

**Slovenská banícka spoločnosť ZSVTS**  
**Základná organizácia pri Ústave geotechniky SAV, Košice**

**Slovakian Mining Society**  
a member of Association of Slovak Scientific and Technological Societies  
a basic unit at the Institute of Geotechnics SAS, Košice

Spoluorganizátori – Co-organizers



## **Z B O R N Í K – P R O C E E D I N G S**

**XXVIII. vedecké sympóziu s medzinárodnou účasťou**  
**SITUÁCIA V EKOLOGICKY ZAŤAŽENÝCH REGIÓNOCH**  
**SLOVENSKA A STREDNEJ EURÓPY**

The XXVIII Scientific Symposium with International Participation  
SITUATION IN ECOLOGICALLY LOADED REGIONS  
OF SLOVAKIA AND CENTRAL EUROPE

**Hrádok**  
**24. – 25. október 2019**

**ISBN 978-80-89883-10-3**

# Zborník - Proceedings

Slovenská banícka spoločnosť ZSVTS  
Základná organizácia pri Ústave geotechniky SAV, Košice  
Slovenské magnezitové závody, a. s. Jelšava  
Štátna veterinárna a potravinová správa SR, Bratislava  
Regionálna veterinárna a potravinová správa Rožňava  
NPPC - Výskumný ústav živočíšnej výroby, Nitra, pracovisko Košice  
Lekárska fakulta Univerzity Pavla Jozefa Šafárika, Košice  
Ústav geotechniky SAV, Košice

XXVIII. vedecké sympóziu s medzinárodnou účasťou  
**SITUÁCIA V EKOLOGICKY ZAŤAŽENÝCH REGIÓNOCH  
SLOVENSKA A STREDNEJ EURÓPY**

Slovakian Mining Society  
a member of Association of Slovak Scientific and Technological Societies  
a basic unit at the Institute of Geotechnics SAS, Košice  
Slovak Magnesite Works, Joint-Stock Company, Jelšava  
State Veterinary and Food Administration of the Slovak Republic, Bratislava  
District Veterinary and Food Administration, Rožňava  
NPPC - Research Institute for Animal Production, Nitra, workplace Košice  
Faculty of Medicine, Pavol Jozef Šafárik University in Košice  
Institute of Geotechnics of the Slovak Academy of Sciences, Košice

The XXVIII Scientific Symposium with International Participation  
**SITUATION IN ECOLOGICALLY LOADED REGIONS OF  
SLOVAKIA AND CENTRAL EUROPE**

**HRÁDOK**

**24. – 25. október 2019**

## **Zameranie sympózia – Symposium Topics:**

- 1. Vplyv emisií a imisií na ovzdušie, pôdu, vodu, rastliny, lesy, zvieratá, potravinový reťazec a ľudskú populáciu v regiónoch Slovenska a strednej Európy**  
**Influence of Emissions and Immissions on Surrounding Air, Soil, Water, Plant, Woods, Animals, Food Chain and Human Population in the Regions of Slovakia and Central Europe**
- 2. Teoretické a praktické aspekty výskumu jednotlivých zložiek životného prostredia**  
**Theoretical and Practical Features of the Research on Individual Components of the Environment**
- 3. Materiály a technológie pre ochranu a revitalizáciu životného prostredia**  
**Technologies and Materials for Environment Protection and Remediation**
- 4. Ekologicky šetrné a energeticky úsporné postupy výroby pre minimalizáciu environmentálnych rizík**  
**Environmentally Friendly and Energy Saving Manufacturing Processes for Ecological Risk Minimization**

**Miesto konania: Hotel Hrádok, SMZ – Služby, a.s. Jelšava, Hrádok pri Jelšave**

**Venue of the symposium: Hotel Hrádok, SMZ – Služby, JSC. Jelšava, Hrádok nearby Jelšava**

**Dátum konania: 24. – 25. október 2019 (štvrtok – piatok)**

**Symposium dates: October 24<sup>th</sup> – 25<sup>th</sup>, 2019 (Thursday – Friday)**

**Rokovacie jazyky sympózia: slovenčina, čeština, angličtina**

**Symposium languages: Slovak, Czech, English**

## **Organizačný výbor / Organizing Committee:**

Doc. MVDr. František Jenčík, PhD. – Košice – čestný predseda †

Ing. Slavomír Hredzák, PhD. – riaditeľ, Ústav geotechniky SAV, Košice – výkonný predseda

Ing. Jozef Hančulák, PhD. – Ústav geotechniky SAV, Košice

Katarína Stuchlá – Ústav geotechniky SAV, Košice

Ing. Oľga Šestinová, PhD. – Ústav geotechniky SAV, Košice

Ing. Janette Žáková – Ústav geotechniky SAV, Košice

RNDr. Anton Zubrik, PhD. – Ústav geotechniky SAV, Košice

Doc. RNDr. Janka Vašková, PhD. – Lekárska fakulta, UPJŠ Košice

MVDr. Rudolf Žitňan, DrSc. – NPPC - Výskumný ústav živočíšnej výroby, Nitra, pracovisko Košice

