity of the orbit [4]. The onset of the current interglacial, the Holocene, occurred during an increase in solar insolation received by the upper atmosphere. Northern hemispheric summer insolation has shown a steady decline during the past 11.000 years, resulting in gradualy declining temperatures over large parts of the Northern hemisphere [5]. Variation in orbital forcing is a large-scale, gradual mechanism which is superimposed by shorter variations in other forcing factors such as solar and volcanic forcing.

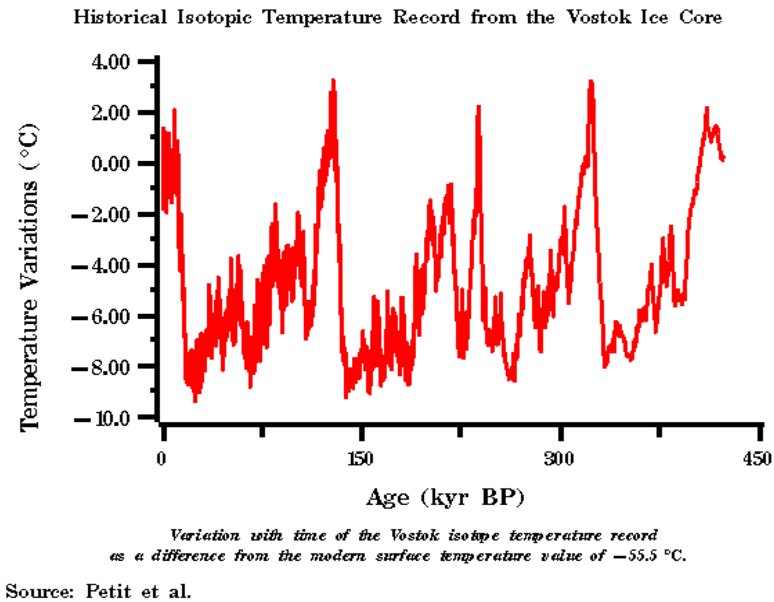

Figure 2. Temperature deduced from ^{18}O records in air bubbles trapped in the Vostok ice core.

Averaged over the globe the total solar energy hitting the Earth depends on its distance from the Sun, and therefore on the ellipticity, but the distribution of the radiation over the globe depends on the tilt and precession. TSI, which is the sum of all irradiance coming from the Sun, varies about 0.1% with the solar cycle (SC). The irradiance is directly absorbed by the Earth and ocean surface and would lead to a small warming of about 0.1 K particularly in the tropics but is thought to be modulated through air-sea coupling. It changes precipitation and vertical motions which in turn influence trade winds and ocean upwelling. During solar maximum this so-called “bottom-up” mechanism is proposed to lead to stronger Hadley and Walker circulations and associated colder sea surface temperatures in the tropical Pacific. Bottom-up mechanisms focus on the effects of changes in visible and infrared (IR) radiation on surface temperature. It will be seen that “top-down” mechanism focus on changes in solar ultraviolet (UV) radiation and associated effects on stratospheric ozone, temperatures and winds.

Spectral irradiance forcing

Besides time variations of total solar irradiance (TSI), variations in solar spectral irradiance (SSI) is important. For reasonable climate sensitivies, the 1 W/m^2 variation in TSI associated with the 11 year solar cycle translates to an estimated change in temperature at the Earth's surface of a mere 0.1 K. However, much of the observational evidence for SC influence in the troposphere and at the surface appear to be regional rather than global in extent. The measurements by the SORCE satellite suggest that over the declining phase of the solar cycle there was much larger decline in ultraviolet radiation [2]. Also, the result of the CAWSES-II science program shows that SSI variations with the solar cycle are much larger than TSI variations and reach about 5% in the UV band for wavelengths between 200 and 300 nm, the wavelength range important for middle atmosphere heating and ozone chemistry [6]. The visible and infrared bands, which have the largest contribution to TSI, exhibit small variations over the SC, only up to 0.5%.

One of the most well understood aspects of the atmospheric response to solar variability is a relative warming of the upper stratosphere (~30-50 km) between minimum and maximum phases of approximately 11 year SC. This warming comes from two main effects: (1) an increase in incoming solar UV (wavelengths ~200-300 nm) radiation, which is absorbed by ozone in the stratosphere; (2) an increase in shorter wavelenght UV radiation (wavelenghts less than 242 nm), which leads to more chemical production of ozone in the mid and upper stratosphere through the photolysis of oxygen. The latter effect leads to an increase in mid and upper stratospheric ozone of a few percent between solar maximum and solar minimum conditions.

Ozone is the main gas involved in radiative heating of the stratosphere. In the Earth's atmosphere, SSI forcing plays a key role in chemical-dynamical coupling via its interactions with atmospheric ozone and as a main driver in the so-called "top-down" mechanism connecting the stratosphere to the underlying tropospheric climate. This mechanism originates in stratosphere where UV radiation modulates local radiative heating at the tropical stratopause. Simultaneously, there is a direct effect on ozone production rates in the upper stratosphere through the SSI variation impact on UV photolysis of oxygen. Since ozone is an important element for the radiative heating, this creates an additional feedback mechanism to the radiative heating impact. The radiative heating changes, both from the direct heating and the ozone feedback, are focused on the low-latitude (equatorial) stratosphere. Changes in heating in the equatorial region affect the equator-to-pole, or meridional, temperature gradient, which the atmosphere attempts to stabilize through the thermal wind balance [7]. The result is west wind anomaly in the subtropical upper stratosphere. These westerly winds change the propagation properties for planetary waves and change atmospheric wave-mean flow interaction.

Because of the thermal structure of the atmosphere from ground to the upper thermosphere, convection between upper and the lower layers is impossible. Their coupling can be done by waves-planetary or gravity waves [8].

CONCLUSION

Any assessment of climate variability and climate change depends crucially on the existence and accuracy of records of meteorogical parameters. Ideally records would consist of long time series of measurements made by well-calibrated instruments located with high density across the globe. Unfortunately, measurements with global coverage started in 1978 when the space-based observations began. A key concern of contemporary climate scientists is to attribute causes, including the contribution of solar variability, to the observed temperature. A number of approaches have been used and in all cases great care needs to be taken to ascertain the statistical validity of the results in the context of natural variability in the temperature data.

ACKNOWLEDGEMENTS

This work is done in the framework of Montenegrin National Project “Physics of Ionized Gases and Radiation”.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
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Students' Learning of the Radioactive Decay Law Using Digital Simulations

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Abstract. In this paper, a review of Radioactivity as a part of Environmental Physics (2nd year of Mechanical engineering and Environmental protection Engineering, The Academy of Applied Technical and Preschool Studies) content is given. Digital simulations were used throughout the classes mentioned above in order to enable the visualization of the radioactive decay law. From all this the conclusion tnat had been reached was that students had achieved visible improvement in understanding this law in spite of the obstacles detected in their previous knowlrdge referring to the mathematical understanding of natural logarithm.

Keywords: Radioactivity, Radioactive decay law, Half-life, visualization, digital simulation

INTRODUCTION

In Environmental Physics, which is a compulsory subject within the study program in Environmental Protection in the second year of basic vocational studies and an optional subject within the study program in Mechanical Engineering, also in the second year of basic professional studies, the topic Radioactivity is studied through the following educational units: Natural Radioactivity, Law of Radioactive Decay, Artificial Radioactivity, Nuclear Fission, Nuclear Fusion, Nuclear Power Plants, Effects of Radioactive Radiation on the Living World, Protection from Radioactive Radiation. Within several years of work on this subject, partial and incomplete understanding of the law of radioactive decay was detected, especially in mathematically formalized terms. Over the years, the author has researched educational approaches that would contribute to a better understanding of this law. One of the approaches presented in this paper involves the use of digital simulation, which has proved to be of utmost importance in online teaching and learning. Negative emotions are mainly associated with radioactivity, as students perceive radioactivity as a harmful phenomenon, and very often mention the catastrophe at the Chernobyl nuclear power plant in 1986, although they were born much later. For example, they do not mention the catastrophe in Fukushima after the tsunami in 2011. Additionally, students do not notice the impact of radioactivity on the evolution or application of radioactive isotopes in medicine.

Today, the media are a special resource for informal learning, so it is very important to consider that, informally, radiation is mostly considered to be radioactive radiation, rather than scientifically defined electromagnetic radiation, whose one part of the spectrum makes up radioactive radiation [1]. In this regard, it is important to properly adopt the concepts of the half-life of the decay constant, the activity of the radioactive source, and knowledge of the law of radioactive decay. For each unstable species (atom or particle), a specific time interval is defined during which half of the initial number experiences a characteristic decay. The moment of disintegration cannot be predicted. During one half-life, half of those atoms, i.e., the nuclei of atoms, which are present at the beginning of that time interval, will always disintegrate.

The law of radioactive decay is mathematically formulated:

$$N(t) = N_0 e^{-t\lambda} \tag{1}$$

where N_0 is the initial number of nuclei, and λ is the decay constant.

The decay constant represents the probability that the system in question would decay in one second.

$$\lambda = \frac{ln2}{T_{1/2}} \tag{2}$$

The number of decays per second is a measurable quantity and it represents the activity of the radioactive source:

$$A(t) = A_0 e^{-\lambda t} \tag{3}$$

It is evident from the formula above that it decreases in the same way over time as the number of undecayed nuclei [2,3].

DIGITAL SIMULATION OF THE LAW OF RADIOACTIVE DECAY

The law of radioactive decay, without mathematical apparatus that includes the function of natural logarithm, which students either do not know or do not know how to apply, can be observed and partially formulated by using digital simulation listed in [4]. Figure 1 shows the layout of the simulation at its initial state. The simulation allows the selection of both the type and initial number of the radioactive isotope nuclei. Figure 2 shows the appearance of the simulation after the expiration of two half-lives of the selected isotope polonium Po-211, which is transformed by α-decay into the lead isotope Pb-207.

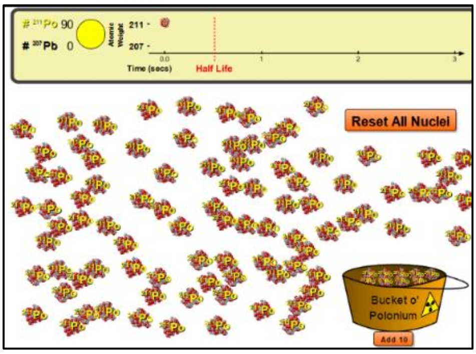

Figure 1. Initial state of the system

By simulating radioactive decay, the following can be observed: statistical character of decay; α-particle emission; transformation of the Po-211 nucleus into the Pb-207 nucleus; change in the number of certain cores over time (in the upper left corner), graphic change of the amount of material over the surface of a circle, whose yellow surface represents a radioactive pattern and the black one represents an element that occurs in the radioactive transformation, time course of radioactive decay (on the horizontal time axis) with the indicated half-life indicated by the red vertical dotted line.

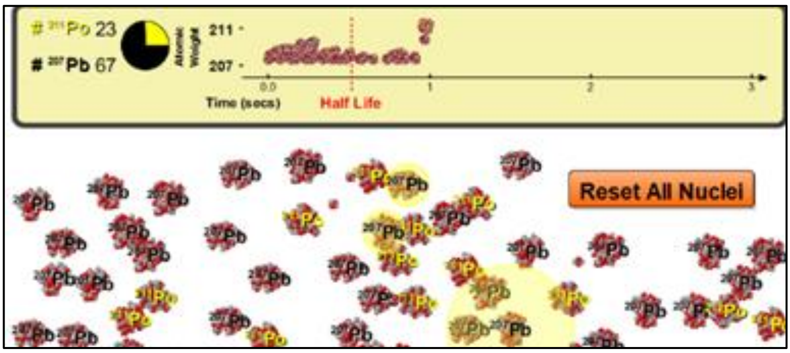

Figure 2. State of the system after two half-lives

In addition to simulating the decay of lead isotopes, it is possible to choose an unknown chemical element with a unit half-life. In this way, it is clearly observed that ¾ of the initial number of nuclei in the sample decayed with double the half-life. Thereby the rule that applies to each radioactive element is noticeable. The statistical nature of radioactive decay is observed by continuous repetition of the simulation via the Single Atom card that can read the decay time of one atom which is by no means equal, in repeated procedures, through measured half-lives of other atoms.

METHODOLOGY OF EXAMINING STUDENTS' UNDERSTANDING OF THE LAW OF RADIOACTIVE DECAY

Students answered pre-test questions on Google questionnaire, and two weeks after the content had been processed, they answered the same questions and additional post-test questions. Among other things, the content was processed by using the simulation of radioactive decay presented in the previous chapter. No one of ten pre-tested students gave the correct answer to the following question: the multiple-choice question about the structure of the alpha particle with the possible answers: elementary particle; a pair of protons; a pair of electrons; a pair of neutrons; hydrogen core; helium nucleus; lithium core. Six students answered that an alpha particle was an elementary particle, one student answered that it consisted of a pair of protons, one that it consisted of a pair of neutrons and two students answered that an alpha particle consisted of two electrons.

When asked what is the ordinal number of the chemical element that is formed by beta minus decay of nitrogen atoms, no student gave the correct answer. As in beta minus decay, one neutron is transformed into a fast electron that emerges from the nucleus and one proton remains in the nucleus, the ordinal number of the transformed atom is 8. Here are students' answers: the same 7 (8 answers); 6 (2 answers). Two students assumed the transformation of an atom into another species but were unable to apply the laws of conservation of amount of charge and number of nucleons. The third question that indicates the non-existence of the concept of natural logarithm for most students was the following one: For ten days the number of radioactive nuclei of a radioactive element decreased by 75%. What is the half-life of that element? The results of the post-test show that 6 students answered this question, whereas 4 students gave correct answers to the additional post-test question. The question was: After how much time does the initial number of nuclei of the carbon isotope C-11 whose half-life is 20.4 min decay?

During the study of the educational topic, it has been noticed that despite the subsequent understanding of the nature of the half-life, and the change in the number of radioactive nuclei of the observed sample, the activity of the radioactive source was not related to this time but was considered constant for any observed time interval. Even after the mathematical proof that implies a certain dependence of activity on time, there was still a widespread opinion that the number of radioactive nuclei will change through its decrease, but that the activity itself would not change. Only after it is pointed out that the dynamics of nucleus transformations can be observed in the simulation, students have claimed that the activity in two consecutive time intervals equal to the half-life is not the same, i.e., that it is smaller in the second interval.

Two consecutive time intervals equal to the half-life are very important for studying the nature of the change in the state of the sample and its activity. With any other time interval, the process of proving change through mathematical formula has not produced understanding. Two consecutive half-lives were useful because of the simple calculation of one half, and consequently the calculation of one half of one half of a certain number.

Most of the students' answers about the nature of radioactive decay point to the conclusion that their previously acquired knowledge is alternative. Namely, the students claim that every radioactive element decays according to a law that is not the same for all elements, and that all atoms of one radioactive isotope decay at the same time. Such misconceptions can be corrected to some extent by applying simulations. Several students have made progress in noticing that lead nuclei, although it is the same chemical element as the element in question, do not decay after equal time intervals, measured from zero moment, because otherwise the decays would be simultaneous, and the simulation shows some nuclei fell apart, and some did not. Using the Single Atom simulation, fewer number of students concluded that two different atoms of the same chemical element do not have to decay at the same time and that it is unknown which of them will undergo radioactive decay earlier. After adopting the division of radioactive radiation into three basic components, students had the opportunity to establish that the same law of radioactive decay applies to this component of radiation through a new simulation, which refers to β decay. Several students had conceptual changes by overcoming the misconception that different chemical elements decompose according to different laws, and noticing that the difference refers to their half-lives, which exist as physical quantities in identical terms - mathematical formulations of the laws of radioactive decay. Also, all students observed a significant conceptual changed by noticing that the activity was variable, while several students were able to establish a relationship of this magnitude with the half-life.

CONCLUSION

Content on radioactivity is an important piece of knowledge that a professional environmental engineer should use. Therefore, the adoption of certain concepts necessary for understanding the phenomenon of radioactivity is an important educational task. Consequently, for the full adoption of concepts and laws, certain alternative concepts, misconceptions, as well as insufficient skills in the application of the mathematical apparatus are often found as obstacles in learning. Thus, the visualization of certain quantities, phenomena and laws has an important place within instruction, especially when it comes to content related to the microworld and phenomena that are not directly sensory detectable. The simulation of radioactive decay, applied in Environmental Physics instruction, enabled students to create an experiment and phenomenologically observe the law of radioactive decay, as well as its interpretation by spontaneous formulation of statements. Also, the simulation enabled the adoption of the concept of half-life and knowledge of the variability of the activity of a radioactive source. After the application of the simulation, the students' progress in understanding the law of radioactive decay was recorded. When it comes to understanding the operation of logarithm, it is interesting that the described approach has led to the change in conceptual perception by a number of students.

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Numerical Modelling of the Adriatic Sea Level Extremes

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Abstract. Hourly tide gauge data originating from nine tide gauge stations located along the Croatian coast of the Adriatic Sea have been collected and analysed in detail. Return values were estimated from residual sea level time series – values from 98.8 (113.5) cm for the northern Adriatic to 59.8 (65.5) cm for the southern Adriatic were obtained for 25 (100) years return periods. The most extreme events were selected and numerically modelled using ocean SCHISM model. The ocean model was forced at the surface with air pressure and wind fields obtained from ALADIN meteorological model. The ocean model proved able to reproduce extreme sea levels, and was used to obtain the spatial distribution of return values along the entire Croatian Adriatic coast. A detailed coastal topography was used to estimated flooding areas for given return periods. The procedure was repeated under the assumption of a uniform sea level rise, of 60 cm, due to climate change.

Keywords: extreme sea levels, storm surges, return periods, numerical modelling, ALADIN atmospheric model, SCHISM ocean model

INTRODUCTION

The Adriatic Sea is infamous for its storm surges [1-4]. This in particular relates to the northernmost Adriatic Sea, i.e., to Venice and the surrounding area where storm surges are known by a local name of Acqua Alta (It. high water) [1]. It is less known that high storm surges can flood and damage the eastern (Croatian) coast of the Adriatic Sea as well [5-7]. Given the expected sea level rise of ~60 cm by the end of 21st century [8] it is likely that events of extreme sea level will become more common and more intense and destructive. Within this paper we focus on analysing extreme sea level events recorded along the eastern (in particular Croatian) coast of the Adriatic Sea.

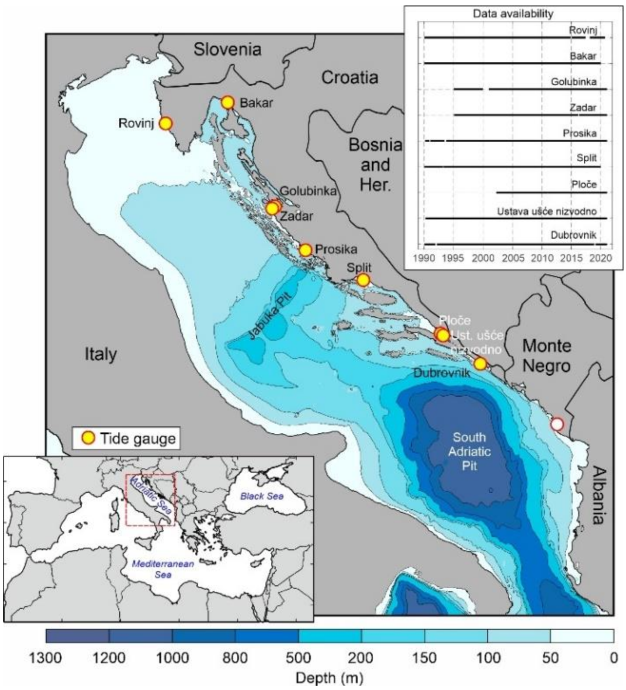

Figure 1. Area of study; tide gauges are marked with yellow circles; data availability is shown in the upper subplot

MATERIALS AND METHODS

Hourly sea level data from 9 tide gauge stations spread evenly along the eastern Adriatic coast (Figure 1) were quality controlled; all spurious peaks were removed. Tidal oscillations were removed from sea level time series using procedure described in [9]. Three strongest sea level extremes per year were extracted for each station, and Generalized Value Extremes (GEV) analysis [10] was applied to estimate values of extreme sea level heights for periods from 2 to 1000 years. It should be noted that values for return periods longer than 100 years are likely non-reliable; mostly due to sea level and atmospheric forcing climate shifts that occur over longer time scales.

SCHISM ocean model [11,12] was used to reproduce selected episodes of sea level extremes. Ocean model was forced at surface by mean sea level pressure and 10-m wind fields originating from the ALADIN meteorological model run by Croatian Meteorological and Hydrological Service. Model outputs were compared with observations, and spatial distributions of extreme sea levels obtained from model were used to estimate spatial distributions of extreme sea levels for return periods of 25 and 100 years.

RESULTS

Results of GEV analysis, for return periods of 2 to 1000 years, are shown in Figure 3a. The most extreme values are estimated for the northern Adriatic (stations Bakar and Rovinj), and the least extreme for the middle and southern Adriatic (Dubrovnik). Given that there are no changes of atmospheric forcing parameters within the next 80 years, one might expect to see 60 cm higher extreme events at all stations by 2100 (Figure 3b).

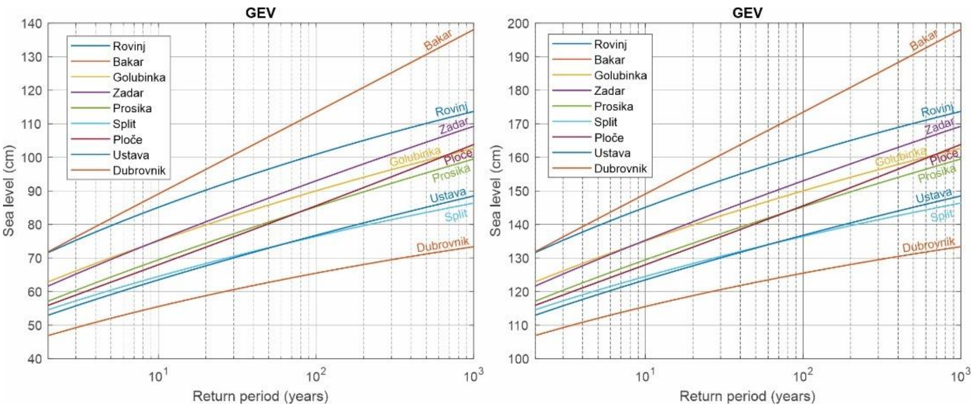

Figure 2. (*left*) return values of extreme sea level episodes; (*right*) return values of extreme sea level episodes under an assumption of climate change characterized by a uniform sea level rise of 60 cm

Observed and modelled sea level time series for the storm surge event of 29-30 October 2018 are shown in Figure 3. One can see that most extreme heights, both in term of value and timing, have been reproduced with a great skill at all stations. However, after the first storm surge maxima model appears to have a negative bias of ~10-20 cm – this is likely due to our choice of Otranto boundary conditions. In Figure 3 we also show maximum modelled sea level along the Adriatic coast during the same 29-30 October event. A characteristic south-to-north sea level height gradient is reproduced clearly revealing the most endangered parts of the Adriatic coast.

Finally, spatial distributions of extreme sea level heights for 25-years and 100-years return periods are shown in Figure 4. It is clear that, in addition to the northern Adriatic, much wider stretches of the eastern and the western Adriatic coast are endangered by extreme sea levels.

CONCLUSION

We have conducted a detail analysis of the Adriatic sea level extremes, including analysis of extreme values. For this aim, we were able to collect and analyse hourly data from 9 long-term tide gauge stations spread evenly along the Croatian coast of the eastern Adriatic coasts. Our results confirm that highest sea levels are expected over the northern Adriatic and that their height decreases towards the south – decrease is faster along the deep sea, and slower along both the eastern and the western Adriatic coast. Within the present climate, stretches of coast of the Adriatic Sea north from Split are endangered by relatively rare extreme floods (Figure 4). Nontheless, given the assumed sea level rise of ~60 cm by year 2100, one might expect that wider stretches of coast will becoma endangered, and that floods will be much stronger. In fact, what is a once in a hundred years flood under present conditions, could become a once per season flood by year 2100.

