20th Balkan Mineral Processing Congress

PROCEEDINGS BOOK

Editors
Esra Baştürkcü
Yusuf Enes Pural
Zeynep Üçerler Çamur

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This congress is dedicated to the memory of Prof. Dr. Güven ÖNAL.

Prof. Dr. Güven ÖNAL
(1940-2024)

President of Balkan Mineral Processing Scientific Committee
(1995-2024)

President of Balkan Mineral Processing Science Academy
(2001-2024)

Dear Readers,

Putting together the proceedings of a congress is, in many ways, a quieter kind of work. One that happens behind the scenes while everything else is taking shape. As the editorial board of BMPC 2026, we have had the privilege of being close to this process from early on, and this volume is the result of that collective effort.

Of the 139 papers included, 13 are plenary presentations, 86 are oral, and 40 are poster contributions. The most active sessions in terms of submissions were Hydrometallurgy, Pyrometallurgy and Bio-Processing with 22 papers, Flotation and Surface Chemistry Processes with 20, and Material Analysis and Mineral Characterization with 18, together accounting for more than 43% of all contributions. These figures reflect where much of the current research energy in the field is concentrated, though the breadth of topics across all 16 sessions points to a community that remains wide in its interests.

Geographically, Türkiye led with 65 contributions, followed by Albania with 11 and Kosovo with 6. Beyond the immediate region, researchers from Finland, Germany, Norway, Brazil, Algeria, and Australia were also among the contributors, reflecting a community that has quietly but steadily grown in reach over the years.

We would like to thank all authors for their submissions and their patience through the review and editing process. Our gratitude also goes to the reviewers, whose careful evaluations were essential in maintaining the scientific quality of this collection.

We hope this volume serves as a useful reference, and perhaps as a starting point for new collaborations.

Dr. Esra BAŞTÜRKÇÜ Dr. Yusuf Enes PURAL Dr. Zeynep ÜÇERLER ÇAMUR

Editorial Board, BMPC 2026 Proceedings

Since 1973: Advancing Mineral Processing Together

For several decades, a significant number of researchers and specialists in the Balkan region have devoted their efforts to advancing the science and practice of mineral processing. Their work has focused on establishing and improving industrial concentration processes, expanding production capacities, optimizing operational performance, enhancing energy efficiency in processes and equipment, and developing innovative machinery and technologies. Through these sustained efforts, mining and mineral processing activities in the Balkans have achieved steady progress and continue to play an important role in the region today.

This long-standing scientific endeavor has led to the emergence of many distinguished researchers in mineral processing across the Balkan region. In 1973, the first Balkan Mineral Processing Committee (BMPC) was established by its founding members: Prof. Dr. Kiriak Petrov Kovachev (Bulgaria), Prof. Dr. Parachiv Ilie (Romania), Prof. Dr. Dusan Salatic (Serbia), and Prof. Dr. Zeki Doğan (Türkiye).

The Balkan Mineral Processing Congress (BMPC) has been held for more than fifty years. The first Balkan Mineral Processing Conference took place in Varna, Bulgaria, from November 12 to 15, 1973. During the final session of that event, the Balkan Mineral Processing Scientific Committee (BMPSC) for Conferences was formally established. Today BMPSC has 27 active members from Albania (3), Bosnia-Herzegovina (2), Bulgaria (2), Greece (3), Republic of Kosovo (3), Moldova (1), Montenegro (3), North Macedonia (3), Romania (3), Slovenia (1), Turkiye (3), and 12 honorary members from Albania (2), Bulgaria (2), North Macedonia (1), Romania (3), Serbia (1), Türkiye (3).

In early meetings of BMPSC, the Committee decided that a Balkan Mineral Processing Conference would be organized every two years (later changed to three years), each time hosted by a different Balkan country. A major milestone in the development of BMPC occurred during the 9th Balkan Mineral Processing Conference, held in Istanbul (Türkiye) from September 11 to 13, 2001, under the chairmanship of Prof. Dr. Güven Önal. At that time, the event evolved from a “Conference” into a “Congress,” reflecting its growing scientific impact, the increasing number of participants, and the high quality of the papers presented. To date, nineteen (19) conferences/congresses have been successfully organized in various Balkan countries, including Albania (2), Bosnia-Herzegovina (1), Bulgaria (3), Greece (1), Republic of Kosovo (1), Romania (3), North Macedonia (1), Serbia (3), and Türkiye (3).