## **Programový výbor / Programming Committee:**

Ing. Jozef Hančulák, PhD. – štatutárny zástupca riaditeľa, Ústav geotechniky SAV, Košice

Ing. Peter Košinár – člen predstavenstva, Slovenské magnezitové závody, a.s. Jelšava

Prof. MVDr. Jozef Bíreš, DrSc. – ústredný riaditeľ, Štátna veterinárna a potravinová správa SR, Bratislava

Ing. Josef Kotlík, CSc. – Fakulta chemická, VUT Brno

Prof. Ing. Stanislav Kráčmar, DrSc. – Fakulta technologická, Univerzita Tomáše Bati ve Zlíně

Prof. Ing. Marián Marschalko, PhD. – Hornicko-geologická fakulta, VŠB–TU Ostrava

Doc. Ing. Vladimír Čablík, Ph.D. – Hornicko-geologická fakulta, VŠB–TU Ostrava

Doc. RNDr. Janka Vašková, PhD. – Lekárska fakulta, UPJŠ Košice

MVDr. Rudolf Žitňan, DrSc. – NPPC - Výskumný ústav živočíšnej výroby, Nitra, pracovisko Košice

MVDr. Peter Milko – riaditeľ, Regionálna veterinárna a potravinová správa, Rožňava

## **Vedeckí garanti / Scientific Guarantees:**

Prof. MVDr. František Lešník, DrSc. – Košice

Prof. MVDr. Jozef Bíreš, DrSc. – ústredný riaditeľ, Štátna veterinárna a potravinová správa SR, Bratislava

Prof. RNDr. Milada Vávrová, CSc. – Fakulta chemická, VUT Brno †

Ing. Josef Kotlík, CSc. – Fakulta chemická, VUT Brno

Prof. Ing. Stanislav Kráčmar, DrSc. – Fakulta technologická, Univerzita Tomáše Bati ve Zlíně

Prof. RNDr. Jaroslav Briančin, CSc. – Ústav geotechniky SAV, Košice

Doc. Ing. Vladimír Čablík, Ph.D. – Hornicko-geologická fakulta, VŠB–TU Ostrava

Ing. Jozef Hančulák, PhD. – štatutárny zástupca riaditeľa, Ústav geotechniky SAV, Košice

Ing. Miroslava Václavíková, PhD. – vedecká tajomníčka, Ústav geotechniky SAV, Košice

Doc. RNDr. Janka Vašková, PhD. – Lekárska fakulta, UPJŠ Košice

MVDr. Rudolf Žitňan, DrSc. – NPPC - Výskumný ústav živočíšnej výroby, Nitra, pracovisko Košice



## **ORGANIZÁTORI**

**XXVIII. vedeckého sympózia s medzinárodnou účasťou  
„SITUÁCIA V EKOLOGICKY ZATAŽENÝCH REGIÓNOCH SLOVENSKA  
A STREDNEJ EURÓPY“**

**d'akujú organizáciám,**

**ktoré prispeli k zdarnému priebehu rokovania sympózia a vydaniu zborníka:**

**Slovenské magnezitové závody, a. s. Jelšava  
Ústav geotechniky SAV, Košice  
Štátna veterinárna a potravinová správa SR, Bratislava  
Regionálna veterinárna a potravinová správa, Rožňava**

## **ORGANIZERS**

**of the XXVIII Scientific Symposium with International Participation  
SITUATION IN ECOLOGICALLY LOADED REGIONS OF SLOVAKIA  
AND CENTRAL EUROPE**

**are grateful to organizations**

**which contributed to successful course of symposium dealings and proceedings edition:**

**Slovak Magnesite Works, Joint-Stock Company, Jelšava  
Institute of Geotechnics of the Slovak Academy of Sciences, Košice  
State Veterinary and Food Administration of the Slovak Republic, Bratislava  
District Veterinary and Food Administration, Rožňava**