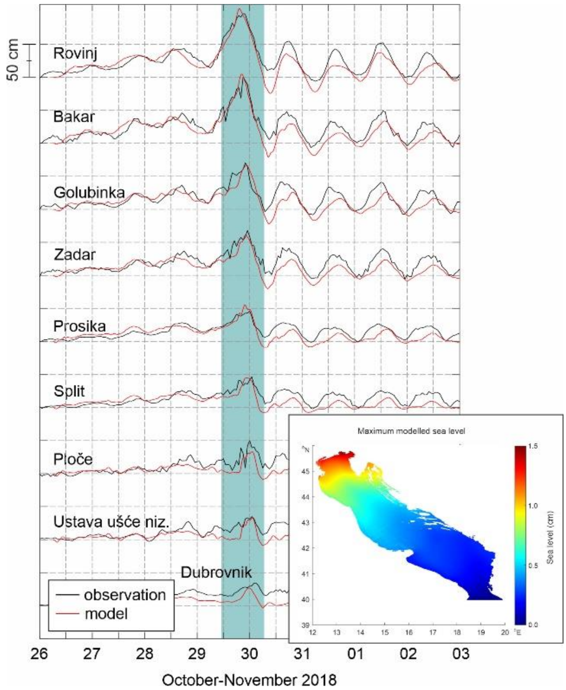

Figure 3. Observed (black) and modelled (red) hourly residual sea level time series during the storm surge event of 29-30 October 2018. Spatial distribution of maximum modelled sea levels is given in inset

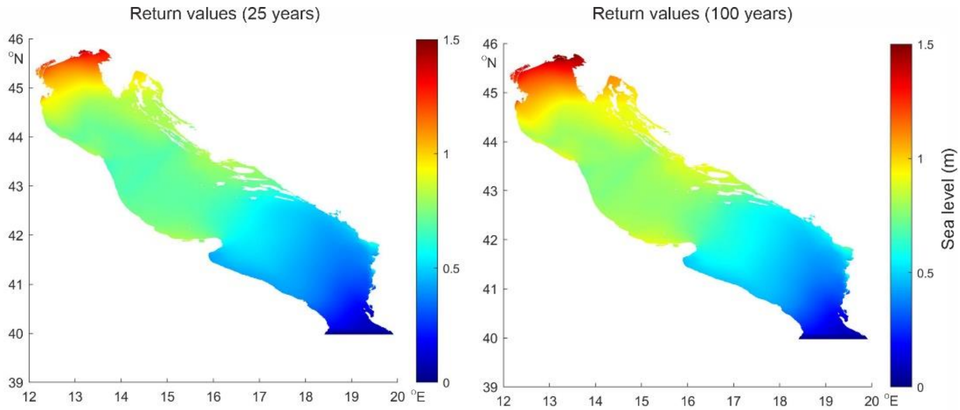

Figure 4. Extremes sea levels for: (*left*) 25-year return period; (*right*) 100-year return period

ACKNOWLEDGEMENTS

This work was supported by project VEPAR (Hrvatske Vode), and by projects ERC-StG 853045 SHExtreme grant and the Croatian Science Foundation by the Croatian Science Foundation project IP-2019-04-5875 StVar-Adri.

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Sustainability and Recycling of Carbon Fibers

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Abstract. Carbon fibre materials are use in many industries, such as aerospace, automotive, military, others. Familiar sources of waste from carbon fiber composites include: manufacturing cut-offs, end-of-life components, out-of-date composite materials, production tools and testing materials. The technology to recycle carbon fiber composites is known already several years. It is capable to create a product with mechanical properties very near to virgin material. Three main recycling methods: mechanical, thermal and chemical are used to avoid accumulation of carbon fibre wastes in the landfills. Pyrolysis and Solvolysis recycling processes are most often used. Carbon fiber recycling technologies are advancing and many suppliers are becoming interested in using recycled fibers. However, the industry of composite recycling is relatively young and is still in the early stages of developing markets for the materials it produces from recyclate. There are known several approaches for reuse the carbon fibers. Recycled carbon fibres can be used as a replacement of virgin materials or for development of fully new products for the market. Recycled discontinues fibres can be also used to increase the functionality of carbon fibers.

Keywords: carbon fiber, waste of carbon fiber, recycled carbon fiber, Solvolysis process, Pyrolysis process

INTRODUCTION

Carbon fiber is made in a process that is partly chemical and partly mechanical [1]. It starts by drawing long strands of fibers and then heating them to a very high temperature without allowing contact to oxygen to prevent the fibers from burning. The carbonization process takes place when the atoms inside of the fibers vibrate violently expelling most of the non-carbon atoms. Thus a fiber is created composed of long, tightly inter-locked chains of carbon atoms with only a few non-carbon atoms remaining. A typical sequences used to form carbon fibers from polyacrylonitrile involves spinning, stabilizing, carbonizing, treating the surface and sizing [1,2].

Carbon fiber can be thinner than a strand of human hair. It increases its strength when twisted together like yarn. Then it can be woven together to form cloth. If needed to take a permanent shape, carbon fiber can be laid over a mold and coated in resin or plastic to create a composite material [1].

Carbon fibers are very strong, has high in stiffness, tensile strength, a low weight to strength ratio, high in chemical resistance, has low thermal expansion and temperature tolerance to excessive heat. Because of mentioned valuable properties, the carbon fibers are used in many industries, such as aerospace, automotive, military and recreational applications [1]. The parts in planes and cars created using carbon fiber are strong but very light. It helps to fiber make the vehicles more fuel efficient. The overall lower weight requires less energy to move them, so less fuel is needed to get them to their destination [2].

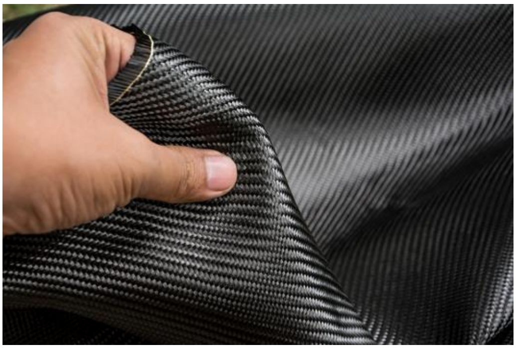

Figure 1: Textile material created from carbon fiber [2]

While carbon fiber parts are durable and have a high tensile strength, they do eventually wear out and need to be replaced. Additionally, producing carbon fiber parts does produce carbon fiber waste [2].

Despite of serious advantages of carbon fiber composite materials their extensive use in different industrial segments has caused a rapidly increasing amounts of waste and high issues globally. Familiar sources of waste from carbon fiber-reinforced composites include: manufacturing cut-offs, end-of-life components, out-of-date composite materials, production tools, as well as testing materials [2].

The conventional way to handle composite waste is their incineration or disposal in landfills. However, new European waste directives on landfills and incineration will pressure these traditional disposal routes for composite materials. To preserve the environment, legislation must be instigated, usually combined with economic instruments, such as taxes, to enforce recycling [2].

Types of recycling procedures

To comply with the legislation, manufacturers of composite products should have solutions for real recycling solutions. Several recycling methods have been tried and classified into three categories: mechanical, thermal and chemical recycling of composites [3].

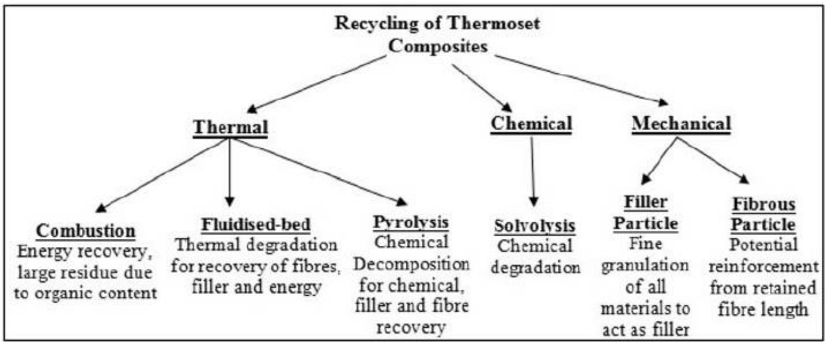

Figure 2: Recycling of Thermoset Composites [3]

MECHANICAL RECYCLING

Mechanical recycling involves the use of crushing, grinding, milling, and/or shredding techniques. All the constituents of the primary composite are minimized in size to particles with a length from 50 μm to 10 mm [2]. The resulting scrap pieces are mixtures of fiber, polymer, and filler and can be segregated by sieving into powdered products (rich in resin) and fibrous products (rich in fibers). Mechanical recycling can be used as a charge, or partial reinforcement in other new products. Mechanically recycled composites are suitable for manufacturing scrap composite materials [2,3].

THERMAL RECYCLING

Thermal recycling processes involve heat to break the scrap composite down and combust the resin matrix, thereby recovering the carbon fibers. The most often used thermal recycling techniques are pyrolysis and fluidized bed procedure. A fluidized bed operates by balancing the downward gravity forces of the weight of the particles in the charge with the upward details created by the high gas flow. This process implies thermal decomposition of the polymer matrix followed by the release and collection of discrete carbon fibers [2]. The operating temperature of the fluidized bed is chosen to cause the polymer to decompose, leaving clean fibers. The temperature must not be too high to avoid the degradation of the carbon fiber substantially [3].

Pyrolysis is a thermal decomposition method for polymers at temperatures from 350 to 700 ◦C in the absence of oxygen and an inert atmosphere, e.g., N2. It allows the recovery of long, high modules fibers, and because of that, it is one of the most widespread recycling processes. Many factors affect the pyrolysis procedure: the composition of the waste, reactor type, and process parameters (heating rate, pressure, residence time, temperature). The troubles with pyrolysis are that the resin is wasted and it requires a lot of energy to perform the recycling process [3].

CHEMICAL RECYCLING

Two principal demands stimulate the progress of chemical recycling technologies, the demand to safely and efficiently process materials challenging to treat with mechanical recycling, and the request to produce high-quality recycled materials [3].

Solvolysis is a chemical treatment using a solvent to degrade the resin. The solvolysis process can recover both the clean fibers and fillers and depolymerized matrix in the form of monomers or petrochemical feedstock. However, it has a low contamination tolerance (e.g., no metals or painting pieces). Solvolysis can offer many possibilities based on catalysts, pressure, temperature, and a wide range of solvents. Solvolysis can be classified according to higher pressure and temperature (temperature > 200 ◦C) and lower pressure and temperature (temperature < 200 ◦C), but generally, lower temperatures are requested to degrade the polymer [3,4].

In chemical recycling, resin degradation is reached using solvents (solvolysis) or water (hydrolysis). The employment of dangerous and concentrated chemicals results in environmental impact, so water or alcohol, which are relatively environmentally friendly, usually replace harmful chemical. However, it is essential to emphasize that water can be effectively used only in sub- or supercritical conditions [4].

Solvolysis is a prime candidate for inline carbon fiber recycling, and developing resins with recycling capabilities in mind leaves opportunity for recycling the resin as well. Some companies are developing resin meant to be reused, so the monomer solution of the resin can actually dissolve cured resin back into a liquid, recurable state. While the integrity of reclaimed carbon fiber isn't compromised, recycled fibers tend to be fluffy and less dense than virgin fibers, so it's difficult to "reweave" them into the carbon fiber sheets [4].

Both pyrolysis and solvolysis started as batch processes, where the process is done after production in small quantities. Recycling in batch processes is better than not recycling at all; however, batch processes are typically more costly than inline processes. This is recycling that can be done within the regular production process, and it's time saving and cost-effective [4].

Figure 3: Carbon fiber waste [4]

Applications of recycled carbon fiber

There are known many potential applications for recycled carbon fibers. They can be used as a structural reinforcement in different composites with a wide range of mechanical properties. Broadly there are several approaches for reuse the carbon fibers [5]:

- replacement of original/virgin materials creating composites with similar mechanical performances but reduced costs,
- development of fully new products for the market - new forms of materials or replacements for glass or virgin carbon fibers.
- Increasing the functionality of carbon fibers - discontinuous fibers may be used in different applications to enhance drape properties and with it to ease the forming of composites in manual or automated way. Exploiting the conductivity of the recycled fibers in applications where reduced mechanical strength is of secondary importance. Manufacturing low fiber areal mass materials, in which discontinuous recycled fiber may be preferred.

Currently the outlook is unclear and many routes for market development are under consideration [5]. Milled fiber is an obvious end use application but it has low mechanical properties as a reinforcement and the market is not significant when compared to the volumes of fiber that may become available. The key driving force for future of recycled carbon fiber-based materials will be the market demand for them. Penetration into the automotive market is seen as a significant enabler for carbon fiber recycling in general and the costs proposed by automotive vehicle manufacturers provide a good target for recovered carbon fiber-based materials [5,6].

The challenge is to manufacture materials from the recovered fiber without significantly increasing the cost. Aluminum is a good mechanical property target as the automotive industry already performs high levels of research into weight saving through the use of this material. These two cost and performance requirements therefore define the area of applicability for recovered carbon fiber products [5].

Composite structural performance depends largely on the mechanical properties and volume content of the reinforcement. How these structural properties can be attained will define the market that the composite will be targeted toward. At an initial level, the mechanical property of virgin and recycled carbon fibers don't appear very different: both of them have insignificant difference in tensile stiffness and interfacial shear strength; in the case of tensile strength, it depends on the chosen recycling process. The commercially available pyrolysis processes can offer fiber with a high degree of strength retention. However, the application depends on the physical form of the carbon fibres. The virgin carbon fiber is continuous and can readily be weaved into the trademark woven pattern that marks it out as belonging to high grade applications, in superlight bicycles, Formula One and aerospace structure. Whereas, the recycled carbon fiber is short and discontinuous, without sizing and in a fluffy form. What they have in common is that both are valuable materials that can be processed specifically for specific applications. For more economical recycled carbon fibre, the markets which can accept lower quality fibres are target [6].

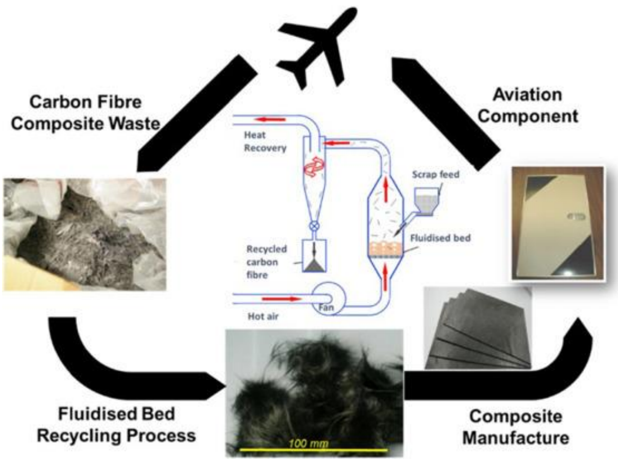

Figure 4: Carbon recycling life cycle [6]

PRODUCTION OF THE RECYCLED CARBON FIBER AND IT BENEFITS

The case for recycled carbon fiber (rCF) is a complicated one. The industry is built on the hope of solving problems - namely, the desire to keep carbon fiber waste out of landfills and to fill a potential gap between carbon fiber supply and demand. It is commonly estimated that around 30% of carbon fiber produced ends up as waste. Meanwhile, as valuable material ends up in landfills, most analysts agree that annual demand for the material could increase current annual production capacity within the next few years. The average estimated global carbon fiber demand is around 65,000-85,000 metric tons per year, with a global nameplate capacity (which is more than actual capacity) of around 150,000 metric tons. And while commercial suppliers of recycled carbon fiber (rCF) point to reclaimed and repurposed material as a potential solution to this supply and demand gap, the rCF industry has its own challenges [7].

The technology to recycle carbon fiber composites has existed for several years and is capable of yielding a product with mechanical properties very near that of virgin material. However, the industry of composites recycling is relatively young and is still in the early stages of developing markets for the materials it produces from recyclate. As the quality of fiber being produced by recyclers increases, questions about cost and availability have come to the forefront [7]. Perhaps the largest challenge for the composites recycling industry is the concern over supply chain security. Commercial suppliers often look to the aerospace industry as a source of production scrap and end-of-life material to be used as recyclate, yet while the amount of waste created by the aerospace industry is large in terms of what is going to the landfill, many OEMs and fabricators have been reluctant to rely on it as a steady supply source for a high-volume product line [7,8].

The argument for using rCF goes beyond sustainability. Reduced cost is also a benefit. For example, rCF manufactured by company ELG Carbon Fibre costs around 40% less than industrial grade virgin carbon fiber. Other commercial suppliers claim their material is anywhere from 20% to 40% less expensive than virgin carbon fiber. Plus, for many applications there is a need for discontinuous fiber formats — which suggests an opportunity where rCF might offer a more sustainable and economical alternative to virgin material. Plus, the quality of rCF being produced has been shown, in some cases, to be on equal to virgin fiber. Company ELG Carbon Fiber, which reclaims carbon fibers using pyrolysis, says its fiber typically retains at least 90% of its tensile strength with no change in modulus. Company Vartega uses a chemical recycling process and claims that its fiber exhibits the same mechanical properties as virgin carbon fiber. Company Shocker Composites uses an inline solvolysis process to reclaim the fiber and claims high quality with no apparent damage to fibers [8].

Given recent improvements over the past several years in rCF processing and fiber quality, commercial suppliers have fled to shift their focus from the down cycling of rCF into lower-performance products and more toward finding appropriate applications that benefit from the material's properties [8].

CONCLUSION

Recycling of waste carbon materials is a complex process. Recycling is necessary because of the pollution and ecology of the planet. There are large number of landfills which keeps carbon fibers wastes, so it is necessary to clear them. The properties of recycled carbon fibers are slightly different from the virgin fibers, however the application of recycled carbon fibers is increasing. All existing recycling methods can be used to recycle carbon itself. The biggest problem is that recycling actually works by burning or chemically cleaning the resin from the fibers. Such a procedure can damage the fibers and change their characteristics. Carbon fiber recycling technology is advancing and many suppliers are becoming interested in using recycled fibers. The automotive and aerospace industries are the main and largest users of carbon. The amount of waste generated by these two industries is large, but with the use of recycled fibers it is possible to dispose of this type of waste [8].

Developments in recycling carbon fiber revolve around reducing the time and energy spent on the process. Most commonly, carbon fiber is reclaimed from end-of-life parts using Pyrolysis or Solvolysis processes [8].

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
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The Mediterranean Meteotsunamis of 24 May 2021

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Abstract. On May 24th, 2021, two locations in the Mediterranean Sea, small island of Ist in the Adriatic Sea and port of Bonifacio located on the southern coast of Corsica, experienced strong short-period (T < 60 min) oscillations of sea level height. Eye-witness accounts, as well as video records, depict a tsunami-like event that caused oscillations in the sea level height. Both events caused flooding of the coastal area and damaged infrastructure. Since there hadn't been any seismic activity prior to these events they were characterised as likely meteotsunami events. Both events were analysed in detail using available sea level and air pressure data, as well as ERA5 reanalysis data. The minute sea level data were downloaded from the Intergovernmental Oceanographic Commission (IOC) (2022): Sea level station monitoring facility and from national agencies databases. Furthermore, air pressure data were obtained from national and amateur meteorological networks. On top of that ERA5 reanalysis was used to analyse the synoptic situations during the events. Sharp air pressure oscillations were found at some stations that could be the reason for the generation of meteotsunamis. The analysis showed that both events occurred during typical meteotsunamigenic Mediterranean synoptic conditions.

Keywords: Meteotsunami, Mediterranean Sea, Atmospheric gravity waves, Seiches

INTRODUCTION

A rare natural phenomenon took place in Bonifacio (France) and Ist island (Croatia) on 24 May 2021. The event was characterized by extreme sea level oscillations. According to eyewitnesses, the seawater receded first, leaving some of the boats stranded (Fig. 1). Few minutes later, the sea level rose around 1 meter above average, causing flooding and material damage [1-3].

Such event could be categorized as a meteotsunami, which had occurred on Ist island before in 1984 and 2007 [4,5]. Meteotsunamis are long ocean waves that originate from short period (T < ~2 h) atmospheric disturbances such as atmospheric gravity waves, squalls, pressure jumps and frontal passages [6]. These long ocean waves are amplified by Proudman, Greenspan or shelf resonance. However, the resonance effects are usually not powerful enough to generate high waves far from coast, but as waves reach shore, wave transformations including harbour resonance, wave superposition, shoaling, refraction and reflection can occur, further amplifying ocean waves [7,8].

Certain areas of the world, for instance Balearic Islands or areas in the Adriatic Sea, are prone to meteotsunamis due to a combination of atmospheric forcing factors, bathymetry and coastal topography. At these regions specific local names for the phenomena exist, “rissaga” in the Balearic Islands, and “šćiga” in the Adriatic Sea [4,6,9].

Meteotsunamis can cause severe damage to the coastal infrastructure especially in low-tidal regions at which coastal infrastructure is not constructed to withstand such strong sea-level oscillations. Furthermore, they are a known generation mechanism for rip currents which are extremely dangerous and can lead to drowning. Therefore, meteotsunamis pose a threat to human life, causing injuries and even death [9, 10].

Figure 1. Left: stranded boats in Ist; Right: flooding in Bonifacio [2,3].

DATA

For conducting our analysis, sea level data, as well as pressure data, was gathered from various stations close to Bonifacio and Ist (there are no measuring stations at the exact locations). Sea level data was downloaded from IOC website (http://www.iocsealevelmonitoring.org/) (all tide gauges used: Genova, Livorno, Ancona, San Benedetto del Tronto and Stari Grad) and pressure data was download from https://archive.sensor.community/ for stations close to Bonifacio i.e., Genova and Collesalvetti. Pressure data for the Ist event was acquired from Institute of Oceanography and Fisheries Split (stations used: Ancona, Ražanj and Vela Luka).

Furthermore, ERA5 eanalysis fields of temperature (850 hPa) and wind speed (500 hPa) were downloaded. Filtering of original sea level series with a cut off period at 3 hours (T = 3h) was done to obtain high-frequency sea level series.

RESULTS AND DISCUSSION

In (Fig. 2.) original sea level series (blue line) and high-pass series (red line) are presented for two stations near Bonifacio (Genova and Livorno) and for three stations near Ist (Ancona, San Benedetto del Tronto and Stari Grad). Maxima in the high-frequency series denotes the time of the meteotsunami event. It is seen that at Bonifacio, event occurred during early morning hours of 24 May, while at Ist, it occurred in the late afternoon of the same day. This indicates that meteotsunamigenic synoptic patterns propagated in general direction from the southwest to the northeast.

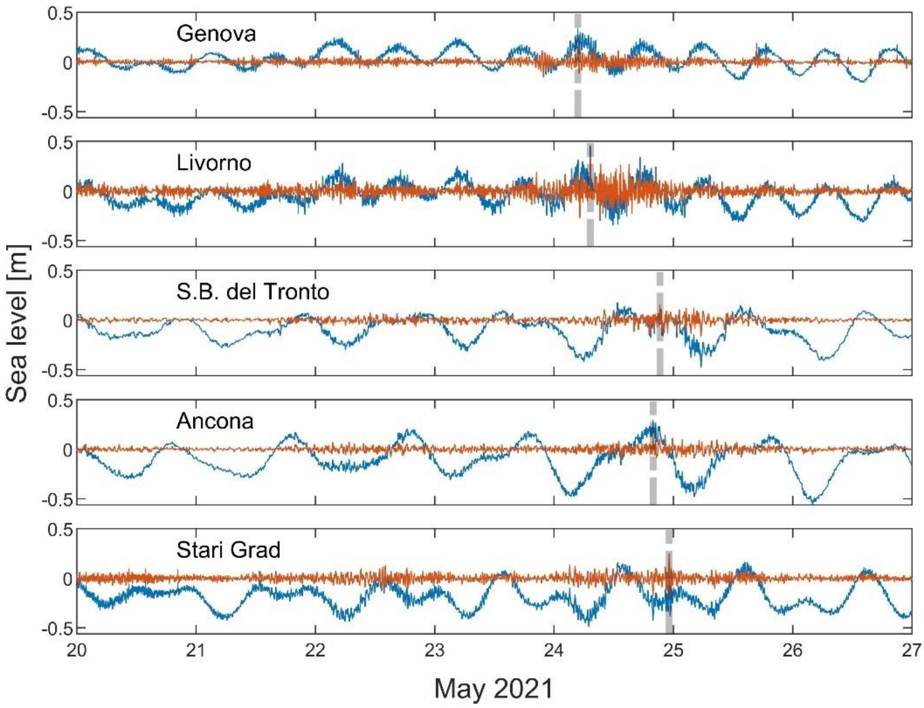

Figure 2. Original (blue line) and high-pass (red line) sea level time series measured at five tide gauge stations. Two upper stations are representative for the Bonifacio event (Genova and Livorno) and three lower for the Ist event (Ancona, San Benedetto del Tronto and Stari Grad).

Inflow of warm air from Africa at 850 hPa (~1500 m) and strong winds at altitudes of 500 hPa (~5000 m) are the main indicators of atmospheric conditions favourable for a metetsunami event [12, 13]. Synoptic conditions for both events are shown in (Fig. 3.).

