Mineral and Energy Economy Research Institute
Polish Academy of Sciences

PhosV4

PHOSPHORUS FRIENDS CLUB IN V4

International Conference

Phosphorus Raw Materials in Visegrad Countries - Building V4's resilience in post-COVID period

Abstract book

April 24, 2024

supported by

Visegrad Fund

International Conference

Phosphorus Raw Materials in Visegrad Countries
Building V4's resilience in post-COVID period

April 24, 2024

The project is co-financed by the Governments of the Czechia, Hungary, Poland and Slovakia through Visegrad Grants from International Visegrad Fund. The mission of the fund is to advance ideas for sustainable regional cooperation in Central Europe.

supported by Visegrad Fund

Scientific Editor

Prof. ***Marzena Smol***
Mineral and Energy Economy Research Institute
Polish Academy of Sciences
Division of Biogenic Raw Materials

Reviewers

Prof. ***Marzena Smol***
Mineral and Energy Economy Research Institute
Polish Academy of Sciences
Division of Biogenic Raw Materials

Cover

Paulina Marcinek & Dominika Szołdrowska
Mineral and Energy Economy Research Institute
Polish Academy of Sciences
Division of Biogenic Raw Materials

Composition

Paulina Marcinek
Mineral and Energy Economy Research Institute
Polish Academy of Sciences
Division of Biogenic Raw Materials

Correspondence address

Division of Biogenic Raw Materials
Mineral and Energy Economy Research Institute
Polish Academy of Sciences
J. Wybickiego 7A str., 31-261 Cracow, Poland
E-mail: smol@meeri.pl
www.min-pan.krakow.pl/psb

© Copyright

ISBN 978-83-67606-38-7

Scientific Committee

Assoc. Prof. Marzena Smol, Mineral and Energy Economy Research Institute, Polish Academy of Sciences, Poland [Chair]

Ludwig Hermann, President of the European Sustainable Phosphorus Platform (ESPP), Proman Management GmbH, Austria

Doc. Ing. Tomáš Bakalár, PhD., Technical University of Košice, Slovakia

Prof. Petro Kapustenko, Brno University of Technology, Czech Republic

Ing. Šárka Zemanová, PhD., Brno University of Technology, Czech Republic

Prof. Eugeniusz Koda, Warsaw University of Life Sciences, Poland

Anna Podlasek, PhD., Warsaw University of Life Sciences, Poland

Katalin Kurucz, PhD., Bay Zoltán Kutatóintézet, Hungary

supported by
Visegrad Fund

PhosV4

How to stay alive in V4?
Phosphorus Friends Club builds V4's resilience

Project *How to stay alive in V4? Phosphorus Friends Club builds V4's resilience* (acronym: PhosV4) aims to increase knowledge and awareness of importance of Phosphorus (P) raw materials for food production in Visegrad Group (V4):

- Czech Republic,
- Hungary,
- Poland,
- Slovakia,

Moreover, project aims to develop Phoshorus management strategy in V4 to secure enough P for food production. Project includes inventory on P-rich waste in V4 countries and economic analysis of possibilities of P recovery from waste. It also includes various awareness-raising events, as workshops and summary conference. Project products as Roadmap for P management in V4 will accelerate implementation of P recovery in V4 and increase independence from P import and ensure safety of food production during/after COVID pandemic.

Project Partners:

- Division of Biogenic Raw Materials, Mineral and Energy Economy Research Institute of the Polish Academy of Sciences (MEERI) – Project Coordinator, Website: min-pan.krakow.pl/psb
- Bay Zoltán Nonprofit Ltd. for Applied Research (Hungary), http://bayzoltan.org
- Technical University of Kosice (Slovakia), Website: http://www.tuke.sk, http://fberg.tuke.sk
- Brno University of Technology (Czech Republic),Website: http://netme.cz/spil/
- Warsaw University of Life Sciences (Poland), Website: https://www.sggw.pl/.

The project is financed by Visegrad Fund, project no. 22110364.
Financing entity website: https://www.visegradfund.org/.
Project website: https://www.phosv4.eu/.