Following the establishment of the Balkan Mineral Processing Scientific Committee, the Balkan Mineral Processing Science Academy (BMPSA) was founded in 2001. Its founding members included Prof. Dr. Güven Önal (Türkiye), Prof. Dr. Zeki Doğan (Türkiye), Prof. Dr. Gülhan Özbayoğlu (Türkiye), Prof. Dr. Suna Atak (Türkiye), Prof. Dr. Dusan Salatic (Serbia), Prof. Dr. Nadezda Calic (Serbia), and Prof. Dr. Parachiv Ilie (Romania). Today, BMPSA has 43 members, including founding members, full members, and corresponding members; unfortunately, some of these distinguished members have passed away. Prof. Dr. Güven Önal served as the President of both the Balkan Mineral Processing Scientific Committee from 1995 and the Balkan Mineral Processing Science Academy from 2001 until his passing on March 31, 2024. Following his leadership, Prof. Dr. Fatma Arslan has continued this responsibility as President.

Participation in the activities of the Balkan Mineral Processing Scientific Committee has created a strong connection between regional scientific development and global

technological trends. It has also provided valuable opportunities for direct interaction among researchers, designers, equipment manufacturers, and investors from the Balkan region and beyond. Over time, the BMPC has evolved into a well-established international event held every three years, attracting participants not only from the Balkan countries but also from many other parts of the world.

The XXth Balkan Mineral Processing Congress (BMPC 2026) was held in Istanbul, Türkiye, on April 9-11, 2026, for the fourth time in the country. The congress is organized by the Mineral Processing Engineering Department of the Mining Faculty at Istanbul Technical University, in cooperation with the Turkish Mining Development Foundation (YMGV). This congress is the first one after Prof. Güven Önal's loss and is dedicated to the memory of Prof. Dr. Güven Önal.

I would like to express my sincere gratitude to the Head of the Mineral Processing Engineering Department, Prof. Dr. Murat Olgaç Kangal, and to the President of the Turkish Mining Development Foundation, Mr. Ali Türkoğlu, for their leadership in organizing this congress. I also extend my thanks to the secretaries of the organizing committee, Prof. Dr. Feridun Boylu and Prof. Dr. Gülay Bulut (BMPSC Secretary), and to Assoc. Prof. Dr. Genc Demi (BMPSC Vice President), to all members of the Balkan Mineral Processing Scientific Committee, to the members of the organizing committee, and to all participants whose contributions have made this congress both valuable and memorable. Without their dedication and support, this congress would not have been possible.

Finally, I would also like to extend our sincere appreciation to the sponsoring organizations and institutions whose generous support has significantly contributed to the successful organization of BMPC 2026.

Prof. Dr. Fatma ARSLAN

President

Balkan Mineral Processing Scientific Committee

Balkan Mineral Processing Science Academy

Dear Participants,

The Mining Development Foundation of Turkey has, since its establishment, continued its efforts to support the development of mining and mineral processing in Türkiye, to promote the effective utilization of domestic resources, and to contribute to the dissemination of scientific knowledge through congresses, conferences, and publications.

The XXth Balkan Mineral Processing Congress (BMPC 2026), held in Istanbul on April 9–11, 2026, represents a well-established regional platform that enables the exchange of scientific and technical knowledge in the field of mineral processing. Organized in cooperation with the Department of Mineral Processing Engineering of the Faculty of Mines at Istanbul Technical University, the congress continues a long-standing tradition of collaboration and knowledge sharing across the Balkan region and beyond.

Over time, BMPC has evolved into an international platform where researchers, engineers, and industry representatives come together to discuss technological developments, operational challenges, and new approaches. The congress supports not only scientific exchange but also the strengthening of professional networks and the development of regional collaborations.

At a time when our Foundation marks its 40th anniversary, the organization of the Balkan Mineral Processing Congress for the 20th time demonstrates both the continuity of institutional knowledge and its transformation into a scientific platform with international recognition.

This year's congress holds additional significance as it is the first BMPC organized following the passing of the late Prof. Dr. Güven Önal, who made important contributions to the Turkish mining sector and the Balkan mineral processing community. Prof. Dr. Güven Önal, who served for many years as the President of the Mining Development Foundation of Turkey and played a key role in shaping its current institutional structure, also held long-term leadership positions within the Balkan Mineral Processing Scientific Committee (BMPSC) and the Balkan Mineral Processing Science Academy (BMPSA). Through these roles, he guided the institutional and scientific development of BMPC and made pioneering contributions to its establishment as an international platform. We remember him with respect, gratitude, and deep appreciation.