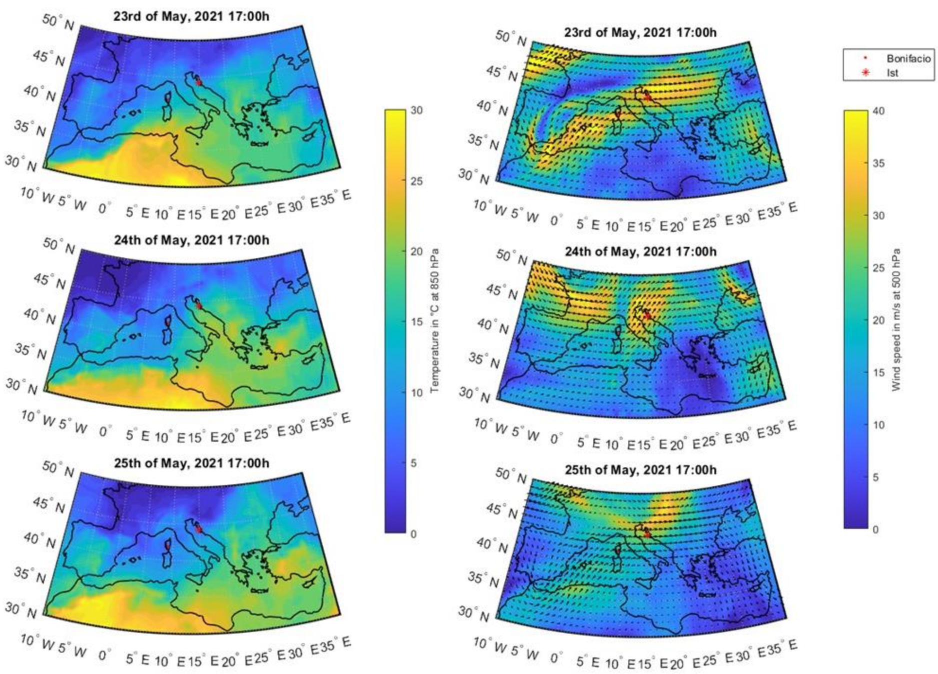

Figure 3. ERA5 reanalysis data for 23, 24 and 25 May 2021 for the Mediterranean Sea. Left plot depicts temperature at 850 hPa while the right depicts winds speed at 500 hPa.

CONCLUSION

Meteotsunami events of 24 May 2021 in Bonifacio and Ist were studied by analysing sea level, pressure and ERA5 reanalysis data. It was found that for both events, there were favourable meteotsunamigenic Mediterranean synoptic conditions. Fortunately, these events caused only minor damage. Nonetheless, meteotsunamis are known to cause much larger damage. Therefore, it is of great importance that this event, and all similar events, are studied and the results of the studies incorporated in future predictions of such events.

ACKNOWLEDGEMENTS

This work was supported by ERC-StG 853045 SHExtreme grant and by the Croatian Science Foundation by the Croatian Science Foundation project IP-2019-04-5875 StVar-Adri.

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The Effects of Earthquakes on the Environment, Monitoring and Prediction – Experience in Republic of North Macedonia

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Abstract. Earthquake environmental effects, monitoring seismic activity and earthquake prediction for the territory of Republic of North Macedonia begins on July 1, 1957 with instrumental observations and research of the seismicity of the epicenter areas. Earthquake occurrence is the result of regional general extension regime due to the collision between African, Arabian and European tectonic plates. Most of the strong earthquakes have normal faulting combined with a strike-slip movements, observed as well on the surface ruptures during their occurrence. Purposes of earthquake's instrumental monitoring - the installation of network for recording earthquakes, is very important for the theoretical and fundamental research in the field of earthquakes. The results of data are also used to determine hazard, vulnerability of structures and risk. With earthquake prediction, seismologists focus on developing earthquake forecasts, that is, quantifying the likelihood of an event occurring.

Keywords: earthquake, seismicity, monitoring, prediction

INTRODUCTION

The present activities in the field of seismology in Republic of North Macedonia are carried out by the Seismological Observatory at the Faculty of Natural Sciences and Mathematics, University "Ss. Cyril and Methodius" - Skopje, founded in 1957. By using the network of analog and digital seismological stations, this Observatory systematically monitors the seismic activity in the territory of Republic of North Macedonia and the bordering areas (40.7-42.4 N, 20.3-23.2 E) and also records the regional and teleseismic earthquakes.

The seismicity is studied on the base of instrumental seismological and microseismical data available at the Seismological Observatory and covers a period of about 1500 years. The territory of the Republic of North Macedonia is in the central and southeastern parts of the Balkan Peninsula. As known, this peninsula is in the internal part of the Euro-Asian tectonic plate, and it has a complex geological structure, which is characterized with an intensive dynamics and geophysical fields anomalies.

An earthquake is the result of endogenous geodynamic force in the Earth's interior, which causes trembling, rolling and vibration of the ground triggered by the sudden release of energy that is stored below the surface of the Earth. The earth shaking does not only cause damage to buildings and other structures but also affects the surrounding environment and our lifestyle significantly. An earthquake can trigger many sudden changes in the environment which can be classified as primary (surface faulting) and secondary effects (displaced rocks, tsunami, ground cracks, liquefactions, landslides).

Predicting earthquakes is not possible today. Earthquake prediction specifies that an earthquake of a specific magnitude will occur in a defined region during a particular period. But we can define many earthquake parameters: the date and time, the location, the magnitude, focal mechanism, moment tensor, active faults, predict the recurrence period equal to 50, 100, 200 and 500 years etc.

OBSERVED SEISMICITY IN THE PERIOD 1901–2021

Three main neotectonics regions spread in the territory of the Republic of North Macedonia and neighboring regions, namely, Vardar zone, West Macedonia and East Macedonia [1], which developed within major, regional tectonic units (Fig.1). These three regions are permanently uplifting with different intensities. The intensity of uplifting of West Macedonia is the greatest, while that of the Vardar zone is the smallest. However, the intensities of uplifting of the three regions are of order of few millimeters per a year.

Those three regions show differences in the seismic activity too, which is the reason to assume them as separate seismic zones, named with the same names. According to the research by the Seismological Observatory, except some collapse earthquakes, all observed historical and contemporary earthquakes in these zones are tectonic. The seismic source for the greatest number of earthquakes is a dynamical faulting (a dynamical relative sliding of walls of a fault). The strongest earthquakes with $M_L \geq 6.0$ occur at the places of crossing of the NW–SE oriented and approximately E–W oriented faults, Fig. 1. The hypocenters of the earthquakes are shallow, mostly located within the Earth's crust, which lower boundary in the Vardar seismic zone is at a depth of 32 km to 35 km, and in the other two zones down to 45 km and deeper. The range of the Richter local magnitudes of the earthquakes is from 0 to 7.8, and of the maximum observed intensities is from II to X degrees of the European Macroseismic Scale from 1998 (EMS-1998). Thus, the earthquake with the highest observed Richter local magnitude of the Balkan Peninsula, valued 7.8, occurred in the epicentral area Pehcevo – Kresna, in 1904 [2].

The epicentral map of the earthquakes in the territory of Macedonia and neighboring regions for the period 1901–2021, together with the neotectonics faults, the borders of the epicentral areas and the stations of the present seismological telemetric network, are presented on Fig.1 [3].

It can be seen that, nearly all the parts of the territory of North Macedonia in the studied period were seismically active, were only a few epicentral area Krushevo, Bogomila, Kumanovo, Veles, Kriva Palanka – Zletovo, and Pelagonia Anticlinorium have weak seismic activity. As known [1], the reason for weak seismic activity of this anticlinorium is that it is a consolidated block with only oscillatory movement since the Precambrian time and still keeps the structure consisted of relicts of the Earth’s Precambrian crust. This structure is quite different in comparison with the neighboring areas.

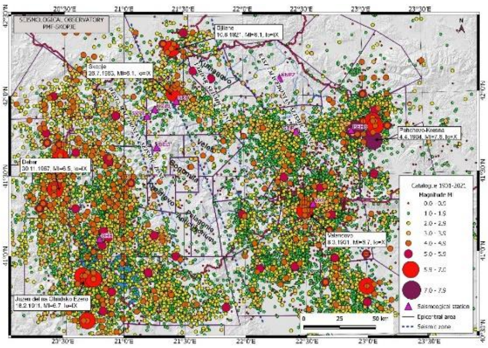

Figure 1. Epicentral and seismotectonic map of the strongest earthquakes with $M_L \geq 6.0$ for the period 1901–2021 with labeled main neotectonics regions

The distribution of earthquakes on the territory of North Macedonia and the neighboring region, in the period 1901–2021, was presented with nearly 30392 located earthquakes, Fig. 2.

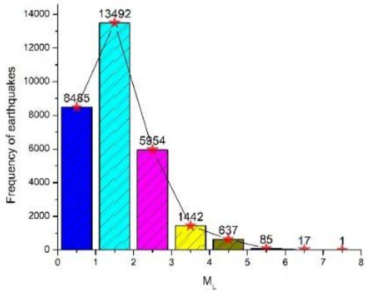

Figure 2. Distribution of earthquakes for the period 1901-2021 at magnitude interval 1

EARTHQUAKE ENVIRONMENTAL EFFECTS

Earthquakes can have disastrous effects on humans and on the environment. Effects of earthquakes can be categorized as primary and secondary. Primary effects occur as a direct result of the earthquake manifested at earth's surface, whereas secondary effects are incited by the primary effects. The primary effects depend on the size of the earthquake and the stress environment, and they can consist of surface faulting, until the earthquake generates tectonic deformation. Secondary effects are incited by the shaking of the ground, like liquefaction, landslide, ground cracking, displaced rocks, etc. [4].

According to the observed seismicity in the considered period and region, the strongest earthquakes whose magnitude is $M_L \geq 6.0$, with many effects on humans and on the environment has occurred in the Debar, Skopje, Valandovo, Pehcevo-Kresna, Southern part of Lake Ohrid and Gjilane epicentral areas. Some of the primary and secondary effects of earthquakes, are shown on Fig. 3.

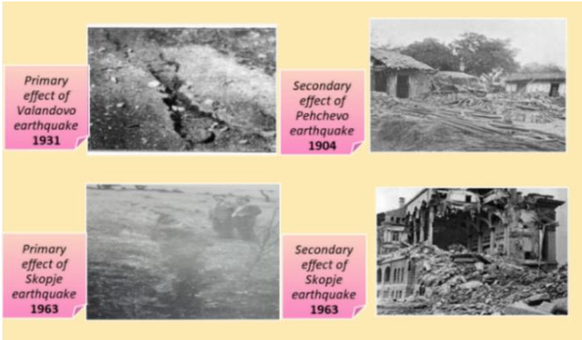

Figure 3. Changes in the environment caused by an earthquakes (up left – photo archive of Seismological Observatory; down left – photo documentation Mihailovic 1936; up right - http://www.fakulteti.mk/news/1404-04/110_godini_od_katastrofalniot_pehchevski_zemjotres_eden_od_najsilnite_vo_evropa.aspx; down right – photo archive of IZIIS)

EARTHQUAKE PREDICTION

The research of the seismic hazard, i.e., of the long-term expected seismicity regarding the maximum magnitude or maximum intensity, are regularly performed in the Seismological Observatory in Skopje. In this research, the Gutenberg–Richter law for earthquakes frequency with respect to magnitude is used, together with the empirical relations between the magnitude and the maximum intensity for the territory of North Macedonia and neighboring regions, as showed in Equation (1), (Gutenberg & Richter, 1954):

$$log\ N(M_{min}) = a - bM_{min} \qquad (1)$$

where N is the cumulative number of earthquakes with magnitude larger than M_{min}, ″a″ and ″b″ are coefficients. The coefficient ″a″ implied seismic activity of the region which depends on the size area, observation period and largest seismic magnitude. Higher values, correspond to a higher seismic activity [5]. Coefficient ″b″ is a characteristic related to the local seismogenic conditions of the region, based on which it is possible to make evaluation of the time return period of the earthquakes in future with respect to the magnitude. The lower value ″b″ represents the higher number of earthquakes, that occurred during the considered time interval. The ″b″ value can be obtained with several methods. Two of the most common methods are using the least squared regression and maximum likelihood estimate. The both methods are based on fitting processes (the first method obtained the ″b″ value by performing least square linear regression of logN versus M, and the second method gives a less biased and less uncertain estimate than the weighted least square method [6]. The input data are the data for all observed historic and contemporary seismicity of this territory. The output data are the maximum magnitudes or maximum intensities which are expected in the particular areas of this territory within certain time period, the so-called return period.

CONCLUSION

Seismological Observatory in Skopje with telemetric network of digital seismological stations systematically monitors the seismic activity in the territory of North Macedonia and the bordering areas and records the regional and teleseismic earthquakes. With the latest instrumentation, real time telemetric network data exchange and used software, earthquakes with local magnitudes down to zero can be recorded and analyzed. The predominant hypocentral depth is in the interval 0–20 km. These data give opportunity to obtaining maps of epicenters, maximum observed intensities, and magnitudes of happened earthquakes during long period of time and return period of maximum expected earthquake. These maps are used in earthquake engineering, in building earthquake resistant buildings respectively in earthquake protection. The economical effect of earthquake prediction and protection is obvious. The installation of networks for recording of earthquakes is equally important for the theoretical and fundamental research in the field of seismology and for application and practical research in the earthquake engineering.

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Predicton the Use of Water for the Needs of Industry in the Republic of Serbia

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Abstract. Industrial wastewater is generated in factories and industrial plants after the use of water in the production process. It is necessary to emphasize how important water is for the planet and that it should be taken into account. Therefore, the emphasis is on water consumption and an analysis of data in the Python programming language has been done, which will help us predict how the growth of water pollution in the field of industry in Serbia will develop in the future. Python 3 within the Jupiter notebook was for data analysis. For this reason, a regression analysis of data based on data on the amount of water consumed in industry was performed in this paper. Based on regression analysis, it is predicted that the water will be used in the future in 2023 and it will be 4667.866666666665 mil per cubic meter.

Keywords: water use, industry, linear regression, analysis, prediction, Python, Jupyter

INTRODUCTION

Python is an open-source general-purpose programming language, a web development ecosystem, and a well-designed platform with extensive [1]. Regression analysis was done in the notebook using the Python code. Since a linear regression was performed, which will be used to determine the prediction, it is necessary to emphasize that the linear regression is to examine does a set of predictor variables do a good job in predicting an outcome variable and which variables in particular are significant predictors of the outcome variable, and in what way do they–indicated by the magnitude and sign of the beta estimates–impact the outcome variable. These regression estimates are used to explain the relationship between one dependent variable and one or more independent variables. A linear regression line has an equation of the form $Y = a + bX$, where X is the explanatory variable and Y is the dependent variable. The slope of the line is b, and a is the intercept[2]. For that reason, it was interesting for the author to present data on the amount of water consumed in the industry in this paper and to make a forecast and notes on how much water should be used for the needs of the industry in the future.

THEORETICAL CONSIDERATION

The use of libraries allows for more compact coding, where there is more time to focus on data analysis. Python's most popular libraries are open-source. The some of following libraries are: numpy, scipy, pandas, matplotlib [3,4]. Numpy [5] is a numerical processing library that supports multi-dimensional arrays. Scipy [6] a scientific processing library providing advanced tools for data analysis, including regression, ODE solvers and integrators, linear algebra and statistical functions. Pandas [7,8] is a data and table manipulation library that offers similar functionality to spreadsheets such as Excel, and matplotlib [9] is a plotting library with tools to display data in a variety of ways.

Linear Regression is a statistical method for plotting the line and is used for predictive analysis [10,11]. Regression analyzes are usually used for forecasting and prediction, in which their application has major overlaps with the area of machine learning[12]. In predictive statistic and machine learning, an atributes with high correlation coefficient often have more influence on prediction variable. The correlation coefficient, as its name implies, is a statistical measure that describes the relationship between variables. The correlation coefficient of two attributes is always range between 1 (Positive relationship) to -1 (Negative relationship) whereas 0 implies no correlation at all [13]. Predictive analysis can estimate future results based on an archive of past data using analysis techniques. It includes various statistical techniques from predictive modeling, machine learning to data mining that analyzes archived data to predict unknown events in the future.

METHOD

The data were taken by the author of the paper from the official website of the Republic Institute of the Republic of Serbia. Only data on the use of water for the needs of industry were taken, and on the basis of these values, a regression analysis was performed in Jupyter notebook, which is supported by the Python programming language (Republic of Serbia, Republic Statistical Office, 2020). Data on the amount of water used for the needs of industry in the period from 2015 to 2020 were collected and shown in the table below [14].

Tabele 1. Water utilization in industry

Years	2015.	2016.	2017.	2018.	2019.	2020.
Water use in industry (mil per cubic meter)	3324	4127	4047	4175	4232	3976

RESULT

Data on the amount of water uses for the needs of industry in the period from 2015 to 2020 are also graphically presented using a bar graph. Figures 1 and 2 present the data using plot chart and using scatter plot.

```
In [2]: plt.plot(years, water)
        plt.show()
        plt.close()
```

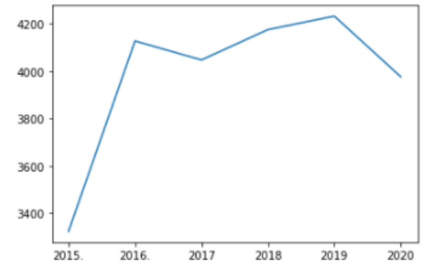

Figure 1. Graphically presentend data using a plot chart

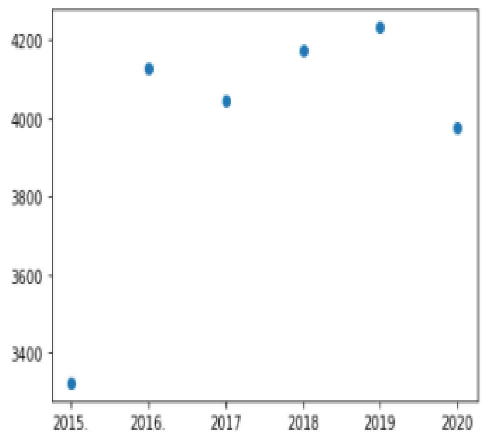

Figure 2. Graphically presented data using scatter chart

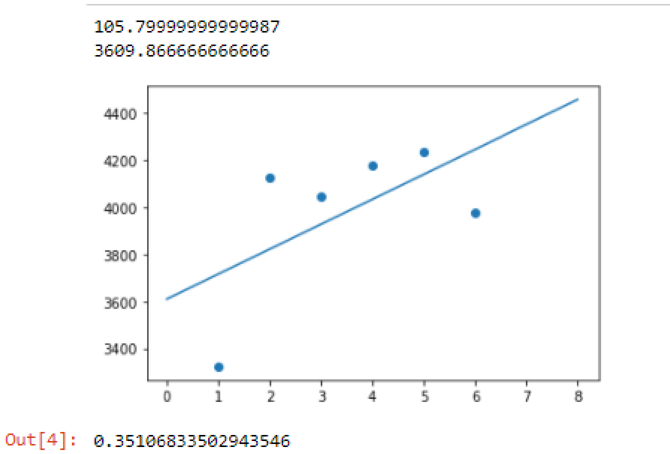

Figure 3. Calculation of the correlation coefficient

The coefficient of determination shows the accuracy of the model. The closer its value is to number 1, the more accurate the linear regression model. To determine this coefficient, a library of sclearn.metrics is needed. The correlation coefficient is 0,351068. The correlation coefficient is shown in Figure number 3. In addition, it was determined by linear regression how the number will move in the future. Water utilization for the needs of industry in 2023 will be 4667.866666666665 mil per cubic meter. This can be seen in Figure 4.

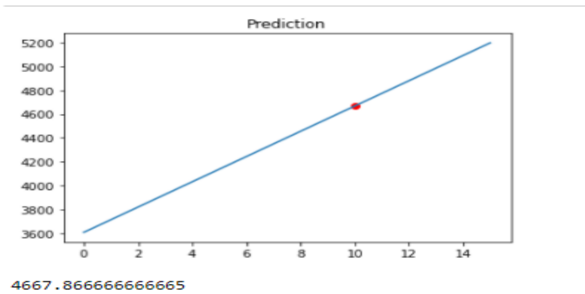

Figure 4. Prediction by linear regression for 2023

CONCLUSION

In this paper, the focus was on using Jupiter Notebook with the help of Python, which has libraries that support graphical data representation as well as various statistics. The paper calculates a simple linear regression based on which it is predicted to what extent water will be used in the future in 2023. Based on that, it can be seen that this number would be 4667.866666666665. In addition, the correlation coefficient was determined, which contributes to better data analysis because it determines the accuracy of the model and in this example is 0.35106833502943546. In the future, it could explore what other methods for data analysis are suitable, especially when it comes to forecasting, given that there are much more complex models that would be more efficient.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
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Impact of Hydrogen-Sulfide (H_2S) on the Environment, the Method of Its Removal and the Types of Natural Gas, which Relate to the Change of Aggregate State in Order to Protect the Environment During Use, Transport, and Storage

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Abstract. For companies engaged in the exploitation, production, refining and transport of oil and gas, in addition to caring for the quality of their products and goods, key factors in establishing and maintaining a successful business are environmental protection, health protection, and safety. The potential impact of the process of exploitation and production of gas on environmental pollution, work and health of the employee is multiple, both in terms of scope and number of problems. This section presents an overview of the potential negative effects on man and the environment arising from the exploitation, production, processing and transport of natural gas. Natural gas or natural gas is a natural fossil fuel that is in a gaseous state in nature. According to its composition, natural gas is a mixture of combustible and non-combustible gases. Compared to other fossil fuels, natural gas is an environmentally friendly fuel. However, it cannot be said that it is not harmful, there are various situations and methods due to which natural gas emits harmful by-products to the environment and humans. Whether dissolved in oil or on its own, natural gas may contain hydrogen sulfide (H_2S), a hazardous substance that must be removed before further processing. Hydrogen sulfide (H_2S) is a very toxic gas that is usually a product of sulfur conversion or products of waste gas combustion on a flare or occurs in the technological processes of crude oil processing. Liquefied natural gas is a natural gas that has been converted from a gaseous state to a liquid aggregate state by a special technological process. Compressed natural gas is compressed natural gas, ie one of the forms in which natural gas is converted for easier transport and storage. The most important thing is that every company that deals with the exploitation, production, processing and transport of natural gas, has a professional team that, with knowledge and experience, will save the environment and every employee from potential negative impacts of by-products.

Keywords: environmental protection, natural gas, hydrogen sulfide, liquefied natural gas, compressed natural gas

INTRODUCTION

For companies engaged in the exploitation, production, refining and transport of oil and gas, in addition to caring for the quality of their products and goods, key factors in establishing and maintaining a successful business are environmental protection, health protection, and safety.

There are two main goals in managing activities related to the environment, health and safety:

1. Reduction of negative effects that may have a risky effect on the environment and normal operating conditions,
2. To prevent any type of accident or incident that could lead to environmental pollution and unwanted situations in the workplace [1].

Environmental protection, as well as protection at work, includes a set of measures and activities aimed at creating conditions that ensure safety at work and preservation of the environment, to prevent and eliminate hazards and harm that can cause injuries at work, illnesses and damage to the health of employees or pollution of the environment. The field of safety and environmental protection is multidisciplinary, containing legal, financial, technical, health, ethical and other aspects.

MATERIAL AND METHODS

In our review paper we initiated Google Scholar database search and we searched available literature.

The potential impact of the process of exploitation and production of gas on environmental pollution, work and health of the employee is multiple, both in terms of scope and number of problems. These problems may be specific to one technology or may be present in a large number of technologies, but differ in the degree of related impacts. This section presents an overview of the potential negative effects on man and the environment arising from the exploitation, production, processing and transport of natural gas.

Natural gas

The first recorded natural gas well was drilled by William Hart, who is considered to be America's father of Natural Gas, in 1821 in Fredonia, United States [4].

Natural gas is a natural fossil fuel that is in a gaseous state in nature [7].

Natural gas occurs in four types of deposits: the first type is natural gas dissolved in crude oil (capture - dissolved); the second type is in contact - in the same reservoir (free) with crude oil (eg in the form of a gas cap); the third type is alone in the gas reservoir - dry free (non-captive) gas; and a fourth type of gas dissolved in stratified water. In case natural gas is in the deposits of crude oil, it is necessary to remove it from the oil in the oil fields before sending it for further processing [1].

In its pure state, natural gas is colorless, shapeless, and odorless. It is a combustible gas, and it gives off a significant amount of energy when burned. It is considered to be an environmentally friendly clean fuel when compared with other fossil fuels (coal and crude oil). The combustion of fossil fuels other than natural gas results in the emission of enormous amounts of compounds and particulates that have negative impacts on human health. However, during natural gas combustion, the emissions of sulfur dioxide are negligible and emissions of nitrous oxide and carbon dioxide are lower, which consequently helps to reduce problems associated with acid rain, the ozone layer, or greenhouse gases [4].

Composition of natural gas

Natural gas is a mixture of combustible and non-combustible gases. Its composition varies considerably depending on the place where it appears. It is characteristic that where it occurs with oil (humid natural gas) there is a greater proportion of gases with more carbon atoms [7].