Mineral and Energy Economy Research Institute Polish Academy of Sciences
Bay Zoltán Nonprofit Ltd. for Applied Research
TECHNICAL UNIVERSITY OF KOŠICE
BRNO UNIVERSITY OF TECHNOLOGY
WARSAW UNIVERSITY OF LIFE SCIENCES

European Sustainable Phosphorus Platform

The PhosV4 project is a member of European Sustainable Phosphorus Platform.

supported by
Visegrad Fund

Introduction

Dear Colleagues,

I am happy to share the book of abstracts with papers presented during the **International Conference – Phosphorus Raw Materials in Visegrad Countries**, which was a summary of the project entitled "*How to stay alive in V4? Phosphorus Friends Club builds V4's resilience*" (acronym: PhosV4), financed by International Visegrad Fund. The aims of the project were:

- to increase knowledge and awareness of importance of phosphorus (P) raw materials for food production in Visegrad Group,
- build P management strategy in V4 to secure enough P for food production.

The Conference was held on 24th of April 2024 as a hybrid event (on-site in Bielany Water Treatment Plant in Poland and on-line). The most important objective of the Conference was to present the issue of P scarcity in V4 and ways to prevent the insufficient amount of P in V4'economy (and thus no possibility of producing food in V4) by innovative solutions (technological, environmental, economic and social) that can be implemented under the Circular Economy and Green Deal Strategies.

There were presentations addressing the issues of P management in various areas, without limiting them to the Visegrad Group countries, but instead encompassing all aspects related to P raw materials. The Conference program included both oral and poster presentations in the English language.

I hope that it was a great opportunity for Participants to exchange knowledge and experiences in the field of sustainable management of a valuable raw material such as Phosphorus.

Assoc. Prof. Marzena Smol

Chair of conference
Mineral and Energy Economy Research Institute, Polish Academy of Sciences, Poland

supported by
Visegrad Fund

Table of contents

supported by
Visegrad Fund

Phosphorus Raw Materials in V4 country – PhosV4 Project

Marzena Smol[1*] Paulina Marcinek[1], Dominika Szołdrowska[1], Tomáš Bakalár[2], Petro Kapustenko[3], Katalin Kurucz[4], Eugeniusz Koda[5], Anna Podlasek[5]

[1] Mineral and Energy Economy Research Institute, Polish Academy of Sciences, Poland
[2] Technical University of Kosice, Slovakia
[3] Brno University of Technology, Czech Republic
[4] Bay Zoltán Nonprofit Ltd. for Applied Research, Hungary
[5] Warsaw University of Life Sciences, Poland

Securing food supplies is key task of all countrie sin the world. One of the key resources that are needed for food production is Phosphorus (P), that is a critical raw material (CRM) for the European economy. Sustainable management of P is crucial for agriculture, food, water and the environment. Strategically, Europe should be independent in supply of P, and therefore, there is a significant need to recover P from P-rich residues, as wastewater and sewage sludge. Actions in this field were already taken in developed countries (DE, CH), where P recovery is obligatory, thus achieving P security in domestic economy. Unfortunately, in Visegrad Group (V4) countries, P use involves losses at every stage in its lifecycle. It is the result of the lack of knowledge of amount and recovery potential of P-rich waste sources, lack of action plan, know-how, financial resources and low awareness on P importance for people's lives. The project "*How to stay alive in V4? Phosphorus Friends Club builds V4's resilience*" was the answer to this demand.

Project included detailed analysis of the P-rich waste in V4 countries, development of roadmap for the sustainable and circular management of P sources in region, transfer of knowledge on P recovery technologies and commercialisation through various workshops:

- Workshop "*Inventory of Phosphorus Raw Materials in V4*",
- Workshop "*Phosphorus Recovery - challenges and perspectives in V4*",
- Workshop "*Our Phosphorus Raw Materials. Our Food. Our Future - V4's resilience in the face of pandemic*",
- Workshop "*Building V4's resilience: Roadmap for Sustainable and Circular Phosphorus Management*".

Results of the project include two scientific papers and two important reports presenting P-involved partner sand activities in V4 as well as Roadmap for P management in V4 (available free of charge on the project website https://www.phosv4.eu/).