As the Mining Development Foundation of Turkey, we would like to express our sincere thanks to the Ministry of Energy and Natural Resources of the Republic of Türkiye, Istanbul Technical University, the Faculty of Mines, and the Department of Mineral Processing Engineering, as well as to all institutions and organizations that contributed to the organization of the congress. We also extend our gratitude to our sponsors, invited speakers, session chairs, authors, reviewers, members of the organizing and scientific committees, and all participants.

We are pleased to present this proceedings book to the national and international mining and mineral processing community and hope that it will serve as a valuable resource for future studies.

M. Ali TÜRKOĞLU
Chairman of the Board
Mining Development Foundation of Turkey

Dear Colleagues,

It is a great honor and privilege to present the proceedings of the 20th Balkan Mineral Processing Congress (BMPC 2026).

Since its inception in 1973 in Varna, Bulgaria, the Balkan Mineral Processing Congress has evolved into a well-established and respected scientific platform, bringing together researchers, academics, and industry professionals from across the region and beyond. Over the decades, BMPC has played a significant role in promoting knowledge exchange, fostering collaboration, and advancing the field of mineral processing.

The 20th edition of the Congress proudly continues this strong tradition by addressing contemporary challenges and emerging opportunities in mineral processing and extractive metallurgy. Particular emphasis has been placed on innovative and sustainable approaches in mineral beneficiation, recycling of secondary resources, critical raw materials, and environmentally responsible processing technologies.

This volume comprises a total of 139 scientific papers, contributed by researchers from 30 different countries, reflecting the truly international character of the congress. The contributions are organized across 16 thematic sections, covering a broad spectrum of topics and demonstrating the diversity and interdisciplinary nature of current research in mineral processing.

The papers included in this proceedings volume represent a high level of scientific quality and provide valuable insights into current research trends, technological advancements, and industrial applications. We believe that this collection will serve as an important reference for both academic researchers and industry practitioners.

I would like to express my sincere gratitude to all authors for their valuable contributions, to the members of the Scientific and Organizing Committees for their dedicated efforts, and to all reviewers for their careful evaluations, which have ensured the high quality of this publication.

I also extend my appreciation to all participants, sponsors, and supporting institutions whose contributions have made BMPC 2026 a successful and impactful event.

I hope that this volume will inspire further research, strengthen international collaboration, and contribute to innovation in the field of mineral processing.

Yours sincerely,

Prof. Dr. Murat Olgaç KANGAL

Chairman, BMPC 2026

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PROFESSIONAL RISK ASSESSMENT IN MINERAL PROCESSING

Marija HADZI-NIKOLOVA*, Dejan MIRAKOVSKI, Afrodita ZENDELSKA, Nikolinka DONEVA

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A B S T R A C T

Risk assessment constitutes a fundamental element in establishing a safe and healthy working environment. The responsibility for conducting the risk assessment process lies with employees, as their active involvement promotes workplace safety, motivation, and organizational trust. Furthermore, risk assessment serves as an indicator of a company's sustainability trajectory by contributing to enhanced capacity development, productivity, and profitability.

In the mineral processing industry, workers are routinely exposed to a wide range of occupational hazards and harmful substances. Accordingly, a qualitative/semi-quantitative risk assessment was conducted using the 5×5 risk assessment matrix across four workstations within a mineral processing plant: flotation operator, filter press operator, mill operator, and flotation shift engineer. The findings indicated that all four positions were classified as high-risk workplaces, leading to the proposal of appropriate control measures aimed at hazard elimination and risk reduction.

Key words: *Flotation, hazards, workplace, safety*

1. INTRODUCTION

The rapid development of technology, accompanied by a constant increase in the power and productivity of machines, contributes to changing working conditions in workplaces in industrial enterprises. Therefore, ensuring safe and hygienic working conditions in production is a serious scientific problem that engineers of literally all specialties have to face, especially at mining (Nuruldaeva et al., 2025). Mining and mineral processing, are with the highest rate of occupational diseases and accidents (Parker at al., 2017), where workers are exposed to the worst and most dangerous working conditions (Marimuthu at al., 2023). Mining can be singled out as an industry with high occupational risk indicators, many works (Gyekye, 2003, Milošević at al., 2025) have singled them out as the most dangerous production environments due to the large number of injuries that occur in them.