Its main and predominant component is methane (CH_4), whose volume share can range from up to 98%. Other fuel gases that make up natural gas along with methane are so-called higher hydrocarbons: ethan (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}). Of the non-combustible gases, or inert gases, the natural gas contains nitrogen (N_2) and carbon dioxide (CO_2) as well as a smaller percentage of sulfur compounds [7].

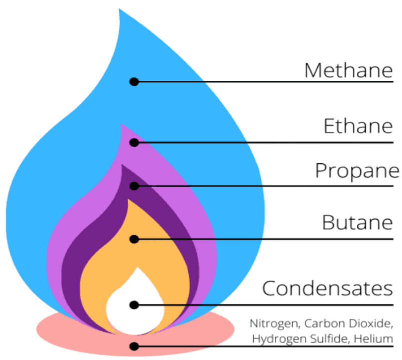

Figure 1 Composition of natural gas [5]

Table 1. Chemical composition of natural gas [5]

Compound	Symbol	Percent in Natural Gas
Methane	CH_4	60-90
Ethane	C_2H_6	0-20
Propane	C_3H_8	0-20
Butane	C_4H_{10}	0-20
Carbon Dioxide	CO_2	0-8
Oxygen	O_2	0-0.2
Nitrogen	N_2	0-5
Hydrogen Sulfide	H_2S	0-5
Rare Gases	He	0-2

Natural gas separation

Since the gas dissolves in oil, it needs to be extracted and separated from the oil, using dedicated separators to remove it. There are two basic types of separators: two-phase, which separate oil from gas, and three-phase, which separate oil, gas and water [1].

The separator configuration can be vertical, horizontal, or spherical, depending on the ratio of gas and oil. During the separation of oil and gas, certain waste material flows are also produced. This phenomenon is present when relatively small amounts of gas are separated from oil, or in remote areas where there is no economic justification for further gas processing. In this context, it is estimated that 50 billion cubic meters of natural gas is lost each year into the atmosphere through ventilation, combustion, and other ways of creating losses. In addition to these hydrocarbon emissions, significant amounts of hydrocarbon-gas compounds containing sulfur can also be emitted. Whether soluble in oil or found alone, natural gas may contain hydrogen sulfide (H_2S) a dangerous substance that must be removed before further processing [1].

Hydrogen sulfide (H_2S)

Hydrogen sulfide (H_2S) is a very toxic gas that usually occurs in the technological processes of crude oil processing. This gas can be deadly even if it is present in very small amounts in the air, for example 300 ppm. Hence the need for periodic risk assessment in facilities where (H_2S) is stored, among other things due to equipment deterioration and wear [6].

Significant amounts are also extracted and produced in refineries, which are usually the product of sulfur conversion or products of burning waste gases on flares. Most reports of H_2S toxicity effects on humans have described acute workplace poisoning [1].

Acute exposure to high concentrations, usually above 1,000 ppm, produces immediate unconsciousness and death within minutes due to respiratory paralysis. At lower concentrations (200 ppm or less), hydrogen sulfide may cause eye irritation; conjunctivitis; blurred vision; and corneal blisters, its opacity, and caries. The presence of carbon disulfide accelerates the development of these symptoms. Symptoms usually disappear within a few days, but a secondary bacterial infection can lead to permanent damage [1].

Thresholds for the determination of hydrogen sulfide by the sense of smell depend on its concentration and time of exposure. The lower limit for (H_2S) odor detection is 0.02 to 0.03 ppm. In concentrations up to 30 ppm (H_2S) has the smell of rotten eggs, while above 30 ppm it can have a sweet smell. Above about 100 ppm, hydrogen sulfide may not be detectable by odor, due to odor fatigue, which may result from prolonged exposure to lower concentrations. Therefore, it cannot rely on the sense of smell as a warning of dangerous H_2S concentrations. Headaches are a common result of exposure to low concentrations of H_2S. There are several reports that persistent adverse effects due to prolonged exposure to H_2S below 50 ppm affect humans. In animal studies, the maximum long-term exposure limit was found to be 10 ppm, and the 50 ppm limit (70 mg per m^3) for short-term exposure [1].

RESULTS AND DISCUSSION

As already mentioned, natural gas, compared to other fossil fuels, is an environmentally friendly fuel. However, it cannot be said that it is not harmful, there are various situations and methods due to which natural gas emits harmful by-products to the environment and humans. One of the harmful by-products that arises as a product of the combustion of waste gas in the form of a torch is hydrogen sulfide (H_2S) Hydrogen sulfide can also be formed as a product of sulfur conversion or in oil refining processes. This section will describe how to remove it. Emphasis is also placed on which is the best way to preserve the environment, ie in which state the natural gas is the safest and in what way it can be transported and stored in the changed aggregate state.

Hydrogen sulfide removal (H_2S)

The removal of hydrogen sulfide is usually done by leaking a natural gas mixture – hydrogen sulfide through a solution of monoethanolamine. It absorbs H_2S. Then H_2S is removed from monoethanolamine and recycled. After that, the extracted H_2S can be burned or sent to factories to obtain pure sulfur. If burned, substantial amounts of SO_2 can be emitted into the atmosphere [1].

Water removal

In addition to removing H_2S, from all natural gases that have a water content of more than 1 kg per 10000 cubic meters of gas, water (dehydration) must be eliminated, before sending for further processing. If the water removal procedure is not carried out, gas hydrates will be formed. Gas dehydration is usually achieved by glycol absorption. Di- or tri-ethylene glycol is used to absorb water from the gas, which is then recycled, and the released water is released into the atmosphere in the form of water vapor [1].

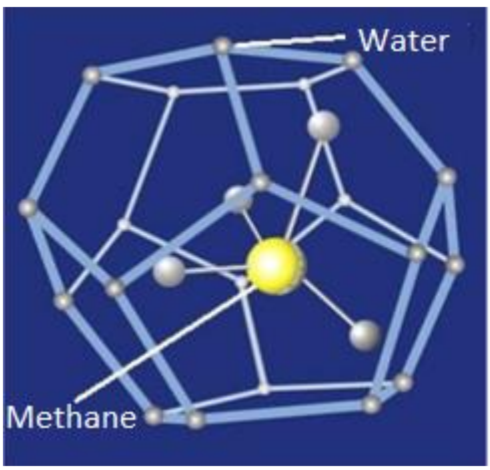

Figure 2 Gas hydrate [1]

Compressed natural gas

Compressed natural gas is compressed natural gas, ie one of the forms in which natural gas is converted for easier transport and storage. In our terminology, it has the abbreviated name KPG, but the domestic name is CNG. The main ingredient is methane, which, compared to other derivatives, has the lowest emission factor CO_2 per unit of energy released and as such contributes to improving air quality, nature conservation and environmental protection. It is used as a heating fuel in industry and households, but also as a motor fuel for internal combustion engines. It is considered the fuel of the future, because it is more energy efficient, economically more profitable than fuel oil, and the environmental aspect of combustion makes it irreplaceable in the near future. This is due to the fact that fuel oil for heating purposes is still used only in the southern part of Europe and that, soon, there will be a ban on the use of fuel oil in our country.

This should be added to the fact that air pollution is, according to the World Health Organization, the largest individual environmental health risk for mankind. According to these data, in the world as a result of breathing polluted air, every year, close to 7 million people die, and the same number, due to the same consequence, lives less than 3 to 6 years. In Serbia, as a result of air pollution, about 5,400 people die prematurely each year [2].

Liquefied natural gas

Liquefied natural gas is a natural gas that has been converted from a gaseous state to a liquid aggregate state at a temperature of -162ºC by a special technological process. Natural gas, when exploited from conventional deposits, is in a gaseous state and consists mostly of methane (usually 80-90%) in its total composition, which individually depends on each specific deposit of this energy source. In addition to methane, natural gas can contain: water, ethane, propane and heavier hydrocarbons, mercury, small amounts of nitrogen, carbon dioxide, sulfur, helium, etc. In order for natural gas to be successfully liquefied, it is first necessary to remove all necessary physical and chemical impurities. These are all impurities that turn into a solid state at higher temperatures than the "dew point" where methane is liquefied, but also from other unwanted elements found in natural gas. The formation of hydrates can lead to side effects, clogging of lines and other equipment in the technological process, but it is necessary to separate from the fluid and impurities that contribute to the process of corrosion. The gas cleaning process is usually part of the liquefaction plant itself. When the "cleaned" natural gas is cooled to a temperature of approximately -256ºF (-161.5ºC), at atmospheric pressure, it condenses, turns into a liquid state (TZG). In the liquid state, methane occupies 600 times less volume than in the gaseous form. Some of its basic characteristics are: that it is not corrosive, that it is colorless and odorless, that its relative density in relation to water is 0.42%, that its critical pressure is 46 bar, critical temperature -82ºC, self-ignition temperature 585ºC, density liquefied gas is 425 kg/m^3 [3].

Liquefied natural gas (LNG) is colorless, odorless, highly flammable and consists of methane (85-95%), ethane, propane and butane. It is non - corrosive and non - toxic, although, like methane, it can cause suffocation if the concentration is high enough when inhaled. To convert natural gas from a gaseous to a liquid state, it needs to go through the process of condensation with liquid nitrogen. The dangers associated with liquefied natural gas are:

- Suffocation;

- Cold burns on the skin during contact;
- Environmental damage in the vicinity of the outflow;
- Fire and explosion [1].

CONCLUSION

There are no literary reports on the association of human exposure to H_2S with carcinogenic, mutagenic, or teratogenic effects. Chronic exposure to H_2S and carbon disulfide, combined, caused weak teratogenic effects in rats. No information is available on the degree of low levels of chronic and acute exposure between refinery workers and persons in the vicinity of the refinery.

Hydrogen sulfide is heavier than air and can accumulate in toxic levels in indoor spaces such as caves, sewers and low areas.

When H_2S can be encountered very often in the workplace, extensive monitoring and alarm devices, employee training, and respiratory protective equipment are required.

During air pollution in the 1964 incident in Terra Haute, Indiana, eye and lung irritation, nausea, abdominal cramps, headache, acute asthma attacks, sleep disorders were observed in the general population, which was exposed to H_2S a to less from 0.125 ppm.

The most important thing is that every company that works with the exploitation, production, processing and transport of natural gas, has a professional team that, with knowledge and experience, will save the environment and every employee from potential negative impacts of by-products. It is also important to have adequate devices and equipment, which will ensure the protection of the environment and employees.

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Conference Proceedings
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Porosity Testing of NiO-Al2O3 Catalysts to Determine the Possibility of Application for Dry Methane Reforming

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Abstract. The influence of NiO content and calcination temperature on the formation of porosity and porous structure of $NiOAl_2O_3$ catalysts, intended for dry methane reforming, was investigated. Dry methane reforming represents the petrochemical and greenhouse gases reduction technology. In the impregnated samples, the NiO content (5.10, 20 wt%) and the calcination temperature (400°C, 700°C, 1100°C) were varied. Total porosity and pore size distribution were examined. It is assumed that the varied parameters significantly affect the possibility of forming the mesoporous structure of the formed catalysts, as one of the criteria for their application in dry methane reforming. The total porosity of the samples in the tested series of NiO contents reaches a maximum after calcination at 700°C. Analyzes of the most common pore radius showed that macropores were present in samples calcined at 400°C and 700°C, with the simultaneous presence of mesopores, depending on the NiO content. According to the results of total porosity and the most common pore diameters, the sample with 5 wt% NiO, calcined at 700°C, can be considered promising for testing in the reaction of dry methane reforming.

Keywords: NiO-Al_2O_3 catalysts, dry methane reforming, greenhouse gases, porosity, pore size distribution

INTRODUCTION

In recent years, with the sustainable industrial development of human society and continuous growth of the population, the further exploitation of limited natural resources such as fossil fuels has attracted increasing attention [1,2]. The increasing energy consumption has led to the global greenhouse effect, which has caused great damage to the world environment and ecology [1,3]. Therefore, to protect the environment and save resources, it is urgent to explore technologies and methods that can replace energy and make better use of natural gas and other fossil fuel derivatives [4].

The dry reforming of methane (DRM) is a chemical process that consists of converting methane and carbon dioxide, identified as the world's most abundant greenhouse gases (GHG) [5], to syngas (hydrogen and carbon monoxide), with an H_2/CO molar ratio of 1 [5,6]. As a result, this process has the potential to mitigate the environmental challenges associated with GHG emissions and to convert biogas and natural gas to syngas [5]. Moreover, the lower H2/CO ratio syngas produced is convenient for the production of hydrocarbons via Fischer-Tropsch synthesis [5], in addition to the synthesis of oxygenated chemicals [5]. The DRM reaction is a complicated process including several catalyzed reactions [1-7]. The main reaction is [7]:

$$CH_4 + CO_2 \leftrightarrow 2CO + 2H_2 \quad (1)$$

DRM is endothermic, thus requiring high temperatures and low pressures. In general, DRM takes place at temperatures varying from 600 to 900°C, using a CH_4/CO_2 molar ratio of 1-1.5 to obtain H_2 yields of about 50% [7,8].

One of the main problems of the DRM process is coke formation. To minimize coke formation it requires adjustments to the process parameters such as temperature, flow rate, design of catalyst [7-9]. Nickel-based alumina catalysts (NiO-Al_2O_3) have been recognized as the most effective materials for DRM, due to their low cost and high activity [7-9]. However, they are sensitive to deactivation by coking.

The textural and catalytic properties (behavior) of NiO-AI_20_3 catalysts significantly depend on the method of preparation and selected parameters in the process of catalyst preparation, as well as on the pre-treatment conditions (calcination temperature) [10].

The influence of NiO loading and calcination temperature on the formation of porosity and porous structure of NiO-Al_2O_3 catalysts was investigated. Variations in nickel loading and calcination temperature were varied to design catalysts for potential application applications in DRM. It is assumed that the varied parameters significantly affect the possibility of forming the mesoporous structure of the formed catalysts as significant textural properties of NiO-Al_2O_3 catalyst [10,11].

EXPERIMENTAL

This chapter describes the method of catalyst preparation and characterization.

Catalyst preparation

For a series of NiO-Al2O3 catalysts prepared by the wet impregnation method, catalyst support, Al2O3, was synthesized. The support was synthesized by precipitation of Al3+ ions from saturated nitrate solution, using 20 wt% NaOH solution at room temperature at pH 9.5. Merck chemicals, p.a., were used for the laboratory preparation of samples. After aging for 24 h, the precursor precipitate was vacuum filtered through a Büchner funnel. The precipitated aluminum hydroxide was washed with distilled water, until a negative reaction to nitrate ions. In the next step, the samples were air-dried at 105°C for 48 h. The sample was then transferred to a porcelain mortar, finely powdered, and air-dried again at 105°C for 6h. The support, Al2O3 was impregnated with a solution of Ni (NO3)2 · 6H2O, at room temperature. The nickel loading in freshly synthesized samples was: 5.1 wt%, 10.0 wt%, 19.9 wt%. The amount of nickel was calculated concerning freshly dried metal oxides.

The samples were calcined in a laboratory annealing furnace at 400°C, 700°C, and 1100°C in a static air atmosphere for 6h.

In the next step, calcined NiO-Al2O3 samples were tested using methods for testing selected textural properties with appropriate equipment.

Catalyst characterization (Wet chemical analysis and Porosity)

The nickel content in the samples was determined by the method of complexing nickel ions with dimethylglyoxime [10].

The total porosity (Q) was calculated from apparent (γ) and true (d) densities [10,11] and determined pycnometrically using mercury as a working fluid [10].

The most common pore radius, r (nm) was determined by mercury porosimetry in an apparatus of the type: Carlo Erba, Series 1500, at a pressure of up to 1-1500 bar.

Nomenclature of the samples

The following unified I - W - T nomenclature of the catalyst samples was used in the paper: I - designate the wet impregnation preparation method; W - nickel loading in wt%, T - temperature of the heat treatment (for example I-5-400 is sample prepared by wet impregnation, containing 5 wt% of Ni, thermally treated at 400°C).

RESULTS AND DISCUSSION

In this chapter, the results of testing the total porosity of samples and characterization of porosity are presented and discussed.

Total porosity

The results of the total porosity of the samples are shown in Table 1.

Table 1. The total porosity of the NiOAl2O2 samples depending on the nickel loading and the calcination temperature

Nomenclature of samples	Total porosity, Q (%)	
I-5-400	53.3	
I-5-700	71.8	
I-5-1100	53.4	
I-10-400	37.7	
I-10-700	43.7	
I-10-1100	36.8	
I-20-400	57.9	
I-20-700	68.2	
I-20-1100	64.2	

The total porosity of the samples (Table 1) at all tested NiO contents reaches a maximum after calcination at 700°C. The obtained result is explained by the fact that in the examined series of samples, the pore network (and thus, most likely, the specific surface area) is the most developed at 700°C. The explanation is supported by the results of the authors [10,11] that the 700°C sintering of the catalyst surface still has no significant effect on the porous structure, nor a specific surface area and thus on the overall porosity. It is assumed that at 700°C also, other physico-chemical processes that worsen the texture, still do not take place on a larger scale, which is not contrary to the assumptions used in this paper. The porous structure (and thus the porosity) at 700°C is formed under the dominant influence of polymorphic transformations of the carrier, with a moderate influence on the formation of chemical interactions of system components. Primarily, spinels are built, which can still be easily reduced at that calcination temperature. Solid solutions are also very likely to build up, which also affects the formation/change of porosity, ultimately. Increasing the calcination temperature from 700°C to 1100°C causes a deterioration in the porosity of the samples (Table 1). the phenomenon can be explained by the fact that the intensification of sintering the catalyst surface and the parallel development of several processes such as thermal enlargement of small pores, spinel formation with strong bonds between system components, polymorphic carrier transformations; in cooperation, they dramatically worsen the examined property of the samples.

Porous structure

Characterization of the porous structure of the samples included the determination of the most common pore radius, r (nm). The results are shown in Table 2.

Table 2. The most common pore radius in catalysts depending on the tested nickel loading and calcination temperature

Nomenclature of samples	Most common pore radius, r (nm)
I-5-400	8.5; 550
I-5-700	7.5; 700
I-5-1100	75.0; 1250
I-10-400	22.5; 350
I-10-700	70.0; 275
I-10-1100	125.0; 250
I-20-400	65.0; 750
I-20-700	7.5; 1000
I-20-1100	500

The results (Table 2) indicate that the catalyst samples have a dominant, bimodal porous structure. In sample I-5-400, the most represented pore radius of 8.5 nm was registered, which belongs to the mesopore area. In the sample I-10-400, pores with a radius of 22.5 nm predominate, while in I-20-400, macropores with a radius of 65 nm are the most common. After calcination at 700°C in the sample I-5-700, pores with a radius of 7.5 nm dominate, while in I-10-700 the presence of mesopores was not registered. It is assumed that in this sample the mesopores are enlarged into macropores with a diameter of 70 nm and 275 nm. In the case of I-20-700, mesopores reappear with a dominant pore radius of 7.5 nm, but at the same time, there are macropores with a radius of 70-1000 nm. Analysis of the most common pore diameters in the samples prepared by wet impregnation showed that the samples calcined at 400°C and 700°C have a similar distribution of pores by radii for all three tested NiO contents. In all samples calcined at 1100°C, with 5, 10, and 20 wt% Ni, the most common are macropores with a radius range of 75-1250 nm. The obtained results confirm the assumptions used in this paper.

CONCLUSION

According to the results of this work, the choice of NiO loading and calcination temperature significantly affects the overall porosity of the samples. The total porosity of the samples at all tested NiO contents reaches a maximum after calcination at 700°C. Samples with 5, 10, 20 wt% after calcination at 700°C have a sufficiently developed porous structure to express the application potential in DRM. Obtained results indicate that the catalyst samples have a dominant, bimodal porous structure. The samples calcined at 400°C and 700°C have a similar distribution of pores by radius for all three tested NiO contents. In some samples from the examined series, the mesoporous structure was detected as predominant, but based on the obtained results, it is not possible to assess whether and which samples would show the potential for application in DRM reactions.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
Technical Faculty "Mihajlo Pupin", Zrenjanin & Faculty of Sciences and Mathematics, Nis

Energy Passport in the Republic of Serbia

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Abstract. By introducing the directive on energy performance of buildings (*EPBD – Energy Building Performance Directive - 2002/91 / EC*) The European Union is trying to provide market mechanisms to improve energy efficiency in buildings, or in other words, it determined the economic value of energy conservation. In accordance with the laws and bylaws, every new building in the Republic of Serbia must be designed and built in such a way as to meet the criterion of the maximum allowed consumption of annual final energy for heating. This requirement applies to all categories of new buildings, as well as to existing ones after extension, reconstruction, adaptation, rehabilitation, extensive renovation or energy rehabilitation. The indicator based on when determining the energy class of a building, in the transition period, is the specific annual energy required for heating, while, after the improvement of relevant national bylaws, the total annual primary energy will be determined, which will be used as a quality indicator. This paper will present experiences in the implementation of the process of energy certification of buildings in Serbia, which began on September 30, 2012, when the application of regulations in the field of energy efficiency of buildings became mandatory.

Keywords: energy efficiency, energy passport, sustainable development

INTRODUCTION

In Serbia, more than 80% of buildings and houses are energy inefficient. Due to poor thermal protection of buildings and poor carpentry, energy is irretrievably lost, and the bills for electricity and heating are too high. In accordance with the Rulebook on conditions, content and manner of issuing certificates on energy performance of buildings ("Official Gazette" of RS, No. 69/2012), but also European Union directives, in addition to new buildings and existing public buildings must have energy passports.

The buildings of the House of the National Assembly of the Republic of Serbia, the Government of the Republic of Serbia and the Palace of Serbia are the first public buildings in Serbia to receive energy passports, which determined their level of energy consumption and recommendations on how to become more energy efficient.

The energy passport of the House of the National Assembly is marked "G", which is the lowest energy class. The building, built in 1936, although renovated several times, is still a big consumer of energy. The buildings of the Government and the Palace "Serbia" are somewhat more energy efficient, they are in the penultimate class "F". With the adoption of the National Strategy for Sustainable Development of the Republic of Serbia in 2008, with the Action Plan for Implementation, energy efficiency has been identified as a priority measure of this strategic framework. The First National Plan for Energy Efficiency of RS was adopted in 2010 and since then the Republic of Serbia has been working intensively on the implementation of energy efficiency in accordance with Directive 2010/31 / EU of the European Parliament and of the Council of 19 May 2010 on energy efficiency of buildings.

Experts and professionals in the engineering profession, representatives of ministries, employees of local self-governments throughout Serbia, employees in the economic sector and financial institutions are actively participating in the improvement of conditions and methods of energy certification of buildings. It is also important to note that the adoption of the new Law on Housing and Building Maintenance ("Official Gazette" of RS No. 104/16) declared the sustainable development of housing with the improvement of energy efficiency in the public interest, which will greatly contribute to the development of this area. Aware of its obligations as a member of the European Energy Community, the Republic of Serbia, in addition to the results already achieved, will continue to work intensively on the development of energy efficiency and achieving European standards in this area.

LEGAL BASIS FOR ISSUING AN ENERGY PASSPORT

Energy passport is a certificate of energy performance of a building that has the content and appearance in accordance with the Ordinance on the conditions of content and manner of issuing certificates, and is issued by an authorized organization. The energy passport provides quantitative information about the property - the energy required for heating or energy class of the property, but also provides information on materials used, comfort conditions in the building and recommendations for improving comfort and reducing energy consumption.

The first page contains general information about the property, the name of the owner, location, photo of the property and energy class. The other side of the passport contains climatic data, data on thermo-technical systems and elements of the thermal envelope, so the passport can provide information on installed materials, thermo-technical systems, carpentry and the like. On the third page, a detailed budget on energy consumption is presented, so even before moving in and staying in the property, we can prepare and see what the expected overhead costs are, which can be of crucial influence when buying a property. The fourth page contains planned measures to improve the energy efficiency of the facility. For each property, except those belonging to energy class A, on this page are written recommendations for improving energy efficiency. Recommendations on the need for earthen facade carpentry are most often made. It is a common comment that existing windows need to be replaced with new windows that meet energy efficiency criteria. The last page of the passport contains definitions, ie explanations of technical terms used in its preparation. The energy passport contains 5 pages, but the most important information is on the first, second and fourth pages. The energy class of a property is determined on the basis of the energy required for heating on an annual basis [1].

There are 8 energy classes from A + to G. Energy class A + represents the highest quality real estate, with the lowest energy required for heating ≤15 kWh / m2a. Energy class G represents real estate with very poor characteristics and the highest required energy for heating> 250 kWh / m^2a. Newly built facilities must meet the minimum requirements for energy class C. Existing facilities where the intervention is performed must improve the existing condition by at least one energy class, so if the existing facility is energy class E after the work must have at least energy class D. All newly built facilities must obtain an energy passport before issuing a use permit. Existing reconstructed facilities must have an energy passport. All properties on the market that are sold / rented must have this document.