## OBSAH

|  |    |
|--|----|
| Úvod .....   | 1  |
| František Lešník: <i>Polutanty a zdravie</i> .....   | 4  |
| František Lešník – Alexandra Valenčáková-Agyagosová – Mária Figurová – Eubica Horňáková:<br><i>Etiopatogenéza adenokarcinómu pľúc</i> .....  | 9  |
| František Zigo – Milan Vasiľ – Juraj Elečko – Martina Zigová – Silvia Ondrašovičová:<br><i>Vplyv mastitíd na parametre mliečnej úžitkovosti v chove dojníc situovanom v marginálnej oblasti Slovenska</i> .....  | 12 |
| Milan Vasiľ – Juraj Elečko – Zuzana Farkašová – František Zigo: <i>Efekt uplatňovania protimastitídnych metód v chove dojníc a ich dopad na kvalita produkovaného mlieka</i> .....   | 18 |
| Rudolf Žitňan – Elke Albrecht – Monika Röntgen: <i>Muscle characteristics in chicks challenged with salmonella and the effect of preventive application of the probiotic</i> .....   | 23 |
| Janka Kluknavská – Janka Vašková – Silvia Timková – Beáta Bolerázka: <i>Priebežné výsledky hodnotenia aktivít antioxidačných markerov v slinách pri ochoreniach parodontu</i> .....  | 28 |
| Martin Haus – Janka Vašková – Marek Stupák: <i>Účinok sulfónamidových derivátov chalkónov na vybrané antioxidačné markery v mitochondriách</i> .....   | 32 |
| Martin Haus – Janka Vašková: <i>Aktivita sulfónamidových derivátov chalkónov voči hydroxylovému radikálu</i> .....   | 36 |
| Petr Levek – Josef Kotlík: <i>Voda nad zlato?</i> .....  | 41 |
| František Mikšík – Štěpánka Freithová – Josef Kotlík – Jiří Kučeřík – Helena Půčková – Alasdair MacLeod: <i>Stabilita vodných molekulárných mŕstkv v rašelině</i> .....  | 45 |
| Vladimír Hisira – Marián Kadaši: <i>Biokumulácia kadmia u diviacej zveri v okrese Košice-okolie</i> .....  | 50 |
| Vladimír Hisira: <i>Vplyv olova na živé organizmy</i> .....  | 54 |
| Eubomír Jurkovič – Tatsiana Kulikova – Edgar Hiller – Peter Šottník – Tomáš Faragó – Jaroslav Vozár – Petr Lacina: <i>Mobilita a bioprístupnosť ortuti a vybraných stopových prvkov v zložkách životného prostredia opusteného Hg ložiska Merník</i> ..... | 58 |
| Eliška Gbúrová Štubňová – Ivona Kautmanová – Darina Arendt – Ján Kautman – Martin Sečanský – Bronislava Lalinská-Voleková: <i>Biodiverzita oblastí ovplyvnených ťažbou antimónových rúd na Slovensku</i> .....   | 64 |
| Bronislava Lalinská-Voleková – Darina Arendt – Dana Szabóová – Ondrej Brachtýr – Tomáš Faragó: <i>Fe oxidy/oxihydroxidy z lokalít ovplyvnených ťažbou antimónu: geochemia, mineralógia, mikrobiológia</i> .....  | 73 |
| Jana Nováková – Ján Pinka: <i>Analýza metód pre vyhodnocovanie znečistenia pôdy environmentálnymi záťažami</i> .....   | 79 |
| Slavica Mihajlović – Marina Blagojev: <i>Potential ways to lower CO<sub>2</sub> emission for cement production</i> .....   | 84 |

|  |     |
|--|-----|
| <i>Silviya Boycheva – Ivan Marinov – Denitza Zgureva – Simona Miteva – Dominika Behunová – Miroslava Václavíková: Application of coal ash zeolites for removal of heavy metals and dyes from polluted waters .....</i>   | 89  |
| <i>Silviya Boycheva – Simona Miteva – Denitza Zgureva – Ivan Marinov: Characterization of fly ashes from thermal power plants in bulgaria supplied by lignite coal .....</i>   | 97  |
| <i>Ingrid Znamenáčková – Silvia Dolinská – Slavomír Hredzák – Alexandra Bekényiová – Michal Lovás: Extraction of lanthanides from coal fly ash .....</i>   | 105 |
| <i>Ján Pinka: Využívanie geotermálnych zdrojov na území východného Slovenska .....</i>   | 107 |
| <i>Ján Pinka: Environmentálne dopady pri vyhľadávaní, ťažbe, spracovaní a pri preprave ropy, uhlia a zemného plynu .....</i>   | 113 |
| <i>Peter Šottník – Ondrej Brachtýr – Ľubomír Jurkovič – Peter Lacina – Jaroslav Vozár – Bronislava Lalinská-Voleková: Sanácie environmentálnych záťaží po ťažbe nerastných surovín na Slovensku .....</i>  | 121 |
| <i>Petr Lacina – Miroslav Plotěný – Michal Hegediüs – Jaroslav Lev: Rychlá a efektivní degradace halogenovaných organických látek procesem katalytické hydrodehalogenace s využitím Raneyovy slitiny přímo v kontaminovaných vodách – technologické aplikace .....</i> | 125 |
| <i>Gergö Bodnár – Dávid Jáger – Daniel Kupka: HPLC-MS analýza podzemnej vody z lokality skládky CHZJD Bratislava-Vrakuňa .....</i>   | 132 |
| <i>Jozef Hančulák – Tomislav Špaldon – Oľga Šestinová: Vybrané charakteristiky atmosférickej depozície v oblasti Košíc vo vzťahu k hutníckemu priemyslu .....</i>  | 140 |
| <i>Ján Pinka: Technológie a technické prostriedky pri hasení ropných a plynových erupcií a požiarov .....</i>  | 146 |
| <i>Ján Pinka: Environmentálne zhodnotenie výstavby prepojovacieho plynovodu Poľsko – Slovensko ..</i>  | 157 |
| <i>Ján Pinka: Hodnotenie environmentálnych a ekonomických dopadov po erupciách a požiaroch ropy a zemného plynu pri vyhľadávaní ložísk uhl'ovodíkov v naftovom podnikaní v Českej a Slovenskej republike .....</i>   | 164 |
| <i>Ján Pinka: Environmentálne technické prostriedky a metódy používané pri čistení ropovodov a plynovodov .....</i>  | 173 |
| <i>Viktoriia Novoseltseva – Halyna Yankovych – Olena Kovalenko – Miroslava Václavíková – Inna Melnyk: Experimental investigations of sorption properties and characteristics of biosorbents obtained from pea peel .....</i>   | 184 |
| <i>Jana Jenčárová – Alena Luptáková – Eva Mačingová: Eliminácia znečistenia vo vodách využitím baktérií .....</i>  | 189 |
| <i>Dominika Marcin Behunová – Miroslava Václavíková: Elektroforetická depozícia materiálov na báze grafénu .....</i>   | 191 |
| <i>Mariia Pasichnyk – Miroslava Václavíková – Inna Melnyk: Features of acrylate nanocomposite films structure with zinc oxide nanoparticles for their potential application in photocatalysis .....</i>  | 197 |