Project could help to increase awareness of V4 on P importance, to establish cooperation that will lead to the development & implementation of P recovery and thus, will allow for securing the demand of this critical material in V4, needed for food production. Thus, it could increase a secured survival of V4 population.

Keywords: Phosphorus, P, food production, sustainable management

Acknowledgments: The project is financed by Visegrad Fund, project no. 22110364.

*smol@meeri.pl

Assumptions of the Roadmap for Sustainable and Circular Phosphorus Management in the V4 Countries

Marzena Smol[1*], Paulina Marcinek[1], Tomáš Bakalár[2], Zuzana Šimková[2], Henrieta Pavolová[2], Kinga Lorencz[3], Petar Varbanov[4], Yee Van Fan[4]

[1] Mineral and Energy Economy Research Institute, Polish Academy of Sciences, Poland
[2] Technical University of Kosice, Slovakia
[3] Bay Zoltán Nonprofit Ltd. for Applied Research, Hungary
[4] Brno University of Technology, Czech Republic

Phosphorus (P) is an essential nutrient for all life forms on Earth, including plants and animals. It plays a critical role in DNA binding. As the second most crucial macronutrient limiting plant growth and productivity in agricultural systems, P is key for crop growth and soil fertility. Its absence in soil diminishes agricultural yield and quality, necessitating fertilization in farming practices.

However, the excessive mining of P compounds for fertilisation has led to a fourfold increase in P inputs into the biosphere since the mid-1900s. This unsustainable use has depleted phosphate rock resources and caused phosphate overabundance in water systems, leading to eutrophication. These factors disrupt the natural P cycle, resulting in nutrient imbalances and the leakage of potential P excess into water bodies, adversely affecting aquatic life and water supplies.

The "RoadMap - V4's resilience in the face of the pandemic in the raw materials and food sector" aims to bolster the resilience of the Visegrad Group (V4) countries in the raw materials and food sector amidst pandemic challenges. It focuses on devising measures for the efficient, sustainable, and circular management of P sources—both primary and secondary—within the V4 nations to ensure an ample supply of P raw materials for food production. This roadmap provides insights into the current significance of P for the well-being of V4 populations and offers recommendations and procedural guidelines for future actions. The developed roadmap shows where to look for sources of P in a situation of unstable imports. In addition, it presents the possibilities of creating new jobs in the development of P technology and construction or operation of installations. Additionally, the roadmap aims to enhance the competitiveness of the secondary raw materials market within the region, positioning it more strongly within the European Union (EU).

Keywords: Phosphorus, P, roadmap, sustainable management, Visegrad Countries

Acknowledgments: The project is financed by Visegrad Fund, project no. 22110364.

*smol@meeri.pl

Influence of Oxygen Concentration on Biocenosis in Denitrifying Dephosphatation: A Case Study of IFAS-MBSBBR

Anna Gnida[1*], Monika Żubrowska-Sudoł[2], Katarzyna Sytek-Szmeichel[2], Jolanta Podedworna[2], Dorota Marciocha[1], Joanna Surmacz-Górska[1]

[1] Silesian University of Technology, Poland
[2] Warsaw University of Technology, Poland

The objective of this study was to assess how varying dissolved oxygen concentrations in aerobic phases affect bacterial biocenosis during denitrifying dephosphatation in a laboratory-scale Integrated Fixed-Film Activated Sludge – Moving-Bed Sequencing Batch Biofilm Reactor (IFAS-MBSBBR). Four series of experiments were conducted, each with different oxygen concentrations ranging from 5.5 to 2 mg O_2/L. Reactor performance was evaluated by monitoring chemical oxygen demand, nitrogen, and phosphorus concentrations. Characterization of activated sludge and biofilm biocenosis involved fluorescent in situ hybridization and denaturing gradient gel electrophoresis. Results showed that when aerobic phase oxygen concentrations were between 3.5 - 5.5 mg O_2/L, wastewater treatment efficiency for biogenic compounds was notably high. However, reducing oxygen concentrations to 2 mg O2/L led to decreased effectiveness in both nitrification and denitrification processes. Furthermore, alterations in bacterial biocenosis were observed, with Accumulibacter phosphatis predominating at the lowest oxygen concentration. Clade II was more prevalent in activated sludge, while clade I was more dominant in the biofilm. These findings underscore the significant influence of dissolved oxygen levels on microbial community dynamics and reactor performance in denitrifying dephosphatation processes.