The Ordinance on the conditions, content and manner of issuing certificates on the energy performance of buildings stipulates that some properties do not have to have an energy passport. According to the Ordinance, they do not have to have an energy passport:

1. existing buildings that are for sale, lease, reconstruction or energy rehabilitation, and which have less than 50 m^2;
2. buildings with an estimated useful life of two years or less;
3. temporary buildings (accommodation of people and construction materials during the execution of works);
4. workshops, production halls, industrial buildings and other commercial buildings which, in accordance with their purpose, must be kept open for more than half of the working hours, if they do not have built-in air curtains;
5. buildings intended for holding religious ceremonies;
6. existing buildings that are sold or the right of ownership is transferred in bankruptcy proceedings, in case of forced sale or execution;
7. buildings that are under a certain protection regime, and in which the fulfillment of energy efficiency requirements would be in conflict with the protection conditions;
8. buildings that are not heated or are heated to only + 12 ° C [1].

The decision on fulfilling the conditions for issuing certificates on the energy performance of buildings is issued by the Ministry of Construction, Transport and Infrastructure of the Republic of Serbia. The energy passport is issued according to the conducted procedure. The issued energy passport is valid if it is certified by an authorized organization. The validity of the energy passport is 10 years.

The classic register (paper version) has been kept in the Ministry of Construction, Transport and Infrastructure since 2013. and it is not part of the digital register (digital database). The digital register has existed since 2014/2015. year and was established as the official Central Register of Energy Passports (abbreviated CREP). At the Central Register of Energy Passports (CREP), 8,095 energy passports are currently registered. CREP is managed by the Republic of Serbia - the Ministry of Construction, Transport and Infrastructure and the Ministry of Mining and Energy.

The energy passport of the building is issued after the energy audit of the building and the evaluation and final assessment of the fulfillment of the prescribed requirements on the energy properties of the building. Energy audit of the building includes:

1. analysis of architectural and construction characteristics of the building, ie analysis of thermal characteristics of the thermal envelope of the building;
2. analysis of energy properties of the heating system;
3. analysis of the system of automatic regulation of the heating system in the building;
4. measurements to determine the energy status and / or properties, when the data cannot be obtained in any other way.

After the energy audit, a report on the energy audit of the building is prepared, which contains:

1) general information about the building; location data; climate data; data on the compliance of the project of the constructed facility with the main project on the basis of which the building was built;
2) technical description of applied technical measures and solutions according to the prescribed criteria, as follows:
   a. functional and geometric characteristics of the building,
   b. applied construction materials, elements and systems,
   c. embedded technical systems,
   d. type of energy source for heating, cooling and ventilation,
   e. thermo-technical installations and lighting systems,
   f. use and participation of renewable energy sources;
3) the required annual energy consumption for the operation of technical systems in the building (final energy) in accordance with the regulation governing the energy performance of buildings;
4) the annual value of the use of total primary energy in accordance with the Rulebook on energy efficiency of buildings;
5) values of CO_2 emissions, calculated in accordance with the Rulebook on energy efficiency of buildings;
6) proposal of measures to improve the energy performance of the building;
7) signature and stamp of the responsible EE engineer who prepared the report [2].

The report on the energy audit of the building also contains data depending on the category of the building, namely: results of measurements and / or recordings - thermographic images of the thermal envelope of the building or parts of technical systems in the building, data on measured U-values of building elements air permeability of a building or part of a building and others. An energy passport is issued for the whole building or for a part of the building. An energy passport is issued for a part of a building when it comes to a building which, according to the Ordinance, is defined as a building with several energy zones. An energy passport can also be issued for a part of a building that forms an independent use unit, such as business premises, an apartment or similar for existing buildings that are sold, leased, reconstructed or energetically rehabilitated. The energy passport is made on the basis of calculated energy needs and energy audit. A building or its independent use unit may have only one energy passport.

CONCLUSION

The building sector provides a significant opportunity to achieve energy savings. According to the estimates of the Government of the Republic of Serbia, the great potential of available measures for improving energy efficiency (EE) lies in the construction fund. According to statistical data from 2010, 61% of the total consumption in this sector is spent on meeting the thermal needs in buildings. Therefore, the greatest potential for energy savings is related to improving the thermal protection of buildings, in order to reduce heat losses. In the housing sector, most of the construction stock was built more than 30 years ago. The average consumption of thermal energy, which is around 170 kWh/m^2, compared to 70-130 kWh/m^2 in Western Europe, indicates a significant possibility of reconstruction of existing facilities and the introduction of measures to improve energy efficiency. Also, EE improvement projects, which have recently been carried out in the public sector in the Republic of Serbia, mostly in schools and hospitals, show that savings ranging from 30% to 40% have been achieved, with attractive payback periods. Improving EE in this sector would benefit the Republic of Serbia in terms of energy security, increasing economic competitiveness in the market and reducing fiscal costs, as well as reducing the impact on climate change [3].

In order for the building, during its lifetime, to have satisfactory energy performance, it is necessary to regularly and properly maintain the building and the system in it. If there is no regular maintenance and the functionality of the system is not completely disrupted, a case of irrational energy consumption occurs almost regularly. The main examples are: damage or complete removal of thermal insulation of devices, pipelines and air ducts, which results in increased heat losses of the system, condensation of moisture from the air and damage to devices and interiors; contamination of the distribution network and equipment elements, which results in increased efforts of pumps and fans and leads to higher electricity consumption for their operation; removing dirty air filters instead of replacing them leads to poor air quality; the cessation of the function of control valves or equipment, except for the deterioration of thermal parameters of the environment (overheating in winter or sub-cooling in summer) inevitably affects increased energy consumption, while in extreme cases can cause systemic damage and great damage and sometimes endanger human lives. As important as it is to design and report systems in a building, their maintenance and proper management are equally important, so that they can give their maximum.

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Conference Proceedings
ICPAE 2022, 31st March– 2nd April, Zrenjanin, Serbia
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Environmental Safety of the Environment from the Aspect of Soil Contamination with Oil

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Abstract. The environmental safety during the exploitation of oil and gas is an extremely important and demanding segment of work of every oil company. Today, life safety and health at work are taken into account more than in the previous decades. Pollution of soil by oil derivatives occurs due to exploitation, refining, transport, storage, use of oil, and partly during accidental spills. The potential impact of oil and gas production is manifold, both in its scope and in numerous problems. These problems may be specific to one technology or may be present in a large number of technologies, but differ in the degree of related impacts. One way of protecting soil due to its contact with oil and oil derivatives can be bioremediation.

Key words: oil, gas, life safety protection, environment, pollution, bioremediation

INTRODUCTION

Life safety and health at work during the exploitation of oil and gas is an extremely significant and demanding segment of work of every oil company, regardless of the type of activity, including the process of (applied) geological research and performing geological exploration [1]. The necessary preventive significance in every stage of work is provided by a systematic approach to health and safety. Protection of life safety is intended for organizations that are aware of the causes and consequences of soil contamination with oil and oil derivatives. Pollution with oil and oil derivatives poses a risk to both human health and the environment. One of the basic ways to decontaminate soil of oil is biodegradation. For microorganisms, contaminated substances represent a substrate for growth, so oil and oil derivatives are decomposed into non-toxic substances and mineralized at the end of the process which actually leads to decomposition into carbon dioxide and water, which are not harmful to the environment. While microorganisms or their enzymes are also used for the bioremediation process to restore the contaminated environment to its original state, this method of purification means the complete degradation or transformation of hazardous organic pollutants into harmless products.

MATERIAL AND METHODS

The origin of oil

The word oil comes from the Persian word nafada which can be translated as the sweat of the Earth. This ancient description is largely similar to a contemporary widespead biogenic teory of crude oil production. According to this teory, oil is said to present a migrated, accumulated product of diagenetic and catagenetic transformations of organic supstances in sedimentary rocks [2].

Englar's theory assumes the origin of oil comes from waterproofed and fermented fats of dead animals accumulated underground under high pressure and temperatures. According to Porphyry's theory, oil hydrocarbons were formed from carbohydrates, while according to Sokolov and Zelenski, oil was made from hydrocarbons synthesized from metals and methane. Theories about the organic origin of oil are based on the hypothesis that oil comes from the remains of plants and animals. According to most of the contemporary theories, oil came from the remains of aquatic organisms (amoebae, planctons, algae, etc.), which depositated and transformed under conditions of high pressure and temperature [3].

Crude oil

Crude oil is found in underground rock formations, which we call reservoirs. These reservoirs consist of sandstone, limestone, or dolomite structure. In the oil reservoirs, there are different amounts and types of natural energy resources in addition to crude oil and natural gas. Division according to the National Petroleum Council 1976; American Petroleum Institute 1976):

- Dissolved gases in crude oil
- Dissolved gases in the salt water deposit that may coexist with crude oil,
- Free gases occurring with crude oil and
- Free water deposits related to crude oil, which does or does not contain dissolved gas.

The exploitation of oil and gas from the reservoir consists of several stages: the process begins with exploration activities, after which primary production is performed, and at a later stage, EOR methods are often used.

Oil and its derivates as sources of energy

Oil gained its true utility only with the invention of the internal combustion engine. This was followed by a great expansion in use, which led to the need to separate different derivatives from crude oil according to their purpose. The separation of different fractions from crude oil is based on their different boiling points, a procedure called fractional distillation. The goal of this procedure is to obtain derivatives that will have optimal characteristics for a specific purpose. Thus, gasoline contains lighter hydrocarbons that burn faster at lower temperatures, while aircraft fuel has components of higher boiling temperatures, whose combustion releases more energy [4]. The fractions made by the distillation of crude oil are shown in Table 1.

Table 1. Fractions from crude oil distillation are shown [5]

Column Crude oil fraction	Number of carbon atoms permolecule	Boiling pointfractions (° C)
Natural gas, butane gas	C_1-C_4	< 20
Petroleum, solvents	C_5-C_6	20-60
Ligroin, solvents	C_6-C_7	60-100
Gasoline	C_5-C_{10}	40-200
Kerosene	C_{12}-C_{18}	175-325
Gas oil, diesel fuel, lubricating oil, fuel oil	>C_{12}	250-400
Refined mineral oils, lubricants, lubricants	>C_{20}	non-volatile liquids

RESULTS AND DISCUSSION

Bioremediation

Bioremediation is an important area of biotechnology, it is economically viable green technology. Soil and surface sediment are the habitat of a large number of diverse microorganisms, ranging from simple prokaryotic bacteria and cyanobacteria to complex eukaryotic bacteria, algae, fungi and protozoa [6]. The essence of remediation is in the use of natural chemical reactions and metabolic processes by which organisms break down parts to provide nutrients and energy. The basic bioremediation processes are oxidation and reduction that can take place under aerobic or anaerobic conditions. The fastest and most complete decomposition of most organic pollutants takes place under aerobic conditions. While anaerobic decomposition of hydrocarbons (mixed cultures of microorganisms) it is possible to decompose: toluene, benzene, naphthalene, phenanthrene, n-alkanes with more than six C atoms [7]. Bioremediation is the use of living organisms, primarily microorganisms, in order to degrade polluting substances to less toxic forms [7,8]. An example of such a situation on the field is the contamination of soil in the area of the Pancevo Oil Refinery. The earth's surface comes into contact with oil and its derivatives. Fuels and grease, which is obtained by refining oil, although more homogeneous in composition than crude oil, contain molecules of different physical and chemical characteristics. There are differences in molecular weight, boiling point, water solubility, hydrophobicity, density and viscosity [10].

Figure 1 Location of the Pančevo Oil Refinery (RNP) complex [9]

For an efficient bioremediation process, in addition to the microorganism being capable of decomposing the contaminant (oil or other) as a carbon source, other factors must be taken into consideration, such as:

- nutrients, source of nitrogen and phosphorus
- humidity,
- temperature,
- aeration, oxygen
- surfactants
- soil characteristics such as pH, mineral composition, texture [10]

The use of microorganisms as biodegrading agents is constantly increasing due to the huge biodiversity, bacteria have developed the ability to decompose oil and other hydrocarbons thanks to enzymatic reactions. The enzymes which are involved in the reactions are found in bacteria and allow the bacteria to use the energy from the chemical bonds of oil and oil derivates for growth and development. Hydrocarbons that have a lower molecular mass and a simpler structure can be broken down more easily. Heavier and more complex hydrocarbons are harder to break down. Out of all, alkanes are the easiest to break down. Bacteria break down alkanes by gradual oxidation to alcohols, aldehydes and fatty acids. Microorganisms that successfully participate in the bioremediation of oil and oil derivates in contaminated soil are bacteria: Nocardia, Pseudomonas, Acinetobacter, Flavobacterium, Micrococcus, Arthrobacter, Corynebacterium, Achromobacter, Rhodococcus, Alcaligenes, Mycobacterium i Bacillus [11].

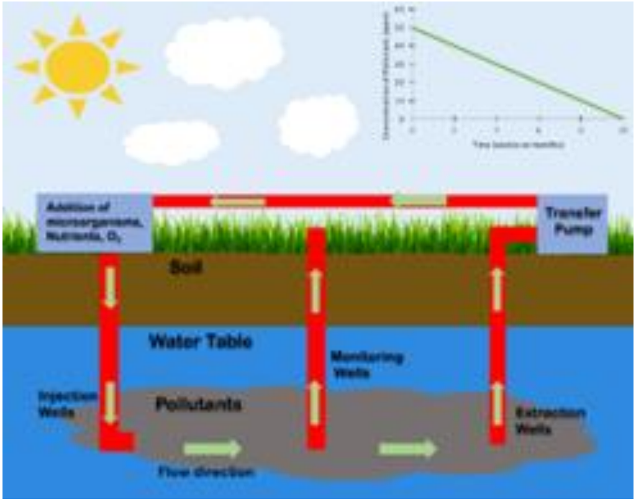

Figure 2.Visual presentation of bioremediation of contaminated soil (https://www.wikiwand.com/en/Bioremediation)

The picture shows a visual presentation which shows bioremediation on the spot. This process includes the addition of: oxygen (usually magnesium peroxide), nutrients (nitrogen and phosphorus) - microbes in contaminated soil to accelerate the process of increased growth of microorganisms in order to remove toxic pollutants. Contamination includes contaminated soil and leaks from underground pipes that infiltrate groundwater systems. The addition of oxygen removes pollutants in a way that entire process system separates carbon dioxide and water [12-14].

CONCLUSION

Based on monitoring and the events happening in the world, we can say that the market of remediation technologies is constantly growing. Bioremediation has significant advantages over other technologies both in terms of finance and efficiency in pollutant removal. The technology of biodegradation, and especially bioremediation, can be said to be the least harmful to the environment, while it is extremely suitable for the strategy of sustainable development. The success of bioremediation of soil contaminated with oil and oil derivatives depends on several parameters: environmental factors, supplementation and availability of nutrients and, of course, facilities. In the future, it is very important to insist on the introduction of biological steps. In Serbia, we are still expecting the development of remediation technologies, while in the world, bioremediation has been used successfully for many years.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
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Use of Waste Biomass for Energy Purposes

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Abstract. The paper presents the availability of biomass in Serbia and its possibility of use for energy production. Biomass is most often used in the form of energy for heating, cooking or heating water. In addition, the use of biomass in cogeneration plants for the production of heat and electricity is becoming increasingly important. The advantages and disadvantages of using biomass for heat production in relation to some other energy sources are presented. The process of production of pellets and briquettes from biomass, as well as some types of biomass combustion systems are presented. The use of waste biomass achieves significant savings on heating, and also reduces the pollution of the environment, especially if this biomass cannot be used for other purposes, for example for animal nutrition.

Keywords: biomass, combustion, heat, pellets, briquettes

INTRODUCTION

Biomass as a renewable energy source is an organically degradable substance of plant or animal origin, as well as a biodegradable part of industrial and urban waste that is converted into energy by various processes. Biomass is most often used in the form of energy for heating, cooking or heating water. In addition, the use of biomass in cogeneration plants for the production of heat and electricity is becoming increasingly important [1-3].

As a renewable energy source, biomass covers: wood biomass (residues and waste from scraping, grinding, waste that burdens the business of the wood processing company), agricurtural waste and residuens (straw, maize, husk, stalks, seeds, husks), animal waste and residuens anaerobic fermentation (faeces - all types of animals + green mass), biomass from waste (green fraction of household waste, biomass from park and gardens from urnabs area, sludge from wastewater collectors) [4-6].

Unlike the process of direct combustion of biomass packaged in the form of bales, by which investors provide their own heat supply, the procedures of briquetting and pelleting biomass are intended primarily to supply other users with biofuels (households, agricultural facilities, production plants and industry). Therefore, pelleting and briquetting of biomass shows a number of advantages over other biomass storage processes (reduced volume, reduced handling and transport costs, significantly less storage space required, greater resistance of materials to biological spoilage processes, increased process efficiency combustion, etc.) [4,7].

Availability biomass in Serbia for production energy

Biomass represents the most important renewable energy source in Serbia represents two thirds of the total potential or 62% of RES, which corresponds to 2.4 million oil equivalent. The energy potential of forestry is estimated at about one million tons of oil equivalent, while the rest belongs to organic raw materials, agricultural waste and crop residues. Instead of burning agricultural residues in the fields, which is prohibited by law, farmers could use these residues for energy production [3,4].

The technically usable annual energy potential of biomass in the Republic of Serbia is about 2.7 Mtoe. The energy potential of biomass from forestry and wood industry (logging and wood residues produced during primary and / or industrial wood processing) is estimated at approximately 1.0 Mtoe, while about 1.7 Mtoe would come from agricultural biomass (agricultural waste and crop residues, including liquid manure) [4,5].

Resources of biomass from agricultural cereals

Grain, barley, rye, corn, sunflower, soybean and oilseed rape make 40% of the total arable land which 75% are produced on small and medium-sized private farms and 25% are agricultural combines and larger companies. The disadvantage is non-standard yields. Fruits and vegetables make 16% of the total arable land. The disadvantage is the relatively high moisture content [1,5].

Biomass can be use for production biogas. Gas generated by a anaerobic process from biomass, ie. from the remainder in agricultural production contains 60-80% CH4 , thermal power 8570 kcal/m^3, or 9960 kWh/m^3. The rest are CO2 (20%), HS. The gas this quality can be used for: production of electricity, as fuel for boilers for industrial use, for boilers for space heating, direct combustion for cooking or lighting, incineration to prevent air pollution [2,8].

Using biomass in energy purposes

Biomass is mostly used for heating house. There are positive experiences with the application of biomass in large plants, but the main obstacles are security of delivery and the cost of biomass. Some companies use their own biomass (for example, wood residues are used in forestry and wood processing companies or agricultural residues on farms for heat production) [6,9].

The use of biomass for energy purposes should be done in such a way that its use cannot be applied in any other way (biomass as food, for example). At the same time, it is necessary that the biomass used for energy purposes meets certain criteria in order to ensure that the appropriate energy, environmental, and other conditions are met. In order to prevent any problems in functioning, it is necessary to define all types of biomass that can be used to provide electricity and heat, biogas and biofuels for traffic, as well as the requirements that must be met.[3,10,11]. In the Table 1 shows energy power of biomass.

Table 1. Energy power of biomass [12]

Source of biomass		Power (toe)
Wood biomass		1 527 678.00
Firewood		1 150 000.00
Wood processing residues		179 563.00
Forest waste		163 760.00
Tree from trees outside the forest		34 355.00
Agricultural biomass		1 670 240.00
Remains of agricultural crops		1 023 000.00
Residues from fruit growing, viticulture and fruit processing		605 000.00
Liquid manure for biogas production		42 240.00
Biofuels for traffic		191 305.00
Total biomass	No fuel for traffic	3 197 918.00
	With fuel for traffic	3 389 223.00

Process of pelleting and briquetting

Pelletizing and briquetting increases the density of biofuels, reduces the cost of transport, storage and handling, the processes of biological degradation of biomass are realy slowed, combustions are reduced, thus cheaper, increased efficiency in the combustion process, etc.[7,12]

The pelleting process means compaction or pressing of crushed bulky plant material into a suitable shape, which has a significantly smaller volume compared to the initial material, ie raw material. The smaller volume provides the possibility of easy storage and transport compared to wood and coal, and in addition the pellet has a significantly lower percentage of solid waste compared to coal and is an environmentally friendly fuel. Pellet has exceptional characteristics, especially in combustion in automatic boilers, because it allows easy handling, automatic dosing and long-term efficiency of the boiler with minimal maintenance costs [7,12]. The figure 1 shows the process of making pellets.

Figure 1. Process of palleting [15]

The briquette may have a prismatic shape or a cylindrical roller shape. Briquettes are formed by pressing crushed particles of lignocellulosic material, without binder under high pressure (150-200 bar), elevated temperature (70-90 ° C) and optimal moisture content in the material (8-12%), which reduces the volume and increases specific mass. Briquetting is done mostly by hand, and the lower thermal power ranges from 15 to 18 MJ/kg. When the briquettes are completely burned, 0.5 to 7% of ash is released, sulfur oxides are not released and the environment is not polluted. That is why briquettes are an ecological fuel [7,12].

Biomass boiler plant

Within the biomass boiler plant presented a high-pressure boiler in which the feed water under a certain pressure is converted into co-saturated steam, with a capacity of 18,000 kWth, maximum steam flow at 100% capacity: 25 000 kg/h, temperature of water: 105°C, work pressure: 47 bar, work temeprature: 260°C, lowest predicted efficiency at 100% capacity: 86%. Fuel consumption (straw pellets) in the boiler was calculated based on the combustion diagram presented in figure 2 [13].

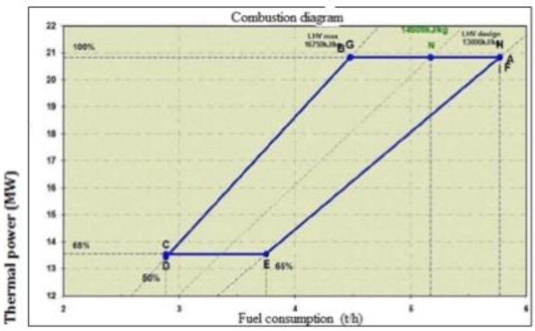

Figure2. Combustion diagram for a biomass boiler

Table 2. shows us the indicative values of the required amount of fuel for steam production in depending on the moisture content of the fuel. Fuel consumption is shown for two boiler capacity values, 100% of boiler capacity and steam production 25 t/h and 80% boiler capacity and steam production 20 t/h.

Table 2. Straw pellet consumption (depending on moisture content)

Thermal power		Moisture content in fuel	Boiler capacity 100%	Boiler capacity 80%
(kJ/kg)	(Kcal/kg)	(%)	(t peleta/h)	(t peleta/h)
13 400	3 200	±25	±5,425	±4,340
14 650	3 500	±15	±4,925	±3,940
16 750	4 000	±8	±4,500	±3,600

Since the expected moisture content in the pellets is about 10%, this value was taken as a reference for the calculation of the annual consumption of pellets in the boiler plant. Hourly fuel consumption for the batch 10% moisture in the fuel was calculated by interpolation based on the values in Table 2.
The expected annual consumption of pellets is shown in Table 3. for boiler capacities of 100% and 80% base 8,000 h of work per year or 333 days. If we assume that the boiler operates with an average capacity of 80% per year straw pellet consumption would be 29,574 t/year. That is 36,968 t/year. for 100% boiler capacity

Table 3. Consumption of straw pellets with a moisture content of 10%

Moisture content in fuel	Boiler capacity 100%	Boiler capacity 80%	Boiler capacity 100%	Boiler capacity 80%
(%)	(t peleta/h)	(t peleta/h)	(t peleta/god.)	(t peleta/god.)
10	4,621	3,697	36 968	29 574

CONCLUSION

Based on the above, it can be concluded that waste biomass is of great importance for energy production, especially heat. Its application achieves significant savings when it comes to heating costs, as well as reducing environmental pollution, especially if biomass cannot be used for other purposes, e.g. animal nutrition.

Nowadays, the consumption of pellets is becoming more popular and widespread due to its own economic viability and environmental acceptance. Also, pellets are very important for heating means and unlike wood very easily and simply their flame can be extinguished and re-ignited. Due to that, their production is growing, both small and small and in large quantities. There are various designs of pellet production plants and the space for their development is large. If you look at the simplicity, economy and environmental friendliness of pellet heating systems, it becomes clear that these are the fuels of the future.

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Some Experiences from the Implementation of the GLOBE Program in Secondary Education

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Abstract. The purpose of this paper is to show that through the implementation of the GLOBE program (**G**lobal **L**earning and **O**bservations to **B**enefit the **E**nvironment), awareness is raised among primary and secondary school students regarding global pollution and climate change; a worldwide community of students, teachers, scientists, and citizens working together to better understand, sustain, and improve Earth's environment at local, regional, and global scales. In this regard, we will show our experiences. Our Vision:"To increase awareness of individuals throughout the world about the global environment, contribute to increased scientific understanding of the Earth, and support improved student achievement in science and mathematics."Our Mission "To increase awareness of individuals throughout the world about the global environment, contribute to increased scientific understanding of the Earth, and support improved student achievement in science and mathematics.