|   |            |
|---|------------|
| <i>Jaroslav Briančin – Bystrík Dolník – Iraidá Kolcunová – Juraj Kurimský – Martin Fabián – Jaroslav Džmura: Vplyv znečistenia ovzdušia na poruchy vedenia vysokého napätia. On-line monitoring .....</i>   | <i>203</i> |
| <i>Anton Zubrik – Mária Kaňuchová – Marek Matik – Slavomír Hredzák: Magnetic carbon composites: relationship of structure to sorption properties .....</i>  | <i>206</i> |
| <i>Věra Vrlíková – Vladimír Čablík – Slavomír Hredzák – Marek Matik – Jaroslav Briančin – Anton Zubrik – Silvia Dolinská – Ingrid Znamenáčková – Olga Šestinová: The possibility of sulfide concentrate preparation from polymetallic ore .....</i> | <i>214</i> |
| <i>Ján Mandula – Jakub Bokomlaško: Test lepidiel a spojív na priamu aplikáciu mikro drôtu na asfaltovú vzorku .....</i>   | <i>220</i> |
| <i>Prezentácia Slovenských magnezitových závodov, a.s. Jelšava .....</i>  | <i>224</i> |
| <i>Obsah .....</i>  | <i>225</i> |
| <i>Údaje o zborníku .....</i>   | <i>228</i> |



### Údaje o CD-ROM zborníku / CD-ROM Proceedings data

Názov / Title:

**SITUÁCIA V EKOLOGICKY ZAŤAŽENÝCH REGIÓNOCH SLOVENSKA A STREDNEJ EURÓPY  
SITUATION IN ECOLOGICALLY LOADED REGIONS OF SLOVAKIA AND CENTRAL EUROPE**

Podnázov / Subtitle:

**XXVIII. vedecké sympóziu s medzinárodnou účasťou  
The XXVIII Scientific Symposium with International Participation**

Editor: Slavomír Hredzák

počet strán / number of pages: 228, náklad: 40 ks / number of copies: 40 ps.

Hradok, 24–25. október 2019 / Hradok, October 24–25, 2019

© Slovenská banícka spoločnosť ZSVTS,  
Základná organizácia pri Ústave geotechniky SAV, Košice, 2019

© Slovakian Mining Society  
a member of Association of Slovak Scientific and Technological Societies  
a basic unit at the Institute of Geotechnics SAS, Košice, 2019

Tlač/Press: Ústav geotechniky SAV, Košice, EQUILIBRIA, s.r.o. Košice

**ISBN 978-80-89883-10-3**

**EAN 9788089883103**



## POTENTIAL WAYS TO LOWER CO<sub>2</sub> EMISSION FOR CEMENT PRODUCTION

Slavica Mihajlović<sup>1</sup> – Marina Blagojev<sup>1</sup>

### Abstract

Rapid technological development leads to an improvement in the quality of life in all spheres of human activity, but at the same time it creates environmental degradation. Therefore, it is important to analyze the negative impact of technological processes, in order to adopt the strategy and define activities for implementation adequate environmental protection rates. One of the major problems in environmental protection is the emergence of greenhouse gas emissions. The world's organizations dealing with environmental protection provide a great stimulus for the development of innovative sustainable solutions in the construction industry. Thus, one of the priorities in cement industry is finding new ways to reduce energy consumption and CO<sub>2</sub> emissions with point on clinker production plants as the biggest CO<sub>2</sub> emitter (the product of the baking process during the portland cement process). In such a way new solutions reduce the amount of clinker, while at the same time, they encourage the use of alternative materials. Materials that can replace the use of cement (supplementary cementitious materials - SCM) as well as mixtures of cement, offer advantages in better characteristics, lower energy consumption and emissions of gases that produce greenhouse effect.