Keywords: denitrifying dephosphatation, polyphosphate accumulating organisms, moving bed reactor, activated sludge, biofilm, wastewater treatment

Acknowledgments: The study was performed as a part of the research project titled “Assessment of the Possibility of Using the IFAS-MBSBBR Reactor for Nutrient Removal from Wastewater, Predominantly in the Process of Denitrifying Phosphorus Removal” [N N523 737340], funded by the National Science Centre (Poland). Preparation of the abstract and presentation was financed by Ministry of Science and Higher Education [08/070/BK_24/0031]. We want to thank Malwina Homa and Katarzyna Drzewiecka for their valuable laboratory assistance.

*anna.gnida@polsl.pl

The possibilities of recovering phosphorus from sewage sludge and leachate from sludge dewatering

Bartosz Łuszczek[1,2*], Dominika Poproch[1,2], Ewelina Chrapusta-Srebrny[1], Katarzyna Biernat-Rosa[1]

[1] Kraków Water, Poland
[2] Cracow University of Technology, Poland

The project investigated the possibilities of recovering phosphorus from sewage sludge and leachate from sludge dewatering. Analysis was made of the possibility of precipitation of magnesium ammonium phosphate (MAP) at various pH levels and various magnesium sources used. Based on the results of laboratory tests, a pilot batchtest program was prepared. The tests were carried out in a pilot station consisting of a recirculating reactor. MgCl2*6H20 was used as a source of magnesium. Doses of magnesium of 180 mgMg/l and 360 mgMg/l were tested at various pH values. A 67-77% reduction of P-PO4 in contaminated leachates was achieved. A 20-66% reduction in P-PO4 was achieved in the digested sludge. The highest reductions were achieved with a magnesium dose of 360 mgMg/l and pH correction. Additionally, pilot tests with continuous sludge flow were carried out. P-PO4 reduction above 90% was achieved at a dose of 360 mgMg/l and pH correction.

Keywords: phosphorus, magnesium ammonium phosphate, wastewater

Acknowledgments: The research was carried out as part of the project RPMP.01.02.01-12-0237/19-00 co-financed by Małopolska Center of Enterpreneurship.

*bartosz.luszczek@wodociagi.krakow.pl

Nutrient Dynamics at Municipal Solid Waste Landfills: Current State of Knowledge and Selected Case Studies

Anna Podlasek*, Eugeniusz Koda, Magdalena Daria Vaverková, Aleksandra Jakimiuk
Warsaw University of Life Sciences, Poland

This study presents a detailed analysis of nutrient dynamics within selected Municipal Solid Waste (MSW) landfills. It offers insight into up-to-date studies related to nutrient occurrences and their environmental consequences at waste management facilities. Within the scope of the presented research, the interrelationships between nitrogen and phosphorus compounds were analysed in comparison with other leachate constituents. Additionally, the manuscript integrates case studies featuring monitoring data to provide real-world examples of nutrient dynamics in diverse MSW landfill scenarios. The case studies present the variability and influencing factors on nutrient concentrations in leachate, enhancing the practical applicability of the findings. The study refers also to the significance of proper landfill design and leachate management strategies to mitigate adverse environmental impacts. By exploring nutrient patterns in MSW landfill leachate and integrating landfill age and management-related analyses, this research contributes a holistic perspective to the ongoing discourse on sustainable waste and leachate management practices.

Keywords: leachate; waste management; phosphorus; nitrogen

Acknowledgments: The authors sincerely thank DEPOZ, spol. s r.o. (Czech Republic) and Miejskie Przedsiębiorstwo Oczyszczania w m. st. Warszawie sp. z o.o. (Poland) for providing monitoring data. Their support was crucial in the successful execution of the research presented in this paper.

* anna_podlasek@sggw.edu.pl

supported by
Visegrad Fund

Circular Economy Model in the Agricultural Sector in the European Union - Barriers and challenges

Maciej Sabal*
AGH University of Krakow, Poland

About a dozen years ago, the economic paradigm that prevails in the European Union is based on a circular economy. An expression of this approach was the announcement of the European Green Deal in 2019. EU directives clearly indicate the need to implement circular principles in various sectors, including agriculture. The Farm to Table Strategy precisely defines the areas to be covered by the change. One of the demands is to halve the use of pesticides and fertilizers, and to increase the amount of land devoted to organic farming.