Keywords: environment, climate change, experience, science,

INTRODUCTION

The interest in time and climate is as old as the history of mankindage. At the same time, the current state of the atmosphere in some places and the topic of conversation for winter and summer. Was last year unusually hot? Is the average temperature in some area due to deforestation or due to the released gases in the atmosphere of a factory? As a prime topic of interest among people that already a few years in not they saw no snow , then in January or February they notice the flowering of some plant species, the presence of many dry winters and many hot summers.

The subject of research on our work is climate change. It is important to provide information, relevant indicators that are located in Macedonia, more precisely in the less industrialized areas, and are not spared from global climate change.

Our school is part of the GLOBE community. Through the comparative analysis of the same physical characteristics for atmospheric measurements for the period from 1967-1976, the measurements made by the students in our school, from the GLOBE team, atmospheric measurements, we will try to prove that the area Valandovo, a little place , we are not spared from the harmful effects of climate change.

Stojan Manolev, Dijana Janeva

ATMOSPHERIC MEASUREMENTS

As members of the GLOBE team, our school has studied and practiced measurement protocols and instruments. In the GLOBE program, the following physical characteristics are always taken into account:

- air temperature (current, maximum and minimum);
- air humidity (relative percentage humidity);
- amounts of snow of rain;
- rain equivalent to snow;
- ph of rainwater;
- coverage of the sky with clouds ;
- soil temperature up to 5 cm depth;

From several parameters we decided to analyze and compare the air temperature (maximum and minimum) and rainfall for the period 2006 year with the period 1967-1976 year in Valandovo.

Temperature

Scientists from all over the world are studying the changes of time with great interest and attention, ie the changes that occur in the Earth's atmosphere, since they directly affect the overall life of man, animals and plants.

For the existence of the glass garden effect, in addition to following the composition of the gases, an important indicator that this effect occurs is the change in air temperature. What are the events on that plan, we compare the monthly average maximum and minimum temperatures from the GLOBE measurements for 2006 for Valandovo with the meteorological data obtained from the archives of the Assembly of the Municipality of Valandovo for the period 1967-1976. The results are displayed tabular and graphically.

Table 1. Average monthly maximum temperature - results

Year	2006											
Month	1	2	3	4	5	6	7	8	9	10	11	12
(^{0}C)	9.1	9.7	14	20.6	23.7	27	32.8	34.1	29.6	22.9	17.1	10.7

Table 2. Average monthly maximum temperature - results from meteorological data

Year	1967-1976											
Month	1	2	3	4	5	6	7	8	9	10	11	12
(^{0}C)	7.3	9.9	13	19.4	25.1	28.5	30.8	30.7	27	20.5	14.5	9

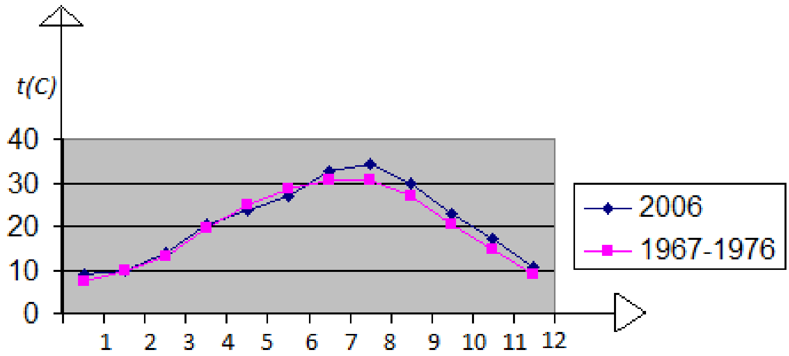

Figure 1. Compared graph of the average maximum monthly temperatures

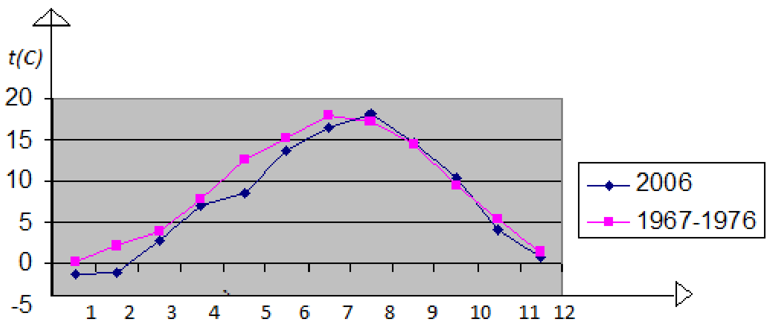

Figure 2. Compared graph of the average minimum monthly temperatures

It is noticeable that according to the temperature data in the four seasons there are no sharp limits and they are characterized by relatively high temperatures and the winter is not very cold.

Precipitation

Rainfall is defined as water in a liquid or solid state that comes from the atmosphere and returns to the surface of the earth.

Knowledge of how much rainfall occurs in some areas, at any time of the year, how many quantities do allow us to define it - with the local climate in one area and the global climate.

For that purpose, we compare the rainfall in the period 1967-1976 with the rainfall in 2006 (table 3 and table 4).

Table 3. Average monthly precipitation for the period 1967-1976.

	1967-1976											
Month	1	2	3	4	5	6	7	8	9	10	11	12
mm*	45.4	50.8	58.5	30.8	67.1	31.9	50.7	31	37.5	57.4	53.2	53.2

Table 4. Average monthly precipitation for the period 2006

	2006											
Month	1	2	3	4	5	6	7	8	9	10	11	12
mm	2.7	0.4	3.5	1.2	0.5	4.4	2.3	0.9	0.7	4	0.5	2.3

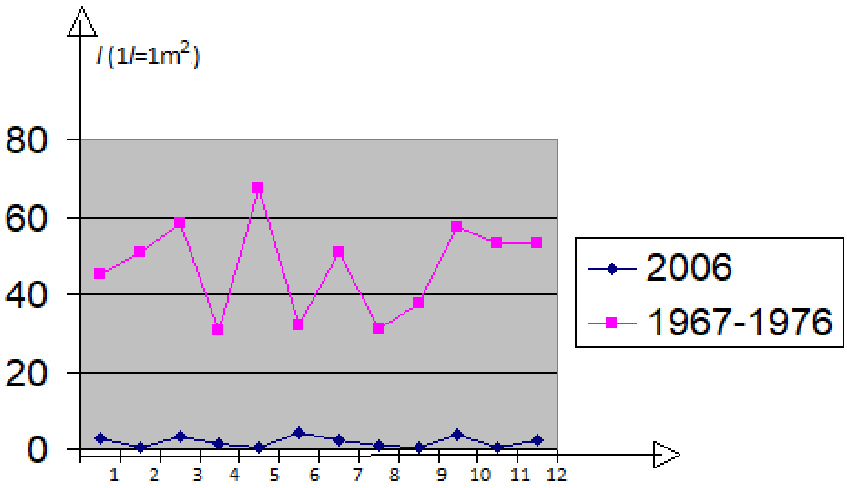

Figure 3. Compared graph of values for the period 2006 so period 1967-1976 year

Comparing the data from the tables or even better showing the constructed graph, it can be concluded that there have been drastic changes in rainfall 30 years ago and now. Namely, the average rainfall for the period 1967-1976 was 47.29 mm, in 2006 it was 1.95 mm or about 24 times more. Given the fact that rainfall contributes to changes in the validity of air condition and soil validity, it can be concluded what drastic climate change has occurred.

Analyzing the average maximum temperature, it can be concluded that in 2006 the average annual maximum temperature was 20.94 ^{0}C, and in the period 1967-1976. year it was 19.64 ^{0}C, ie if there was an increase in the average maximum temperature of 1.2.

* 1 mm of raindrops is equivalent to 1 liter of water per one square meter 1l/ m^2

Analyzing the average minimum temperature for the same period, it is concluded that the average minimum temperature in 2006 is 1.1 ^{0}C increase in relation to the period 1967-1976. Analyzing the average daily temperature, we conclude is January and the coldest month in Valandovo, with the lowest temperature of -13^{o}C in 2006. July is the warmest month with the highest temperature of 43 ^{o}C. Average temperature values for 4 years of sesons are:

- Winter 9.8 ^{o}C Summer 31.3 ^{o}C
- Spring 20.6 ^{o}C Autumn 23.2 ^{o}C

CONCLUSION

The purpose of the study was to find information that would be relevant to the climatechange indicators in Valandovo. Analyzing only two physical parameters of air temperature and quantities of precipitation, and the narrow correlation of these two parameters with humidity of air, atmospheric pressure and temperature of soil, it is obvious that the Valandovo region is subject to climate change.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the Ministry of Environment and Spatial Planning for its continued support with the experimental devices for the implementation of the GLOBE program.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
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Air Pollution and Its Effect on Human Health

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Abstract. Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulfur dioxide. Air pollution has been a major environmental problem impacting billions of people worldwide. Our primary objective in this review paper was to determine the association or lack of association between air pollution and human health. Our secondary objective was to discuss major air pollutants and impact on human health of selected air pollutants.

Keywords: air pollution; environment; health effects; public health; outdoor air pollution; indoor air pollution;

INTRODUCTION

The World Health Organization defines air pollution as contamination of the indoor or outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution [1]. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulfur dioxide [2]. Air pollutants, such as carbon monoxide (CO), sulfur dioxide (SO2), nitrogen oxides (NOx), volatile organic compounds (VOCs), ozone (O3), heavy metals, and respirable particulate matter (PM2.5 and PM10), differ in their chemical composition, reaction properties, emission, time of disintegration and ability to diffuse in long or short distances. Air pollution has both acute and chronic effects on human health, affecting a number of different systems and organs [3]. Air pollution is an important risk factor for noncommunicable diseases (NCDs). The United Nations high-level meeting on NCDs, held in September 2018, recognized air pollution as one the five major risk factors, alongside tobacco smoking, the harmful use of alcohol, physical inactivity and unhealthy diets [4].

History of air pollution

Air pollution is not new but the volume and concentration of contaminants has steadily increased with the development of modern civilization and can be very harmful to human health, even deadly. The Greeks and Romans noted the polluted air millennia ago, as documented in writings of Theophrastus and Seneca. 4 The source of this foul air was stoves, home heating, and smelting of ore for lead and silver, and more generally from the growing population and concentration of people in cities. The unrestrained use of fossil fuels and subsequent air pollution was much worse in the Industrial Revolution. In developed countries, changing fuel sources and installing pollution control devices have substantially improved air quality. However, developing countries such as India and China have struggled to balance rapid industrial growth with air pollution control. While there are ways to reduce air pollution from large point sources like power plants, non-point sources such as automobiles and trucks are increasing dramatically as economies develop. Ongoing research documents the serious health problems associated with air pollution, particularly for children [5].

MATERIAL AND METHODS

We conducted a scientific review of available literature published over the last 20 years. Our primary objective was to determine the association or lack of association between air pollution and human health. Our secondary objective was to discuss major air pollutants and impact on human health of selected air pollutants. We initiated a PubMed database search and Google Scholar search using terms “air pollution health effect” “air pollution in Serbia” “indoor air pollution,” “outdoor air pollution” and “air pollution history”. Effort was made to provide both positive and negative studies where appropriate. After analysis of the available data, this paper concludes with public health recommendations based on the existing scientific evidence.

Major air pollutants

Particle pollutants are major parts of air pollutants. In a simple definition, they are a mixture of particles found in the air. Particle pollution which is more known as PM is linked with most of pulmonary and cardiac-associated morbidity and mortality [6,7]. They have varied in size ranging mostly from 2.5 to 10 μm (PM2.5 to PM10).

Ground-level ozone with the chemical formula of O3 is a colorless gas which is the major constituent of the atmosphere. It is found both at the ground level and in the upper regions of the atmosphere which is called troposphere. Ground-level ozone (GLO) is produced as a result of chemical reaction between oxides of nitrogen and VOCs emitted from natural sources and/or due to human activities. On ecological aspect, O3 can reduce carbon assimilation in trees leading to deforestation which may affect global food security in long-term exposure [8,9].

Carbon monoxide with chemical formula of CO is a colorless and odorless gas, which is produced by fossil fuel, particularly when combustion is not appropriate, as in burning coal and wood.

Sulfur dioxide with the chemical formula SO_2 is a colorless, highly reactive gas, which is considered as an important air pollutant. It is mostly emitted from fossil fuel consumption, natural volcanic activities, and industrial processes.

Nitrogen oxides are mainly emitted from motor engines and thus are traffic-related air pollutants.

Lead with the chemical formula of Pb is a toxic heavy metal that is widely used in different industries [10]. Lead (Pb) pollution may result from both indoor and outdoor sources. It is emitted from motor engines, particularly with those using petrol containing Pb tetraethyl. Smelters and battery plants, as well as irrigation water wells and wastewaters, are other emission sources of the Pb into the environment [10,11].

RESULTS AND DISCUSSION

Particle pollutants and their effect on human health

The size of particle pollutants is directly associated with the onset and progression of the lungs and heart diseases. Particles of smaller size reach the lower respiratory tract and thus have greater potential for causing the lungs and heart diseases. Moreover, numerous scientific data have demonstrated that fine particle pollutants cause premature death in people with heart and/or lung disease including cardiac dysrhythmias, nonfatal heart attacks, aggravated asthma, and decreased lung functions. Depending on the level of exposure, particulate pollutants may cause mild to severe illnesses. Long-term exposure to current ambient PM concentrations may lead to a marked reduction in life expectancy. The increase of cardiopulmonary and lung cancer mortality are the main reasons for the reduction in life expectancy. Reduced lung functions in children and adults leading to asthmatic bronchitis and chronic obstructive pulmonary disease (COPD) are also serious diseases which induce lower quality of life and reduced life expectancy. Strong evidence on the effect of long-term exposure to PM on cardiovascular and cardiopulmonary mortality come from cohort studies.

Ground-level ozone and its effect on human health

Ground-level ozone is believed to have a plausible association with increased risk of respiratory diseases, particularly asthma [12]. As a powerful oxidant, O_3 accepts electrons from other molecules. There is a high level of polyunsaturated fatty acids in the surface fluid lining of the respiratory tract and cell membranes that underlie the lining fluid. The double bonds available in these fatty acids are unstable. O_3 attacks unpaired electron to form ozonides and progress through an unstable zwitterion or trioxolane (depending on the presence of water). These ultimately recombine or decompose to lipohydroperoxides, aldehydes, and hydrogen peroxide. These pathways are thought to initiate propagation of lipid radicals and auto-oxidation of cell membranes and macromolecules. It also increases the risk of DNA damage in epidermal keratinocytes, which leads to impaired cellular function [13]. O_3 induces a variety of toxic effects in humans and experimental animals at concentrations that occur in many urban areas [14]. These effects include morphologic, functional, immunologic, and biochemical alterations. Because of its low water solubility, a substantial portion of inhaled O_3 penetrates deep into the lungs but its reactivity is scrubbed by the nasopharynx of resting rats and humans in around 17% and 40%, respectively [15].

Carbon monoxide and its effect on human health

The affinity of CO to hemoglobin (as an oxygen carrier in the body) is about 250 times greater than that of oxygen. Depending on CO concentration and length of exposure, mild to severe poisoning may occur. Symptoms of CO poisoning may include headache, dizziness, weakness, nausea, vomiting, and finally loss of consciousness. The symptoms are very similar to those of other illnesses, such as food poisoning or viral infections. No human health effects have been showed for carboxyhemoglobin (COHb) levels lower than 2%, while levels above 40% may be fatal. The mechanism of such toxicity is the loss of oxygen due to competitive binding of CO to the hemoglobin heme groups. Cardiovascular changes also may be observed by CO exposures that create COHb in excess of 5%. In the early 1990s, Health Effects Institute performed a series of studies associated with cardiovascular disease to determine the potential for angina pectoris with COHb levels in the range of 2–6%. The results showed that premature angina can occur under these situations but that the potential for the occurrence of ventricular arrhythmias remains uncertain. Thus, the reduction in ambient CO can reduce the risk of myocardial infarction in predisposed persons.

Sulphur dioxide and its effect on human health

SO2 is very harmful for plant life, animal, and human health. People with lung disease, children, older people, and those who are more exposed to SO2 are at higher risk of the skin and lung diseases. The major health concerns associated with exposure to high concentrations of SO2 include respiratory irritation and dysfunction, and also aggravation of existing cardiovascular disease. SO2 is predominantly absorbed in the upper airways. As a sensory irritant, it can cause bronchospasm and mucus secretion in humans. Residents of industrialized regions encountered with SO2 even at lower concentrations (<1 ppm) in the polluted ambient air might experience a high level of bronchitis. The penetration of SO2 into the lungs is greater during mouth breathing compared to nose breathing. An increase in the airflow in deep, rapid breathing enhances penetration of the gas into the deeper lung. Therefore, people who exercise in the polluted air would inhale more SO2 and are likely to suffer from greater irritation. When SO2 deposits along the airway, it dissolves into surface lining fluid as sulfite or bisulfite and is easily distributed throughout the body. It seems that the sulfite interacts with sensory receptors in the airways to cause local and centrally mediated bronchoconstriction. According to the Environmental Protection Agency (EPA) of the USA, the level of annual standard for SO2 is 0.03 ppm. Due to its solubility in water, SO2 is responsible for acid rain formation and acidification of soils. SO2 reduces the amount of oxygen in the water causing the death of marine species including both animals and plants.

Nitrogen oxides and its effect on human health

Nitrogen oxides are important ambient air pollutants which may increase the risk of respiratory infections, they are deep lung irritants that can induce pulmonary edema if been inhaled at high levels. They are generally less toxic than O_3, but NO_2 can pose clear toxicological problems. Exposures at 2.0–5.0 ppm have been shown to affect T-lymphocytes, particularly CD8+ cells and natural killer cells that play an important role in host defenses against viruses. Although these levels may be high, epidemiologic studies demonstrate effects of NO_2 on respiratory infection rates in children. Coughing and wheezing are the most common complication of nitrogen oxides toxicity, but the eyes, nose or throat irritations, headache, dyspnea, chest pain, diaphoresis, fever, bronchospasm, and pulmonary edema may also occur. In another report, it is suggested that the level of nitrogen oxide between 0.2 and 0.6 ppm is harmless for the human population.

Lead and its effect on human health

Pb exposure is often chronic, without obvious symptoms. It can affect the different parts of the body including cardiovascular, renal, and reproductive systems, but the main target for Pb toxicity is the nervous system. Pb disrupts the normal function of intracellular second messenger systems through the inhibition of N-methyl-D-aspartate receptors. Pb may also replace calcium as a second messenger resulting in protein modification through various cellular processes including protein kinase activation or deactivation. Abdominal pain, anemia, aggression, constipation, headaches, irritability, loss of concentration and memory, reduced sensations, and sleep disorders are the most common symptoms of Pb poisoning. Exposure to Pb is manifested with numerous problems, such as high blood pressure, infertility, digestive and renal dysfunctions, and muscle and joint pain.

CONCLUSION

Air pollution has a significant impact on human health, triggering and inducing a variety of diseases that result in high morbidity and mortality rates, particularly in developing countries. As a result, controlling air pollution is critical and should be at the top of the government's priority list. These countries' policymakers and legislators must update all air pollution laws and regulations. A powerful environmental protection organization must lead the coordination of various departments involved in air pollution. An effective environmental protection organization should have adequate budgets for administration, research and development, monitoring, and full environmental control, including air pollution.

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Geophysical Measurement Over Tuzla Salt Deposit with a Target to Research Environment Properties

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Abstract. The salt exploitation in salt deposit in Tuzla, BiH, from long time ago made huge problems on surface of terrain and impact on the environment. Consonance with that information's we get idea to realize geophysical measurements over ERT method (Electrical Resistivity Tomography method) how we can present condition mass above salt deposit. It's made of three profiles, two perpendicular on fractures visible on surface terrain and one length, with a deep to the 150 m, depending from length of profiles. The result of research shows as clearly on how is near surface underground water, and to on provisory stable part of mass over which contact is on the surface terrain induce different brand fractures, which has induced damage many objects on surface. Long period of sinking induced by uncontrolled salt exploitation impact on underground water which was salted and on different way polluted surface vegetation.

Keywords: salt exploitation, geophysics, sinking, fracture, environment

INTRODUCTION

The city of Tuzla had a long time period problem with sinking because of salt exploitation underground of city. As a consequence, many objects in the central city zone have been destroyed. Exploitation salt over uncontrolled melting salt was used over 116 years. This type of exploitation initialized the biggest problem which was manifested on the surface like: fractures, field harvesting, fractures on objects, objects deviation, etc. More intensive deformation on the surface of the terrain, objects and infrastructure started from 1956, when more intensive exploitation has started. From that time, systematic follow deformation on surface terrain used geodetic methods started. The result of these measurements showed the sinking zone over 500ha and how is in central zone sinking over 12 m for the period 1956-1999. On some places, deformation and sinking follow exploitation with sometime late, for a different for crossing part, where exploitation don't follow sinking. All that information can present some empty space with unstable soil with high velocity of salt and fresh water. That was reason to us to use geophysical measurements (ERT method) with technical and experts support of colleagues from Bologna University, Italy.

The method of electro resistivity tomography (ERT)

The ERT method was directly related to emission of electrical waves with different velocity and receiver on other side. Any material of soil-rock has different resistivity from which depends the electric wave acceleration over material. As a result, we get tomography (graphic) with a different colour for each intensity of resistivity, what depends on: type of material, temperature, presence of water and many other factors.

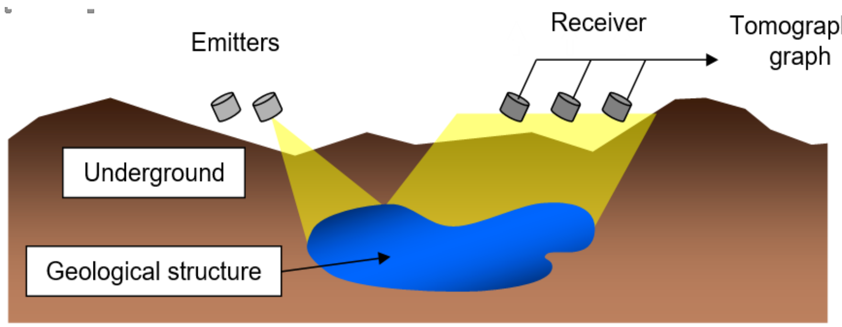

Figure 1. Schematic view of electro resistivity method

As we can see on the figure 1, emitters are located on the one side and receivers sending electrical signal on the other. Distance between electrodes and number of all electrodes determine depth and precision of the measurements. With use of more electrodes, more correct result we get and with bigger distance between two last electrodes, depth of measurement is increased. In the data post processing it is possible to experiment with result of measurements, if we give software different electrodes (emitter-receiver). In our case, distance between installed electrodes was 15 m (for two cross over profile) and for central profile 20m, what was been enough for tomography deep 100-120m, and for central profile till 160m.

Resistivity of groundwater varies between 10-100 Ωm, depending on presence of salt in water (like on table 1).

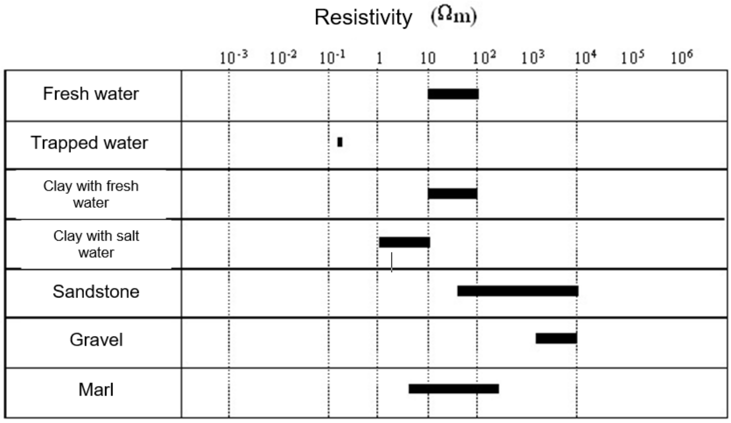

Figure 2. Resistivity values for different kinds of material

The results of geophysical measurements in Tuzla

Geophysical measurements didn't provide detailed data, because of small depth of measurement. But, they are enough to get theoretical prediction on the surface with deficit mass in underground.

Figure 3. Connection of electrodes with equipment by cable

Very clear from the map we can see how on the place where is underground strong material in contact with pure material come to different reaction on surface like fracture, break and zone of fault. Electrodes on short distance profile were installed 30 cm in soil in a distance of 15 m (Figure 3).