**Keywords:** CO<sub>2</sub> emission, greenhouse effect, sustainable development, environmental protection

---

### Introduction

Implementation of environmental policy sets ecological economics as the best and most complete analytical framework for evaluating the success of production activities [Benson and Jordan, 2015]. The economic aspect of sustainable development lies in the more efficient use of available resources, while minimizing the negative impacts on the environment [ESDN, 2016]. One of the priorities is to eliminate all the contributing factors to the greenhouse effect [Gonçalves and Mil-Homens].

The essence of the problem of the greenhouse effect is the global warming of the Earth's surface. Namely, part of the heat radiation from the Earth's surface is reflected into the atmosphere where it is absorbed by certain gases (CO<sub>2</sub> and CH<sub>4</sub> which are found in the atmosphere as pollutants) and returned to the earth again, further warming it up [Gadea Rivas and Gonzalo, 2019]. Such effects are achieved in greenhouses, hence the name greenhouse effect that leads to global warming [Selin and Mann, 2019]. Furthermore, global warming is the onset of the steady rise of temperature of planet Earth [Breckned and Sunde, 2019].

The greenhouse effect is an expression for warming of the earth's surface caused by energy disbalance between the amount of radiation received from the sun and energy that get back toward space as infrared radiation, as shown in Fig. 1. The greenhouse effect causes part of energy to be waylaid in the atmosphere, absorbed and released by greenhouse gases such as carbon dioxide, water vapor, methane nitrogen suboxide and nitrous oxide [Le treut et al., 2007]. Nonetheless, when considering their individual impact, carbon dioxide, CO<sub>2</sub>, is the most important because its emissions account for as much as three quarters of all anthropogenic greenhouse gas emissions [EPA, 2017]. Concentration of CO<sub>2</sub> in atmosphere is steadily increasing (Fig. 2) while two main sources of emissions of this gas to the atmosphere are: oxidation of fossil fuels and carbonate decomposition. For this study, it was of interest to investigate cement as the largest source of CO<sub>2</sub> emissions from the decomposition of carbonates. On Figure 3 it is shown CO<sub>2</sub> emissions from fossil-fuel use and cement production in the top 5 emitting countries and in European Union

---

<sup>1</sup> Slavica Mihajlović, PhD., MSc. Marina Blagojev, Institute for Technology of Nuclear and other Mineral Raw Materials, Belgrade, m.blagojev@itnms.ac.rs

[Olivier et al., 2016; Kuba, 2018]. In addition, production of cement expanding rapidly worldwide, with current levels of global production equivalent to more than half a tonne per person per year (Fig. 3).

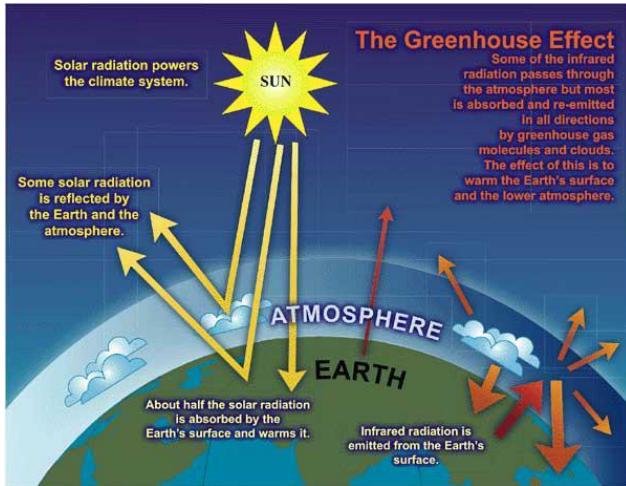


Fig. 1. Simplified diagram illustrating the greenhouse effect [Le Treut et al., 2007]

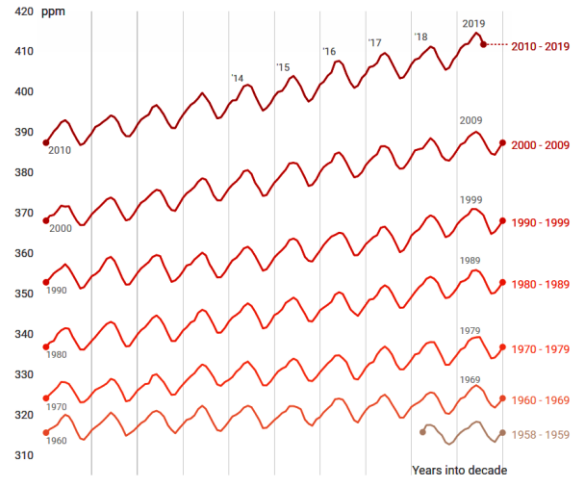


Fig. 2. Simplified diagram illustrating the greenhouse effect [Aisch, 2018]