The purpose of the speech is to present the main challenges of implementing the Farm to Table Strategy, based on the results of qualitative research conducted among farmers on circular agriculture. The research shows, among other things, that few of the demands expressed in the Strategy are recognized by farmers, and the inconsistency of the Strategy regarding, among other things, the nitrate directive has been noted. On the basis of the research, as well as the literature on the subject, the main barriers related to the implementation of the Strategy have been identified, concerning EU law on the one hand, and the way in which changes in the law are communicated on the other. The paper will present recommendations for future EU action on the implementation of circular agriculture. In the context of the ongoing crisis in the community countries related to the situation of farmers, this issue seems urgent to consider.

Keywords: closed-loop economy, agriculture, directive, European Union, fertilizers

*sabal@agh.edu.pl

supported by
Visegrad Fund

The Role of Phosphorus in the Synthesis and Functionalization of Organic Compounds

Katarzyna Sala*, Magdalena Bańkosz, Bożena Tyliszczak

Cracow University of Technology, Poland

Phosphorus plays a key role in organic chemistry, both through its biological functions and technological applications, especially in the context of polymeric materials used in regenerative medicine and anti-cancer therapies.

Polymeric materials are increasingly used in regenerative medicine due to their ability to adapt to different conditions. Phosphorus, as a component of many biomaterials, plays a key role in ensuring the biological compatibility and mechanical properties of these materials. In addition, modern technologies using phosphorus polymers enable controlled drug release in anticancer therapies, leading to improved treatment efficiency and effectiveness.

In the study discusses the importance of phosphorus as a biological element and its impact on human health. In an organic chemistry perspective, phosphorus is an essential component of many chemical compounds that play a key role in living organisms. Phosphorus compounds, such as adenosine triphosphate (ATP), are essential for the proper functioning of the body, participating in metabolic processes, DNA and RNA synthesis, and bone and tooth formation. The use of phosphorus-containing polymers in regenerative medicine may lead to better therapeutic outcomes by ensuring biocompatibility and providing the necessary components for tissue regeneration.

In summary, phosphorus is found in numerous chemical compounds that play a key role in the metabolic processes of living organisms and in the synthesis of organic chemicals. An integrated approach, combining biological, technological and chemical aspects, can contribute to better results in tissue engineering, regenerative medicine and anti-cancer therapies.

Keywords: phosphorus, chemistry, polymer materials, medicine, tissue engineering

Acknowledgments: This paper was prepared as part of the SMART-MAT Functional Materials Scientific Circle conducted at the Tadeusz Kościuszko Faculty of Materials Science and Physics, Krakow University of Technology. The project was financed from funds from the state budget awarded by the Minister of Science and Higher Education as part of the programme 'Students Scientific Circles Create Innovations' in the project 'Transdermal Systems in Targeted Therapy of Skin Tumours'.

* katarzyna.sala@student.pk.edu.pl

Phosphate bonding by $CaCO_3$-iron oxide magnetic particles in wastewater matrix

Mateusz Skalny*, Jakub Czeremuga, Tomasz Bajda
AGH University of Krakow, Poland

Adsorption is a widely applied method to separate and recover phosphorus (P) from complex media such as eutrophic waters, process waters, or wastewaters. Due to the complex chemistry of phosphorus in such media, it is challenging to selectively and effectively separate it. Phosphate readily forms bonds with various elements such as Fe, Al, Ca, or Mg, resulting in soluble complexes or precipitation as crystalline phases. When designing an adsorption system, it is essential to determine the physicochemical interactions between the solid adsorbent and phosphorus species in the treated water.