Deformations on the surface of the terrain can recognize in urban area easily, where fractures and break we can see on asphalt, objects and other engineering objects. For a different form space without objects, where deformation is a bit difficult to recognize on the surface. That is location from the north-east side of salt deposit, where vegetation covers stronger and disable visual view on the surface of terrain.

On the map 1, location of measured profile recognized by GPS is presented. Profile AA" and BB" is positioned vertically on fractures on surface terrain and profile CC" is vertical on two profiles mentioned before.

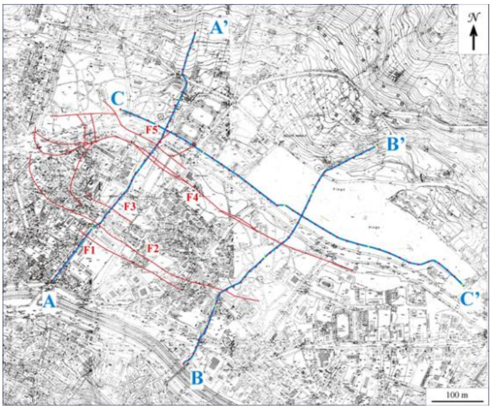

Figure 4. The geophysical profile on the terrain (AA", BB", CC"), with F1 to F5, the biggest fracture on the surface of terrain is registered

Where is often change different strong material and tectonic activity we can see on that place acumullation groundwater like consequence of break natural groundwater flow. Fractures on the surface terrain exist usualy on the place contact point stable and unstable part of soil.

On the profile AA" (figure 5) relative resistivity of material varies about 18 Ωm, what presents relative high resist, with the most low resistivity from 7 Ωm. This condition of resistivity gives us direction to conclude how is massive very deformed, cuted and like that good place for collect and flow groundwater.

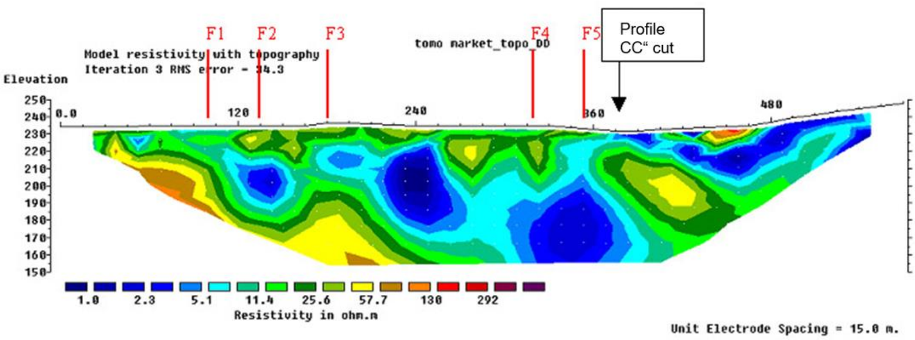

Figure 5. Tomographic profile AA´ post-processing by method dipole-dipole

On the general overview, resistivity varies from 20 Ωm, in some zone till 7 Ωm in others. If we look from geological side, marl with nice granulated sand can exist till 100 m. These layers exist on 50 m tick marl, that way increase resistivity below 100 m deep can correlate with more present salt water. On the zone present „anhydrite horst“ (on the profile marked like F4), become late sink zone, especial if we talk about contact zone anhydrite and zone of intensive sinking. That process caused destroy of all objects which were built on them. In the base on the any change material which builds cover soil salt deposit become to process of shearing, what have for consequence fractures on the surface of terrain.

Even we know how the border of end salt deposit finish by „anhydrite ridge“ on the surface, we have a situation how the sinking zone is a lot bigger because of impact deppression funnel. That way we can say how fractures F1 and F2 present last elements of impact deppresion tunnel. In that part is very high horizontale move, for a different from center of sink where we can see active just vertical move terrain.

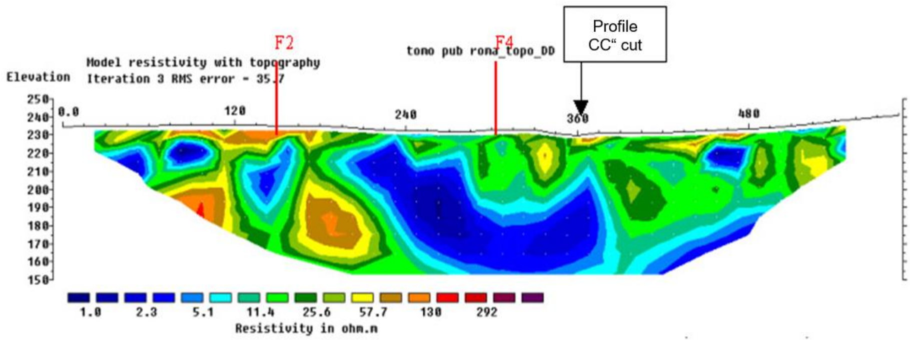

Figure 6. The tomographic profile AA´ post-processing by method dipole-dipole till depth of 150 m

If we look profile AA' we can see how quality of rocks in underground reflected on surface, this information can be very important to predict how the surface behaves in the future period.

Over interpretation profile CC' (figure 7) should be taken in consideration how on part of Pinga we have more than 15 m artificial embankment. From the model of resistivity we can see how underground we have blocks which „flow“ in labile material which have a lot of water. We can recognize too, how on the place fracture on the surface of terrain come to infiltration fresh surface water and their flow underground, what is extra impact on massive stability.

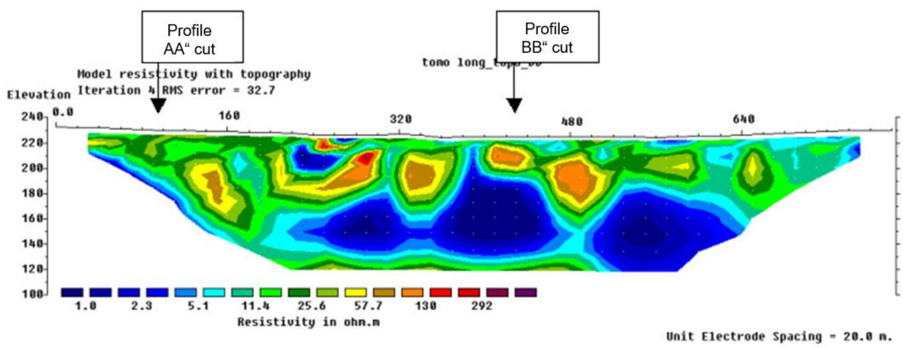

Figure 7. The tomographic profile CC´ post-processing by method dipole-dipole till depth of 100 m

CONCLUSION

The exploitation on salt wells in Tuzla was stopped in 2003, but that was not the end of sinking. From that time, sinking over year has been lower and lower but till now didn't stop. All empty space below Tuzla was filled by salted water and engineering geological process continued to happen even exploitation stopped and try to get some stable position. All this process was not explored enough and we can just guess future conditions of soil over the old salt deposit.

Geophysical exploration was applied on this area for the first time, providing with interesting data and defining some direction for the future exploration. From the geophysical graphics we can see how surface water over fracture infiltrates below surface and mixes with salt water. In the future, special attention should been given to the fracture properties. Should be made geophysics research made deeper, research with georadar or refraction seismics is recommended, that will give us better and more quality results.

Salt water impact on environment and we can found on surface some spring which damage vegetation around. After the end of salt exploitation, groundwater increases on surface and mixes with spring water. Long time of salt exploitation impact on landslide, sinking, soil collapse on surface, all off that total destroy environment and pretend to become place of waste deposit and bacterial hot spot.

From the all information presented in this publication we can conclude how application of modern geophysics methodology in detection damage on salt massive deposit can get very useful data. This result gives us a good base for the future research with modern technology.

ACKNOWLEDGEMENTS

Acknowledgments to the Region Emilia Romagna, Province of Ravenna and CIRSA - University of Bologna, for financing the project. Municipality and University of Tuzla provided data and cooperated for the field survey.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
Technical Faculty "Mihajlo Pupin", Zrenjanin & Faculty of Sciences and Mathematics, Nis

Climate Change Education - Guidelines and Recommendations

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Abstract. In contemporary literature, climate change education is viewed and defined as a basic instrument for empowering institutions, groups and individuals for climate change mitigation and adaptation. The paper elaborates on climate change education in the context of education for sustainable development with special reference to guidelines and recommendations for its implementation in the education system and practical realization (curriculum design, development of key competencies, etc.).

Keywords: climate change education, sustainable development, curiculum, key competencies

INTRODUCTION

In professional and scientific literature, the problem of climate change is described as: "global challenge of magnitude that human beings have not encountered before" [1, p. 3]; one of the most controversial global problems in the last fifty years [2]; probably the most important global problem of the 21st century [3]; "a wicked problem that threatens the continuity of life" [4, p. 339]; one of the most serious challenges on the path to sustainable development [5] etc.

In a broader sense, climate change refers to those changes in the Earth's climate that can be attributed to anthropogenic[*] impacts, including global warming[†] and other environmental impacts that, among other things, lead to rising sea levels, agricultural disruptions, extreme weather events, biodiversity loss [8] etc. There are multiple causes of climate change whose effects are gradual and mutually conditioned, and an intervention in one area can bring unexpected changes in another area [9].

This is understandable given that there are many factors at play in the climate system, including the Sun, the Earth's atmosphere, the Earth itself, oceans, ice, flora and fauna, as well as different aspects of their interaction that are difficult to identify and predict.

[*] It is well known that there are some scientists who claim that temperatures are not rising at all, some scientists that claim that temperatures are rising, but due to natural reasons, and not human activities, as well as some scientists that believe that antropogenous global warming is real, but that its effects will not be so serious or destructive [6].

[†] According to the special report IPCC [7], the world should switch completely to sustainable resources by 2050 in order to avoid the catastrophic temperature rise of 2°C.

According to authors, this is a ‘super wicked’ problem that cannot be solved through a technical “engineering” approach, because it is based on value perspectives and has countless potential solutions that cannot be tested beforehand [10].

If humanity seeks to respond to the challenges of climate change, it must turn to education, which has a key role in promoting understanding and helping individuals, society and governments make informed decisions. In this regard, it is important not only to provide the necessary information, but to ensure that education, especially schools, is mobilized to re-orient society towards sustainable practices [11]. Thus, education for sustainable development emerged as a “cornerstone for the fight against climate change” [12, p. 2] all over the world. Such education promotes multi-stakeholder social learning, emphasizes the empowerment of communities and citizens, engages with key issues such as human rights, poverty reduction, sustainable livelihoods, environmental education and gender equality in an integral way; and encourages changes in behaviour that will create a more sustainable future. Climate change education is therefore a subject that fits well within the ESD agenda [5]. Education for sustainable development includes a variety of educational responses to climate change, promotes a systematic and multidisciplinary understanding of causes and effects, and proposes learning approaches that contribute to the development of critical thinking and problem-solving skills, and attitudes and knowledge for making informed and responsible decisions. In other words, education for sustainable development provides a framework for climate change education [13] which is “increasingly becoming one of the world’s best hopes for preparing individuals to adapt to and mitigate[‡] the effects of climate change impacting their communities” [14, p. 106].

CLIMATE CHANGE EDUCATION FOR MITIGATION AND ADAPTATION

The goals of climate change education are often described as “climate literacy”, and include the understanding the climate and climate change from a scientific point of view; empowering individuals, organizations and institutions for informed decision making; behavior change; and stewardship, where appropriate. Sometimes, the ultimate goal is to achieve positive effects on the climate, which is reflected in the mitigation of greenhouse gas emissions, but also in the increase of the capacity to adapt to the effects of climate change [15]. Education focused on mitigation of greenhouse gas emissions implies learning oriented towards changing consumption patterns (e.g., using renewable energy sources, creating greener technologies), i. e. towards changing lifestyles, economies and social structures based on the overproduction of such gases. In addition, the commitment of educational institutions to climate change mitigation is reflected in their quest to

[‡] Mitigation and adaptation are two basic strategies in solving climate change problems. The first strategy refers to the interventions which have a goal to reduce the concentraton of greenhouse gases (investment in clean energy, forest conservation, etc.), while the second strategy refers to the measures which aim at reducing the vulnerability of natural and human systems to the effects of climate change and adaptation to changing climate through adjustments in social, ecological and economic systems [5].

become carbon neutral and energy efficient, and to reduce their environmental footprint. When it comes to climate change adaptation, the role of education is crucial because it contributes to the acquisition of knowledge and skills needed for informed decision-making about ways to adapt individual lifes and livelihoods, as well as ecological, social or economic systems to the changing environment [5]. Education for climate change adaptation includes disaster education, i. e. learning how to behave in case of fire, flood, drought, storm and other natural disasters. Since children are particularly sensitive to the consequences of natural disasters, curricula that include local disaster risks and ways of responding to them can improve the resilience of young people [16]. In addition, education can increase the resilience of particularly vulnerable communities, i. e. communities most likely to be affected by the consequences of climate change, through the acquisition of knowledge about how the climate change will affect them and what they can do to protect themselves from possible negative consequences [1].

It can be concluded that climate change education is oriented towards different populations - children, youth and adults, who should make their occupations and roles (as consumers, travelers, activists, etc.) more sustainable. For this reason, climate change education involves both school and university programs, as well as non-formal and informal education [2]. In order to answer the question of how to integrate this education into school systems and everyday life, the authors of this paper focused on numerous guidelines and recommendations given within conventions, declarations, manuals, articles, and other relevant sources.

METHODOLOGY

The desktop research was conducted with the aim of identifying guidelines and recommendations in the field of climate change education. Databases that were used include Google Scholar, KoBSON, Science Direct and UNESCO Library, and the following keywords were searched: climate change education, education for mitigation, education for adaptation, climate change education guidelines, climate change education recommendations, climate change education handbook. The search led to 64 sources. After their initial review, by reading abstracts or introductions, 17 sources were singled out. These sources were analyzed in detail in order to identify those that contain recommendations and/or guidelines for climate change education. There were 10 such sources, and their guidelines and recommendations are presented below.

IMPLEMENTATION AND PRACTICAL REALISATION OF CLIMATE CHANGE EDUCATION

Article 6 (Education, Training and Public Awareness) of the *United Nations Framework Convention on Climate Change* [17] emphasizes the need to: develop and implement educational and public awareness programs on climate change and its consequences; provide public access to the information on climate change; ensure public participation in tackling climate change; provide training of scientific, technical and managerial staff, etc.

The recommendations presented in the *International Alliance of Leading Education Institutes* [11] have been formulated in order to inform and qualify policy initiatives concerning climate change and education. These recommendations address: the need for schools to take a leading role in education for sustainable development; empowering universities in the preparation of future teachers in this field and the role of governments in empowering teachers for the practical implementation of education for sustainable development; establishing interaction between researchers, teachers, NGOs, etc. in order to exchange knowledge, develop the curricula, etc; the need to increase the research on education for sustainable development in order to identify current trends, desirable practices, problems of general relevance etc.

The publication *"Combating Climate Change through Quality Education"* [18] provides the following recommendations: (1) education should become an integral part of strategies aimed at climate change adaptation and mitigation, given that education helps individuals and communities acquire the necessary knowledge and skills and change their attitudes and behaviors; (2) it is necessary to promote education for sustainable development, which includes disaster risk reduction, quality learning, and environmental and climate change education, i. e. to achieve cooperation of policy makers in these fields in order to develop a common understanding of a coherent approach to leveraging education to combat climate change; (3) it is necessary to finance education aimed at combating climate change, with a focus on the education of young women[§]; (4) it is necessary to strengthen the knowledge base, exchange of information and networking of communities dealing with education for sustainable development, climate change, risk reduction, environmental education, etc. (e.g., sharing good practices, lessons learned, the most effective adaptation and mitigation measures).

The study *"Informing Effective Responses to Climate Change"* [19] provides recommendations which, on the one hand, indicate the need for a research program in order to: establish baseline levels of public understanding and responses to climate change and monitor changes in climate literacy, including knowledge, risk perception and behaviour; assess the effectiveness of various strategies and programs in the field of climate change education and communication; provide support in increasing the capacity of educational institutions, scientists and students to cooperate with various groups and stakeholders needing climate information. On the other hand, the recommendations are: to promote teacher training programs in the field of climate change education; create educational tools, materials and technology, including web-based materials, related to climate change; set national climate education standards; provide guidance and support to climate change education in informal environments, such as museums, zoos and aquariums.

Based on the analysis of relevant sources, Anderson [5] singles out recommendations for climate change education teaching and learning. The author emphasizes that climate literacy can be improved through "sustained, active learning activities using integrated,

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[§] The education of young women in this area will contribute not only to the fight against climate change, but also to the establishment of environmental sustainability, the fight against HIV/AIDS and other diseases, decreasing child and maternal mortality, and related aspects of sustainable development [18].

cross-discipline curricula" [5, p. 198]. Climate change education is based on active learning aimed at solving problems in the local community. In addition to acquiring knowledge about the concepts and implications of climate change, it is important to develop problem-solving skills and critical thinking, i. e. strengthen the capacity of individuals to achieve positive outcomes. Problem-based education can encourage students to behave in a sustainable manner if they are presented with information and behaviour change options in order to reduce their personal environmental footprint. Narrative techniques, visual imagery and persuasive texts have proven to be very successful techniques for learning complex problems such as climate change. Finally, the author [5] points out that teacher education is essential for providing quality climate change education.

The Lima Ministerial Declaration on Education and Awareness-raising of 2014 particularly emphasizes the need for determined educational initiatives aimed at the climate change issues [2]. This document points out that education, training, public awareness, participation and access to information are essential for achieving climate-resilient sustainable development in all countries. The need to encourage all governments to integrate climate change content into curricula and awareness-raising on climate change into development and climate strategies and policies was also emphasized [20].

UNESCO [1] offers the following recommendations on how education for sustainable development and climate change education can be integrated at the national level: (1) policy development - governments need to integrate this type of education into all levels and types of education, as well across the curriculum; (2) governance and resources - the integration of this education at the national level requires strong government support, with cross-sectoral coordination and harmonization; (3) curriculum development - it is necessary to ensure that education for sustainable development and climate change education feature at all levels of education, which requires creating new work units for teachers, developing new pedagogical approaches focused on critical thinking and problem-solving skills, and adapting the curricula to local contexts; (4) capacity-building of teachers and education planners - teachers and non-teaching staff must understand climate change and have locally-adapted materials for classroom use; (5) public awareness, communication and stakeholder involvement - governments should support non-formal education opportunities provided by communities, civil society and the media.

In 2016, UNESCO and the UNFCCC** published guidelines aimed at improving education, raising awareness and informing the public about climate change and sustainable development, within the *"Action for Climate Empowerment (ACE) programme"* [21]. The guidelines include 4 phases and 10 steps that help countries develop a National ACE Strategy. The initiation phase includes the following steps: establish coordination; gain a strong conceptual base; take stock of existing national policies and plans; and create a monitoring and evaluation plan. The planning phase covers the next steps: assess needs and delivery capacities; create draft strategic plan; and

** The United Nations Framework Convention on Climate Change provides an overall framework for intergovernmental cooperation in the fight against climate change. Under this Convention, governments: (1) collect and exchange information on carbon emissions, national policies and best practices; (2) launch national strategies aimed at reducing emissions and adapting to the effects of climate change; (3) cooperate in preparing for adaptation to the impacts of climate change [13].

conduct stakeholder consultations. The implementation phase includes: establishing cross-sector partnerships for implementation and mobilizing financial and technical resources. The last phase refers to monitoring, evaluation and reporting and involves creating a monitoring, evaluation and reporting plan.

In the UNESCO publication *"Getting Climate Ready: A Guide for Schools on Climate Action"* [12] the whole school approach to climate action[††] was emphasized, with guidelines for including climate action in four fields: school governance; teaching and learning; facilities and operations; and community partnerships. The first guideline refers to school governance and involves *creating a climate action team*, whose role is to develop, implement and, if necessary, change the school's climate action plan in cooperation with other stakeholders. Teaching and learning includes the following guidelines: *teach climate change within all subjects* (e.g., in visual arts students can create posters about the impacts of climate change, in language classes they can write poems and stories in response to photos or videos about climate change, etc.); *teach critical* (identifying information necessary to examine a problem, making recommendations, etc.), *creative* (searching for possibilities, designing solutions, etc.) *and futures thinking skills* (envisioning probable, possible and desirable futures, applying the precautionary principle etc.); and *empower students to take action* (e.g., by engaging students in campus change projects). The next guideline is related to facilities and operations, and it states that *schools should become models of climate action* through actions aimed at reducing the consequences of climate change and protecting the environment (planting trees, increasing energy efficiency, etc.). The last guideline refers to *building community partnerships for learning and teaching* (e.g., through learning outside the classroom, organizing trips in the local community, experiential learning, etc.).

Publication *"What is Excellent Climate Change Education?"* [22] offers the following guidelines for excellent climate change education: (1) framing is everything – when creating climate change communications, a special consideration should be given to the target group and the way in which information can be interpreted; instead of being viewed as an environmental problem, climate change can be presented in the context of social and economic sustainability, as a public health problem, etc; (2) remember the audience - climate change education should be adapted to students' developmental stages (e.g., environmental appreciation and environmental sensitivity should be developed in preschool and lower grades of primary school, while later the focus is on problems, values, research and practical skills); (3) go beyond science - fear-based messaging is not effective when it comes to encouraging behavior change; it is necessary to shift the focus from problems to solutions (e.g., with the help of images, metaphors, computer technology); (4) action oriented - instead of provoking concern about the global issues, students should be encouraged to take concrete action (e.g., for climate change mitigation).

[††] The whole school approach to climate action refers to a situation in which every aspect of an educational institution, i. e. school management, teaching contents and methods, campus and facilities management, and cooperation with the wider community, includes actions aimed at reducing climate change [12].

CONCLUSION

In recent years, climate change and debates about the anthropogenic contribution to global warming have become a subject of interest at all levels of society, including scientists, politicians, citizens, students and various types of organizations [23]. The analysis of the literature indicates the connection between climate change education and education for sustainable development. The complexity and dynamics of climate change require its consideration in the context of education for sustainable development. There is a consensus that climate change education should include aspects (environmental, social, economic, cultural, etc.) that will raise awareness of the different perspectives, problems and challenges posed by anthropogenic impacts on nature and the environment in general, with a focus on interdisciplinary approaches to this issue.

The analysis of recommendations and guidelines given in relevant sources suggests that there are common recommendations for educational work in the field of climate change. Those recommendations and guidelines can be cathegorized as follows:

(1) *policy making and cross-sectoral cooperation* - empowering governments and relevant ministries to coordinate actions in the field of climate change education, integrating climate change education into national strategies and policies;

(2) *non-formal and informal education, public participation* - designing educational programs to raise awareness of climate change, public availability of climate change information, empowering active public participation in addressing climate change issues;

(3) *schools, curriculum and didactic aspects* - combating climate change as a part of everyday school life, integrating climate change content into curricula, availability of relevant educational resources, encouraging students' critical thinking and problem-based learning;

(4) *teacher competencies* - adequate preparation of future teachers for educational work in the field of climate change, their empowerment for the implementation of education for sustainable development and climate change education, promotion of professional development programs in this field;

(5) *strengthening research capacities, networking and good practices* - broader coverage of climate change issues through research, exchange of experiences, good practices and information between stakeholders, such as researchers, scientists, NGOs, institutions, etc.

The diversity of the fields of action in relation to climate change education points to its complexity and the need for joint efforts to intensify education in all these sectors. Climate change education, as a subject of state policy, an integral part of formal, non-formal and informal education, and a focus of research efforts, is a necessary step towards achieving the *ultimate* goal of climate change education, i. e. towards climate change mitigation and adaptation.

ACKNOWLEDGEMENTS

This research was published with the support of the Ministry of Education, Science and Technological Development of the Republic of Serbia, following the Agreement on Realization and Financing of Scientific Research of the Scientific Research Organization in 2022, Agreement Registration Number 451-03-68/2022-14 /200148.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
Technical Faculty "Mihajlo Pupin", Zrenjanin & Faculty of Sciences and Mathematics, Nis

Student Preconceptions About Carbon Fluxes

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Abstract. Physics students typically have prior knowledge on the topics of carbon emissions and atmospheric carbon dioxide concentrations, which stems largely from high school education. To some extent it can be argued that students also gain some ideas about these topics from the media. However, when teaching about carbon cycles at the graduate level precise quantitative data analysis is required and it is often found that the students do not have adequate information on the topic of carbon cycles, especially in the atmosphere. Of particular interest is the issue of data access: Do students know where to get reliable data on atmospheric carbon dioxide concentrations? Do they know how to access it, download it and analyse it on the fly? Positive response is seldom the case, which is rather unfortunate since physics students should possess such skills, to engage in public space more easily. To create effective ways of teaching about carbon cycles a plausible approach is to draw upon analogies with prior well-established ideas that the students are well acquainted with. For example, by using the analogy between accelerated motion and the rise of atmospheric carbon concentrations, we demonstrate how to effectively teach about rising atmospheric concentrations at the bachelor and high school level. We first devise a poll with questions on carbon cycle in the atmosphere, such as: data access, rate of increase of carbon dioxide, the effect of photosynthesis, emissions per capita and so on. Afterwards we demonstrate to the students how to easily access the data and do the analysis themselves.