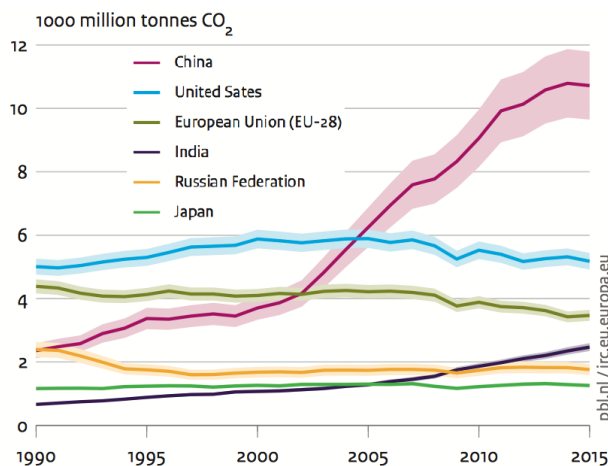


Fig. 3. CO<sub>2</sub> emissions from fossil-fuel use and cement production in the top 5 emitting countries and European Union [modified from Kuba, 2017]

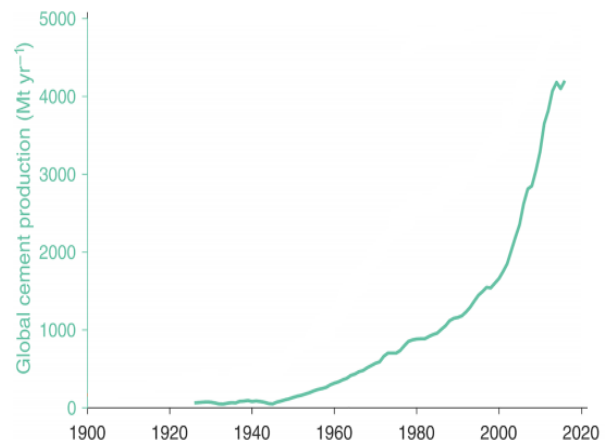


Fig. 4. Global cement production to 2016 [modified from Andrew, 2019; BP, 2019]

## SCM (supplementary cementitious materials) as possible way to reduce CO<sub>2</sub> emission in the atmosphere

### Portland limestone cement

Total emissions from the cement industry could contribute as much as 8% of global CO<sub>2</sub> emissions [IEA, 2017]. Global warming gas is released when the raw material of cement, limestone and clay is crushed and heated in a furnace at high temperature ( $\pm 15000^{\circ}\text{C}$ ). Each year, approximately 1.89 billion tons of cement (which is a major component of concrete) have been produced worldwide. One way to reduce greenhouse gas emissions per ton of cement produced is to use limestone from the quarry. Specifically, mixing Portland cement clinker and limestone (5% to 15% limestone) produces portland limestone cement (PLC) [Barrett et al., 2013; Mrema, 2010]. Production of Portland limestone cement leads to reduced levels of CO<sub>2</sub> emissions and reduced energy consumption when compared with the production of the same quantity of Portland cement, thus contributing towards more sustainable construction materials [Nisbet 1996]. This represents a

promising approach for the world market. First application of this type of cement dates from 1965, when Heidelberger produced 20% limestone cement in Germany [Schmidt 1992]. Later in Canada, up to 5% of limestone could be contained in Portland cement since 1983 [Barrett et al., 2013]. ASTM International allowed the same percentage of limestone in Portland cement in 2004, followed by AASHTO (American Association of State Highway and Transportation Officials) in 2007. These changes will result with reduction in energy consumption of 11.8 trillion Btu<sup>1</sup> and over 2.5 million tonnes of CO<sub>2</sub> per year [Tennis et al., 2011]. As response to growing pressure to reduce clinker content in cement, the Canadian Standards Association (CSA) introduced a new cement classification in 2008, in which Portland cement can have up to 15% limestone. Based on many studies and valid tests, portland limestone cement containing up to 15% limestone can make the same concrete as pure Portland cement [Barret et al., 2013; Tennis et al., 2011; Hooton et al., 2009]. This implies the same strength, durability and other features. Any increase in the amount of limestone usually reduces the clinker content by an additional 10%. When 40 to 50% supplementary cementitious materials is added - the effective reduction of clinker concentration in concrete exceeds 50%.

The technical benefits of applying SCM in concrete are as great as their impact on creating even better solutions that are one step ahead in green building. In most cases, mixed cements can be replaced, in 1:1 ratio, with classic Portland cement. Numerous organizations, including the American Concrete Institute (ACI) and the Cement Slag Association (SCA), offer detailed guidance and recommendations to construction companies that make concrete and use it during construction. Also, certification program as LEED (Leadership in Energy and Environmental Design) will continue to provide a major influence to develop and create even better, more innovative sustainable construction solutions.