In this study, we examine the adsorption mechanism of phosphate from environmental matrixes like wastewater, river water, and DI water using $CaCO_3$-iron oxide magnetic particles synthesized from steelmaking dust. P interactions with materials were investigated using FTIR spectroscopy, TEM, and EDS imaging. Steelmaking dust after functionalization through dissolution recrystallization protocol shows a drastic increase in phosphate adsorption capacity. Moreover, the P removal efficiency and adsorption capacity are far better in the river and wastewater matrix than in DI water. This phenomenon is attributed to the presence of divalent cations such as Ca^{2+} and Mg^{2+} in environmental water samples. The enhanced capacity for phosphorus removal is associated with the precipitation of calcium phosphate (CaP) or magnesium phosphate (MgP) and the ionic strength of such solutions. Functionalized steelmaking dust has the potential to serve as an effective adsorbent for the removal of phosphorus, which can subsequently be extracted from effluent through magnetic separation techniques.

Keywords: adsorption; phosphorous recovery; wastewater

Acknowledgments: This research was financed by the National Science Centre, Poland Grant No. 2021/41/B/NZ9/01552.

* mskalny@agh.edu.pl

supported by
Visegrad Fund

Biofuels from Algaes and Microrganism

Gaweł Sołowski*

Bingol University, Turkey

The European sustainability plan for 2030 assumes conversion from fossil fuels into renewable sources. Therefore many countries besides Europe published many plans of using microbial and algae as relevant parts, also. Both methods often combine themself for optimization. Butanol and ethanol can be obtained by acetone-butanol-ethanol bacteria but more solutions are from algae, while hydrogen is from dark fermentation. The algaes approached increased from hydrogen source by photolysis also as feed for green chemistry, green polymers biofuels and pharmacy. The microbial methods of hydrogen production include dark fermentation (DF), biophotolysis, photofermentation (PF), and microbial electrolysis cells (MEC). Biophotolysis is a process similar to photosynthesis but these plants by contact with Solar light split water into hydrogen and oxygen. Biophotolysis uses cyanobacteria and algae (macro and micro). Due to the high applicability of these organisms as feed or raw materials are more assessed as feed for other hydrogen generation ways. We can reduce the greenhouse effect by employing biophotolysis organisms that capture carbon dioxide. At the same time, algae can produce materials for the chemistry, pharmacy, and energy industries. Algaes are lipid-rich plants and after biophotolysis and biosorption can be then fed for dark fermentation. In dark fermentation, the rest are partially converted by anaerobic bacteria into hydrogen and unconverted for biodiesel. All methods are easier controllable than others and therefore are relevant parts of newly designed waste management plants both in industrial and municipal waste sectors. All earlier mentioned methods are sustainable methods for replacing and closing the loop of fossil waste also with the addition of biocenosis.

Keywords: biofuels, algaes, microbials, hydrogen production, dark fermentation

* gawelsolowski@gmail.com

supported by
Visegrad Fund

The influence of phosphorus on the strength of low-emission steels in the automotive and aviation industries

Karolina Sulima*, Krzysztof Chyła

Silesian University of Technology, Poland

Based on research and available literature, the impact of dendritic phosphorus segregation on the properties and structure of low emission "green steels" heat-treated was analysed, through surface phosphorus segregation and phosphorus segregation to the grain boundaries occurring during heat treatment of iron alloys, and their long-term operation at elevated temperatures in elements operating in automotive and aviation industry devices. Based on the impact tests carried out on steel with an admixture of phosphorus, it was found that the segregation of the above-mentioned chemical element reduces the impact strength and increases the brittle transition temperature. The higher the phosphorus admixture content and the higher the strength properties of iron alloys, the lower temperatures the alloy becomes brittle, which worsens its strength and may result in faster material damage.

Keywords: low-carbon steel, phosphorus, strength properties

* karolina.regulska1993@gmail.com

supported by
Visegrad Fund

Visegrad Fund

PhosV4

PHOSPHORUS FRIENDS CLUB IN V4

Leader

Mineral and Energy Economy Research Institute
Polish Academy of Sciences

Project Partners

Bay Zoltán Nonprofit Ltd. for Applied Research

TECHNICAL UNIVERSITY OF KOŠICE

BRNO UNIVERSITY OF TECHNOLOGY

WARSAW UNIVERSITY OF LIFE SCIENCES

The PhosV4 project is a member of European Sustainable Phosphorus Platform.

European Sustainable Phosphorus Platform

ISBN 978-83-67606-38-7