Keywords: carbon fluxes, carbon emissions, Keeling curve, student preconceptions

INTRODUCTION

At present global carbon emissions are estimated at 10 gigatons of carbon per annum (Friedlingstein, et al., 2020). It is estimated that half of the annual emissions end up in the atmosphere, a quarter on land and a quarter in the ocean. The part which remains in the atmosphere causes an increase in carbon dioxide concentrations, as evident strongly in the Keeling curve, which subsequently adds to the greenhouse effect. This turn of events is well known to all modern-day physicists and environmental scientists, especially climate experts.

What is arguably less well known, are the precise numbers of carbon fluxes. For example, the global annual carbon assimilated in photosynthesis (primary production), both on land and at sea, is estimated at 100 gigatons of carbon (Field et al., 1998). Therefore, for the first time in the Anthropocene, the rate of carbon emissions of our civilization is an order of magnitude lower than the rate of global annual primary production (Lenton &

Watson, 2014). Comparing the two numbers by a "back of the envelope calculation" one immediately grasps that two dominant forces at play are our civilization and the biosphere. This is also evident in the Keeling curve as a seasonal cycle superimposed on a non-linear trend.

This subsequently relates to the issue of sustainability in the following manner: the economy is coupled to carbon emissions and carbon is sequestered in part by the biosphere. For example, in the ocean, we speak of the biological pump (Williams & Follows, 2011), a process in which assimilated carbon sinks to depth and is in effect isolated from the atmosphere. In this context the biosphere provides a service, namely removing excess carbon from the atmosphere and the oceans. However, at present, the rate of removal and storage is preceded by the rate of emissions and is likely to stay as such, since the processes act at different time scales. In short, the problem is a temporal one: the consequences of our present actions will be felt by subsequent generations (Perman et al., 2011), amongst which are the very students that study these topics today.

It can be argued that awareness about anthropogenic carbon emissions amongst students varies greatly. The extent to which they are exposed to this topic varies between generations of students and also due to their interests. For example, students who study environmental physics, chemistry and ecology are arguably more likely to be aware of such issues, as they are presumably more inclined to explore them. In modern-day environmental curriculums at the bachelor and master levels, carbon fluxes are thought typically in *Meteorology* and *Climate Change* courses. The Keeling curve is typically presented to the students to demonstrate the recent rise in atmospheric carbon concentrations.

However, other components of the carbon cycle are seldom discussed during bachelor and even master courses. It is often the case that students acquire the excess information on the topics relating to carbon fluxes and abatement procedures from the media. Unfortunately, this information is seldom quantitative and, in most cases, presented with a certain dose of urgency, the so-called doom and gloom journalism. This may leave more students stranded between media-driven frenzy and solid quantitative facts.

With this in mind, we have attempted to quantify student preconceptions on the topic of carbon fluxes, with a focus on the atmosphere. We made a simple 10 questions poll given below. Subsequently, we provide a simple and effective way of demonstrating basic facts about carbon concentrations in the atmosphere, and more importantly, we give students simple ways of acquiring reliable data on atmospheric carbon concentrations.

METHODS

With the goal of examining the knowledge and opinions about the concentration and representation of carbon dioxide in the environment, a created poll (see Table 1) was anonymously conducted during the academic year of 2021/2022 at the University of Split, Croatia.

Table 1. The questions poll given to the students, with correct answers given in bold

Questions	Answers			
1. Do you have any experience with atmospheric carbon data?	A) Yes	B) No		

2. Will the atmospheric carbon dioxide concentration be higher next year?	**A) Yes**	B) No		
3. How is the carbon dioxide concentration changing in the atmosphere?	**A) Increasing**	B) It is stable	C) Decreasing	
4. Does photosynthesis affect carbon dioxide concentration in the atmosphere?	**A) Yes**	B) No	C) I do not know	
5. Does carbon dioxide concentration in the atmosphere depend on the season?	**A) Yes**	B) No	C) I do not know	
6. More carbon is stored in the:	A) Atmosphere	**B) Ocean**		
7. Estimate how much carbon does each person emit annually due to their lifestyle.	A) 10 kg or less	B) 100 kg	**C) 1000 kg or more**	
8. Estimate the global annual anthropogenic carbon dioxide emissions in tons.	A) 35 000	B) 35 000 000	**C) 35 000 000 000**	
9. Estimate how lower were the carbon dioxide concentrations in the atmosphere during your birth.	A) 1% less	B) 5% less	**C) >10% less**	
10. How long does the carbon dioxide remain in the atmosphere?	A) 1 year	B) 10 years	**C) 100 years and more**	D) I do not know

That way, the students from the *Faculty of Chemistry and Technology* and the *Faculty of Science* expressed their familiarity with the facts about the carbon fluxes issue. The information about the surveyed students is given in Table 2.

Table 2. The number of surveyed students by gender and faculties.

	Faculty of Chemistry and Technology	**Faculty of Science**	∑
Males	14	18	32
Females	94	15	109
∑	108	33	**141**

The answers were analyzed by groups of closely related issues. The first question was observed separately, in order to get an insight into previous experiences of students in working with carbon dioxide data. The following two questions revealed the awareness of carbon dioxide concentration change in the atmosphere. Questions 4, 5 and 6 encompass the very link between the environment and carbon dioxide, while the last four questions deal with the assessment of human and civilization impact on atmospheric carbon concentration. The answers to the questions are shown in percentages.

RESULTS AND DISCUSSION

In Fig. 1. the percentage of students with previous experience in atmospheric carbon data analysis is given, revealing that the majority were never involved in such activities.

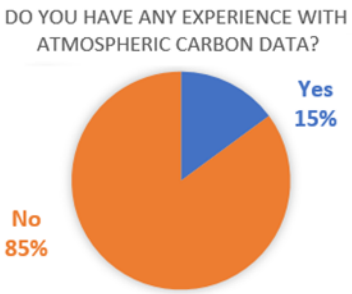

Figure 1. The percentage of experienced students in carbon data analysis.

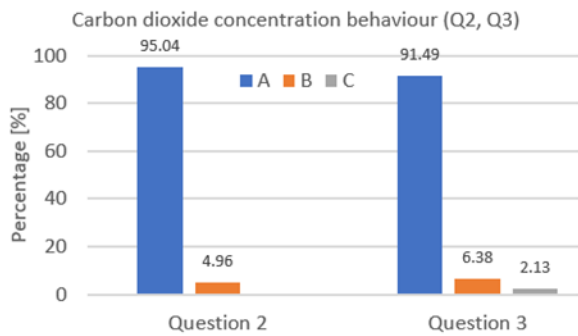

Figure 2. The answers about the changes in carbon dioxide concentration.

When thinking about the next year's expected concentration, and the character of its change, most students agreed to an expected increase next year, with increasing concentration in general. More than 90% of students are aware of such a change occurring (see Fig. 2). Speaking of photosynthesis and the seasonal effect on the carbon dioxide concentration and whether it is mostly stored in the atmosphere or the ocean, the students had more divided opinions, being mostly aware of the photosynthesis effect (86%), little less on the seasonal impact (around 60%), but in a disagreement in what is its main storage (Fig. 3). More than half of students chose the atmosphere rather the actual ocean as more abundant in carbon dioxide. Regarding the photosynthesis and seasonal impact, 56% of students knew both answers, while only 26% was right about all the questions from Fig. 3.

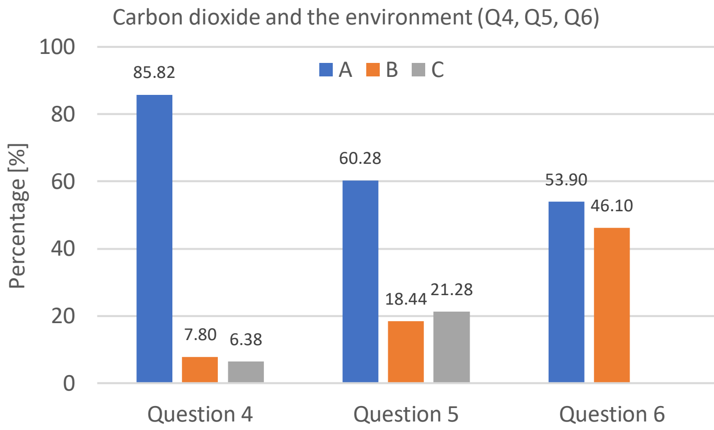

Figure 3. The questions encompassing the environment and carbon dioxide relation.
In the end, the estimation of the human impact of carbon dioxide concentration is given within the answers to the last four questions, showing that the golden mean was mostly and wrongly chosen as the answer for the enormous annual produced mass, concentration change, and long presence of carbon dioxide in the atmosphere (Fig. 4.).

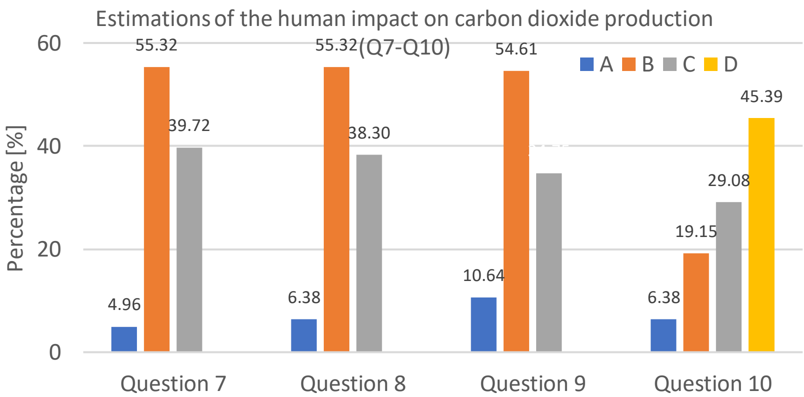

Figure 4. The questions about quantitative estimates were mostly answered wrongly

In the only question where the option was not to answer, that option was mostly chosen (45%), making the estimations the hardest among these basic questions. 23.5% of students were both right about how much carbon dioxide each person emits annually and at the same time what is the global annual anthropogenic emission, while only 3.5% knew all the answers to the questions from Fig. 4.

When observing the percentage of students by the number of correct answers, a Gaussian trend was noticed. The first question was not included in Fig.5. due to its lack of a correct answer. Only 2.84% of students had all the correct answers (9/9). 24.11% had a result of 5 correct answers. Interestingly, among the students who reported previous activity in carbon dioxide data analysis, the average score was (5.57 ± 1.43), while the less experienced students had a slightly lower score of (5.14 ± 1.63). Hence, we cannot confirm that previous experiences with carbon dioxide data, lead to greater awareness and knowledge about it.

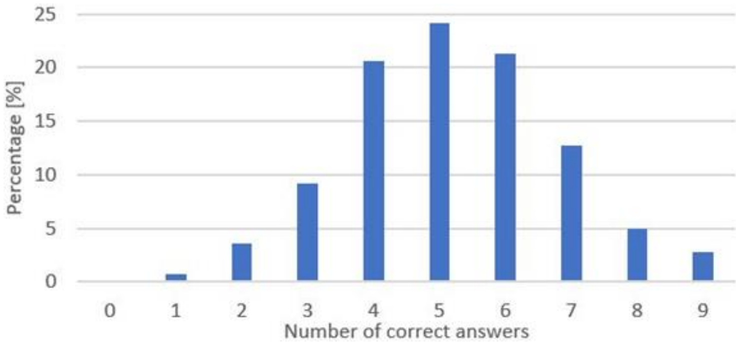

Figure 5. Percentage of students by the number of correct answers

CONCLUSION

A simple poll was conducted on 141 students at the University of Split related to the topic of carbon fluxes. The aim of the poll was to ascertain their preexisting knowledge and awareness on the issue carbon fluxes and atmospheric carbon dioxide concentrations. We found that the majority of the students had no prior experience with atmospheric carbon dioxide data, were mostly aware of the recent trends in carbon emissions but were less so aware of their magnitude. With respect to this issue, we gained insight at what elements should be emphasized in present physics and chemistry curricula related to environmental issues. Finally, we recommend easily accessible data sets that the students can access, download, and analyze the data in accordance with their curricula. The data we recommend provide a simple, yet effective way to teach students basic facts about carbon concentrations and fluxes.

These data on carbon fluxes can be easily acquired from The Global Carbon Project at www.globalcarbonproject.org. Here the students can get the latest numbers on atmospheric carbon concentrations as well as other parts of the carbon cycle. The website also provides the global carbon budget annually, the latest being the Global Carbon Budget 2021 accessible via essd.copernicus.org/preprints/essd-2021-386/. This can also be used as literature for seminars and lectures. The website also provides numerous up-to-date figures and presentation materials, which are easily accessible via robbieandrew.github.io/GCB2021/ and more importantly open source.

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Conference Proceedings
ICPAE 2022, 31st March – 2nd April, Zrenjanin, Serbia
Technical Faculty "Mihajlo Pupin", Zrenjanin & Faculty of Sciences and Mathematics, Nis

A Physically-Based Numerical Model for Pollen Forecast

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Abstract. One of the largest healthcare issues is the emergence of allergies, which is frequently triggered by pollen particles. Inhaled pollen grains released by trees, grasses, and ragweed are the most significant risk factors for developing asthma. Establishing a forecasting system with the objective to issue early warnings for high concentration pollen episodes is of particular interest but still challenging task. Over the last decade several pollen models have been developed to predict the atmospheric pollen process. In this study the characteristics of newly developed physically-based numerical pollen model PREAM (Pollen Regional Atmospheric Model) is presented. The potential of the model to correctly mimic extreme pollen events in Melbourne, Australia will be demonstrated.

Keywords: pollen, numerical simulation, forecasting

INTRODUCTION

More than 300 million people worldwide have asthma [1] resulting, at the global scale, in approximately 180,000 deaths annually, most of which are preventable. Approximately 50% of adults and 90% of children with asthma had an allergic form of the disease [2]. The allergy occurrence is often caused by pollen and has today increased to such an extent that is regarded as one of the major current healthcare problems. The strongest risk factors for developing asthma are inhaled substances and particles that may provoke allergic reactions; pollen grains emitted by trees, grasses, and ragweed are among the most commonly present particles. The pollen dispersion process is mainly driven by atmospheric conditions. It starts with the pollen emission which depends on plant phenology, the diurnal plant physiological cycle, and on near-surface atmospheric conditions. When a plant reaches the pollination period, pollen emission is triggered by sufficiently strong near-ground turbulence associated often with stormy weather. Emitted pollen is then dispersed by vertical air mixing and by free-atmospheric horizontal transport. In the final phase of the pollen atmospheric process, pollen grains settle down to the Earth surface by wet deposition (due to precipitation) and by dry deposition (due to gravity and near-surface turbulence). In order to predict and/or study the atmospheric pollen process, several pollen numerical models have been developed over the last decade: e.g., SILAM, COSMO-ART models [3,4]. Of particular interest is the question whether models can predict extreme pollen episodes generated by thunderstorm processes which can affect human health dangerously. Thunderstorm-cased asthma, usually called 'thunderstorm asthma' (TA) is a striking event in which patients could experience life-threatening asthma attacks caused by extreme numbers of pollen grains [5]. During thunderstorms, a local-to-mesoscale atmospheric circulation usually generates formation of a cold-air downburst with strong surface winds, associated with a cold-air outflow front. If a thunderstorm occurs during a pollen season, favorable conditions for intense pollen uptake and transport (such as convection, cold-air outflow) are fulfilled.

The objective of this study is to examine the capacity of the PREAM (Pollen Regional Atmospheric Model) pollen model to predict excessive TA events such as the Melbourne case. PREAM is a version of the DREAM regional dust aerosol atmospheric model [6] modified in our study to predict pollen dispersion. It is an online model driven by the atmospheric NCEP WRF Nonhydrostatic Mesoscale Model, referred onwards as WRF-NMM and developed to be easily applicable over different geographical domains and with arbitrary spatial resolution.

METHODOLOGY

The atmospheric WRF-NMM model component has prognostic variables distributed horizontally over the Arakawa semi-staggered E-grid. In the vertical, the terrain-following hybrid pressure-sigma coordinate is used. The atmospheric large-scale transport is based on the horizontal advection numerical scheme which preserves energy and enstrophy. The non-hydrostatic atmospheric processes, becoming important for horizontal scales finer than approximately 10 km, are introduced in the model through an add-on non-hydrostatic module that can be turned on/off, depending on the resolution. The vertical diffusion is handled by the surface layer scheme and by the turbulence scheme. For horizontal transport of positive-definite scalars, the WRF-NMM mass conservative positive-definite advection scheme is used which permits no formation of new false concentration maxima and reduces to a minimum the numerical dispersion. The scheme is applied for the horizontal advection of pollen concentration, specific humidity, and cloud water and turbulence kinetic energy.

PREAM simulates all major components of atmospheric pollen processes such as emission, horizontal and vertical turbulent mixing, long-range transport and pollen wet and dry deposition. It numerically solves the following Euler-based pollen mass conservation equation:

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} + \nabla_h(K_H \nabla_h C) + \frac{\partial}{\partial z}\left(K_v \frac{\partial C}{\partial z}\right) + \left(w - v_g\right)\frac{\partial C}{\partial z} - \left(\frac{\partial C}{\partial t}\right)_{SR} + \left(\frac{\partial C}{\partial t}\right)_{SN} = 0 \qquad (1)$$

Here, C is the pollen concentration; u, v and w are horizontal and vertical velocity components; v_g is the pollen gravitation settling velocity; ∇_h is the horizontal gradient operator; K_H and K_V are the lateral and vertical mixing coefficients; subscripts SR and SN indicate pollen sources and sinks, respectively. During the model integration, the calculation of a pollen grain emission is made over model grid-point cells declared as pollen potential sources. Once emitted into the atmosphere, the pollen aerosol is driven by turbulent vertical mixing, by horizontal and vertical advection and by deposition processes. The parameterization of the pollen source is based on the WRF-NMM approach of mass emissions from the surface-atmosphere interface. The emission is dependent on the near-surface turbulent state and its level intensity is regulated by a thin viscous sub-layer inserted between the model surface and the first model layer [7].

The dry deposition of pollen is parameterized following the scheme including gravitational settling, Brownian and turbulent deposition at the air-surface interface, and interception and impaction at the surface roughness elements [6]. The scheme takes into account properties of the depositing particles (size, density), features of the depositing surfaces (roughness, land cover, land texture) and conditions of the lower atmosphere. Different parameterizations are used for the following two groups of surfaces: a) bare soil, ice and sea, and b) land covered by vegetation. The wet removal of the concentration by precipitation is predicted by the atmospheric model where at each model time step the removal is calculated using a constant washout parameter [7].

RESULTS AND DISCUSSION

Following the objective of our study to examine the capability of the pollen model to predict extreme thunderstorm asthma conditions such as the 2016 Melbourne event, we specify the model domain to cover the south-western part of Australia. In the vertical, there are 28 model levels spanning from the surface to 50 hPa. The horizontal resolution is set to 1/20 deg, leading to approximately 8 km grid distance within the model domain. With this, vertical velocities originating from the non-hydrostatic dynamics are enhanced and the convective processes more realistically represented. The model's basic time step is set to 18 s. The pollen advection and lateral diffusion are computed every 2 time steps, the pollen emission and vertical diffusion are updated every 4 time steps, and the convection and large scale precipitation are calculated every 8 time steps. The model was run over the period 14-22 November 2016. The initial and boundary conditions for the atmospheric model part are specified using weather prediction parameters of the ECMWF global model. Since there are no satisfactory three-dimensional pollen concentration observations to be assimilated, the initial state of pollen concentration in the model is defined by the 24-hour forecast from the previous day model run. Only at the ''cold start'' of the model on 00:00 UTC 14 November 2016 the initial pollen concentration was set to zero. The geographical distribution of potential sources of grass pollen was represented using the Australian Land Use and Management (ALUM) classification data (ABARES, 2017) at 50 m horizontal resolution.

The model accurately predicted the cold front passage over Melbourne and the surface pollen counts combined with 10 m wind streamlines (Figure 1). The model confirms that northerly winds associated with the cold front lifted the pollen from the pastures near Melbourne. Hot dry northerly winds at 16:00ADT contributed to increased airborne pollen concentration. Cold air downdraft circulation brought pollen down to the ground level. A mixture of humid air and high airborne pollen concentration approaching Melbourne is considered to be a cause for pollen grains rupturing which made them easier to penetrate deep into the lower human lung airways. However, the current PREAM model version does not yet parameterize pollen grain rupturing process. During the TA event in the wider Melbourne area, thousands of patients with respiratory distress asked for medical assistance.

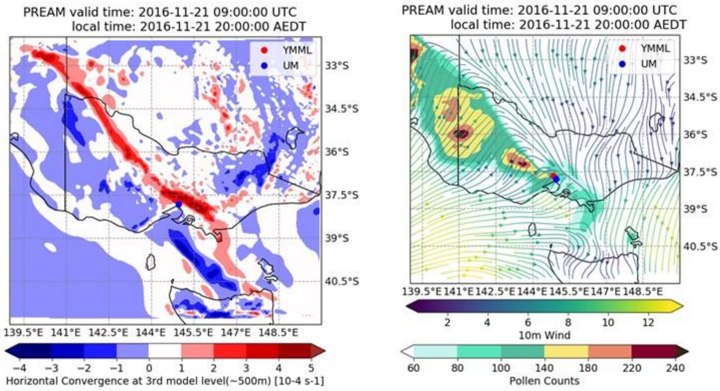

Figure 1. Model predictions at 20 ADT on 21 November 2016. The model near-surface horizontal wind convergence indicating the movement of the thunderstorms (left); the model surface pollen concentration (right)

Figure 3 shows the time evolution of predicted and observed pollen concentrations during the Melbourne TA event. Grass pollen concentrations are daily averages observed at the University of Melbourne, Parkville site during 16-27 November. The available daily-averaged measurements [8] indicate occurrence of a weaker pollen event during 16-17 November. The model simulated this pollen event by predicting of 102 grains/m^3 in 1hr values on 17 November. The model daily average for the same period shows 30 grains/m^3 compared to the observed 77 grains/m^3. The timing of the daily averaged peak for this secondary event was accurately predicted.

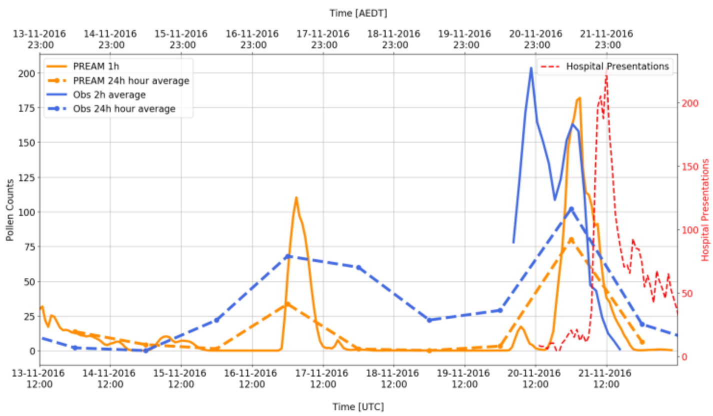

Figure 2. Time evolution of the pollen counts and hospital presentations for the Melbourne TA event during the period 13-22 November.

On 21 November 2h-averaged observations show a two-fold maximum of which the second peak of 160 grains/m^3 actually triggered the TA event. The model correctly predicted the timing and values the second maximum. As a result of these extreme concentrations, the number of hospital presentations as shown in the Figure 2 abruptly increased over the next few hours.

CONCLUSION

The world's largest and most catastrophic epidemic thunderstorm asthma event occurred in Melbourne on 21 November 2016, Australia. In this study we implemented a regional Euler-type pollen prediction model over the Australian state of Victoria in order to explore its capability to predict the Melbourne pollen event. The model simulation covering the period 16-22 November 2016 was verified against available pollen counts observed at a Melbourne site. The model correctly identified the increased pollen concentrations from the weaker observed peak on 16 November. More importantly, the extreme pollen concentrations on the 21st November, which triggered the epidemic asthma, was quite well represented by the model, in terms of both timing and location. However, whether the proposed prediction system can reasonably perform over longer (e.g. seasonal) time frames will require further research. Ongoing research is also related to the parameterization of the pollen grain rupturing process in the model, which is considered as one of the key component for developing successful TA early warning system.

ACKNOWLEDGEMENTS

The European Centre for Medium-Range Forecasting (ECMWF) forecasts are used for initial and boundary conditions in the model. ZM and LI acknowledge funding provided by the Institute of Physics Belgrade, through the grant by the Ministry of Education, Science, and Technological Development of the Republic of Serbia.

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