Finding new ways to further reduce energy consumption and CO<sub>2</sub> emissions is a top priority for cement manufacturers. Thus, new solutions are constantly being created with result of reducing the amount of clinker while increasing the use of alternative materials. With these next-generation cements, consumers can use the same amounts of SCM in mixture, but also by adding up to 15% lime in clean Portland cement. All this is for the same purpose, which is to reduce carbon emissions in the construction sector.

#### *Solar Thermal Electrochemical Produced (STEP) cement*

Concrete is the most widely used building material in the world, and large quantities of cement are required to obtain it. The production of cement, which accounts for 15% of the concrete mix, is responsible for up to 8% of the total carbon dioxide (CO<sub>2</sub>) emitted into the atmosphere as a result of human activities. This is supported by the fact that for every 10kg of cement produced, 9kg of CO<sub>2</sub> is emitted into the atmosphere. The chemical reactions that take place during the production of cement emit large amounts of carbon dioxide, of which 60% of the emission is during the production of CaO from CaCO<sub>3</sub>. Therefore, a great deal of research in the world has focused on addressing this problem and finding ways to obtain concrete components otherwise.

STEP – Solar Thermal Electrochemical Production, is advanced solar energy conversion with high efficiency through the use of the solar spectrum in order to generate energy rich chemicals. Researchers at The George Washington University, led by Dr. Stuart Licht, have developed a process called CO<sub>2</sub>-free solar thermal electrochemical production of calcium oxide [Licht et al., 2012]. This is, in fact, a way of thermally decomposing limestone (CaCO<sub>3</sub>) and obtaining CaO that goes into cement without emitting carbon dioxide. It is known that the solubility of CaCO<sub>3</sub> in water is 6x10<sup>-5</sup> mol/kg of solution, while for calcium oxide this value is three times lower - 2x10<sup>-5</sup> mol/kg, with calcium hydroxide as product of solubility. On the other hand, Licht explains that this situation

---

<sup>1</sup> British thermal unit

is reversed at high temperatures in molten carbonates, which allow endothermic, electrolytic synthesis and CaO deposition [Licht et al., 2012].

Figure 5 shows a new, solar, CaO process based on oxide solubility irregularities, without carbon dioxide emission.

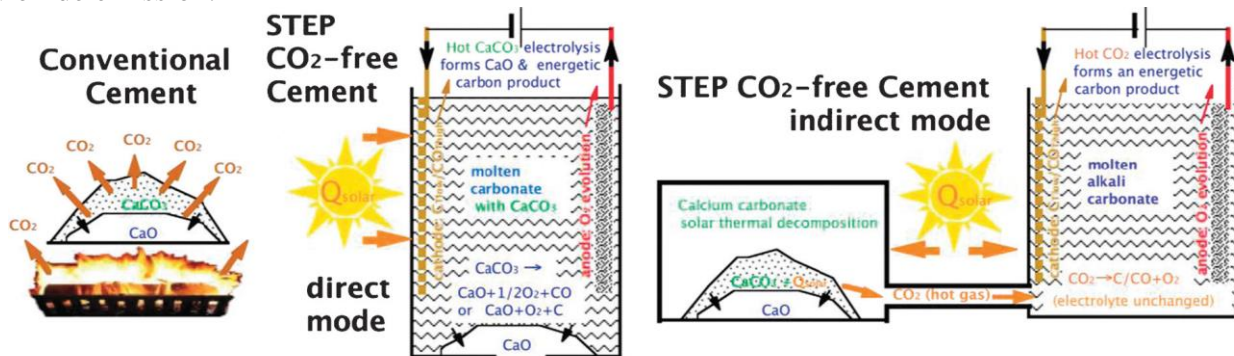


Fig. 5. Simplified solar production of CaO without CO<sub>2</sub> emission [Licht et al., 2012]

The contribution of the new solar process is that the electrolysis of molten carbonate forms oxides, which become calcium oxide when mixed with calcium carbonate. This avoids the formation of carbon dioxide and eliminates the fact that the production of cement has an impact on the formation of greenhouse gases.

## Conclusion

Climate change caused by human activities is an exceptionally large problem that has a direct impact on the environment. One of those changes is the global warming of planet Earth caused by the increased release of greenhouse gases into the atmosphere. The greenhouse effect is a natural phenomenon that, by its presence, allows life on planet Earth to a certain extent. However, a big problem arises when one disrupts the natural processes in the direction of their intensification by their activities. Therefore, it is necessary to direct the production of individual materials towards alternative solutions, using components and processes that do not have a negative impact on the environment and intensify the greenhouse effect such as a new process for cement production.

## Acknowledgements

This scientific paper resulted from the research funded under the Projects TR 034013 and TR 034006 by the Ministry of Education, Science and Technological Development of the Republic of Serbia from 2011-2019.

## References

1. ANDREW, M.: Global CO<sub>2</sub> emissions from cement production, 1928–2018, Earth Syst. Sci. Data Discuss., <https://doi.org/10.5194/essd-2019-152>, in review, 2019.
2. "ASTM Standard C595/C595M," in Standard Specification for Blended Hydraulic 437 Cements, ed. ASTM International, West Conshohocken, PA, 2012.
3. AISCH, G.: Carbon dioxide concentration over time, 2017. <https://blog.datawrapper.de/weekly-chart-carbon-dioxide/> (accessed on 26.9.2019)
4. BARRETT, T. – SUN, H. – WEISS, W. J.: Performance of Portland Limestone Cements: Cements Designed to Be More Sustainable That Include up to 15% Limestone Addition. Publication FHWA/IN/JTRP-2013/29. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2013. <https://doi.org/10.5703/1288284315335>.
5. BENSON, D. – JORDAN, A.: Environmental Policy: Protection and Regulation. In. International Encyclopedia of the Social & Behavioral Sciences (Second Edition), 2015, 778-

783. <https://doi.org/10.1016/B978-0-08-097086-8.91014-6>
6. BP: BP Statistical Review of World Energy June 2019. Retrieved from: <https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html> (accessed on 27.9.2019)
  7. BRECKNER, M. – SUNDE, U.: Temperature extremes, global warming, and armed conflict: new insights from high resolution data. In: World Development 123 (2019) 104624. <https://doi.org/10.1016/j.worlddev.2019.104624>
  8. European Sustainable Development Network (ESDN), Janeiro de 2016. Basics of SD strategies. Obtained in 11-2015, de European sustainable development network (ESDN): <http://www.sd-network.eu/>
  9. GADEA RIVAS, M. D. – GONZALO, J.: Trends in distributional characteristics: Existence of global warming. In: Journal of Econometrics, article in press, 2019. <https://doi.org/10.1016/j.jeconom.2019.05.009>
  10. GONÇALVES, V. A. – MIL-HOMENS, F.: Energy management system ISO 50001:2011 and energy management for sustainable development. In: Energy Policy, Vol. 133 (2019), 110868. <https://doi.org/10.1016/j.enpol.2019.07.004>
  11. HOOTON, R. D. – NOKKEN, M. – THOMAS, M.D.A.T.: Portland-Limestone Cement: State-of-the-Art Report and Gap Analysis for CSA A 3000, SN3053, Cement Association of Canada, Toronto, Ontario, Canada, 2007. 60 pages.
  12. IEA: Energy Technology Perspectives 2017: Catalysing Energy Technology Transformations, International Energy Agency, Paris, ISBN: 978-92-64-27597-3, available at: [www.iea.org/etp2017](http://www.iea.org/etp2017) (accessed on 27.9.2019)..
  13. KUBA, M.: Impact of climate changes on civil engineering structures. University of Zagreb, 2017.
  14. LICHT, S. – WU, H. – HETTIGE, C. – WANG, B. – ASERCION, J. – LAU, J. – STUART, J.: STEP cement: Solar Thermal Electrochemical Production of CaO without CO<sub>2</sub> emission. In: Chem. Commun. 2012, 48, 6019-6021. <https://doi.org/10.1039/c2cc31341c>
  15. MREMA, A.: Comparison of the properties of Portland cement and Portland limestone cement. Conference: Advances and Trends in Structural Engineering, Mechanics and Computation, 2010.
  16. NISBET, M.: Reduction of Resource Input and Emissions Achieved by Addition of Limestone to Portland Cement, PCA R&D Serial No. 2086, Portland Cement Association, Skokie, Illinois, 1996.
  17. OLIVIER, J.G.J. – JANSSENS-MAENHOUT, G. – MUNTEAN, M. – PETERS, J.A.H.W.: Trends in Global CO<sub>2</sub> emissions: 2016 report, Hague, PBL Netherlands Environmental Assessment Agency, 2016. 86p.
  18. SELIN, H. – MANN, M. E.: Global warming. Publisher: Encyclopaedia Britannica, inc, September, 2019. <https://www.britannica.com/science/global-warming>.
  19. SCHMIDT, M.: Cement with Interground Additives - Capability and Environmental Relief, Zement-Kalk-Gips, Vol. 45, No. 2, 1992, 64-69; and Vol. 45, No. 6, 1992, 296-301.
  20. TENNIS, P. D. – THOMAS, M. D. A. – WEISS, W. J.: State-of-the-Art Report on Use of Limestone in Cements at Levels of up to 15%, SN3148, Portland Cement Association, Skokie, Illinois, USA, 2011, 78 pages.
  21. UCAR, Center for Science and Education: The Greenhouse Effect, 2011. Retrieved from: <https://scied.ucar.edu/longcontent/greenhouse-effect> (accessed on 26.9.2019).
  22. EPA, United States Environmental Protection Agency: Overview of Greenhouse Gases. Retrieved from: <https://www.epa.gov/ghgemissions/overview-greenhouse-gases> (accessed on 26.9.2019).