Mining has always constituted one of the most dangerous industries. This is confirmed by data published in Eurostat, OECD, or by national organizations, such as, in Poland, the State Mining Authority. The reports presented by these organizations indicate the main risk groups and the effects of their occurrence in mining plants. Prepared reports on accidents in mining indicate their causes and circumstances of occurrence (Tubis at al., 2020).

Many processes in the mining are characterized by specific working conditions, and high occupational health risks for workers. Mining have the highest levels of occupational morbidity - up to 24.3 per 10 thousand workers (Preobrazhenskaya at al., 2016). Increased occupational risk has a negative impact on the health of workers, worsens the indicators of general and occupational morbidity, increases mortality from chronic non-infectious diseases (Mandal at al., 2022; Freeh and Iles, 1985; Chebotarev and Sementsova, 2021; Kiryakov and Sukhova, 2015).

Mineral processing plants are an important element of the overall process of extraction and processing of mineral raw materials. They combine different technologies, various types of

production equipment, operate with high capacities and generally observe a rather complex technological process (Kostadinova and Vladkova, 2025).

Technological processes of mineral processing can be conditionally divided into three main stages: operations of preparation for enrichment - crushing, screening and transportation of raw materials, enrichment processes and operations to obtain concentrates (drying, packaging, loading).

The key occupational hazards associated with mineral processing plants are dust, noise, vibration and mechanical injuries (Nuruldaeva at al., 2025).

Risk assessment is a proven technique for improving the quality of input to safety management, aiming to prevent accidents by “debugging” designs and operating methods etc. before accidents occur, rather than responding to accidents which have happened and aiming to prevent recurrence (Guide to Reviewing a Mine Risk Assessment of mine equipment and operations, 1997).

2. MATERIAL AND METHODS

Risk is defined as hazard or danger having adverse consequences for individuals. The U.S. Atomic Energy Commission in 1975 has identified risk as 'the probability of occurrence of particular consequences over a specific period of time' (Risk assessment and its management in mining industry, 2012). Risk assessment is process for estimate of the likelihood of getting injury or adverse health condition.

The structured process associated with risk assessment helps to characterize the major hazards and evaluate engineering, management and work process factors that impact how a mine mitigates its highest risk.

Although there is a spread range of approaches and risk assessment techniques, in essence, they all contain the same fundamental steps (Risk assessment and its management in mining industry, 2012). These are:

- Identify hazards–something with the potential to cause harm;
- Assess the likelihood, or probability, of harm arising from the hazard;
- Assess the severity of harm resulting from realization of the hazard;
- Combine assessments of likelihood and severity to produce an assessment of risk;
- Use the assessment of risk as an aid to decision making.

A 5x5 matrix to risk assessment of four workplaces (flotation operator, filter press operator, mill operator, and flotation shift engineer) in the mineral processing have been used (Table 1).

Table 1. Particle size distribution of representative ore sample

		Consequence				
		1	2	3	4	5
Likelihood		Minor	Low	Medium	High	Major
Almost certain	5	2	3	4	4	4
Likely	4	2	3	3	4	4
Possible	3	1	2	3	3	4
Unlikely	2	1	2	2	3	4
Rare	1	1	1	1	2	3

Some risks may be higher but will be well managed and therefore acceptable. An example of the actions taken based on the risk rating is shown in Table 2.

Table 2. Risk measures (Risk assessment education resource, Mining Safety and Health Advisory Committee, 2023)

Risk level	Risk measures
4– Major	Immediate action required Identify and implement controls to manage risks Highest level of management needs to be involved
3 – Significant	Immediate action required Identify and implement controls to manage risks Senior site management needs to be involved
2 – Medium	Implement control to manage risks Responsibility must be defined
1– Low	Implement controls as required Manage by routine processes

Risk assessment of four workplaces (flotation operator, filter press operator, mill operator, and flotation shift engineer) in the mineral processing is given in Table 3.

3. RESULTS AND DISCUSSION

Professional risk assessment in mineral processing plant on four workplaces have been conducted based on the findings of more researches study, as well as routine measurements of physical and chemical occupational hazards conducted by the accredited AMBICON Laboratory within the Faculty of Natural and Technical Sciences across numerous mines in North Macedonia. It was determined that operators in mineral processing plant are exposed to a complex combination of adverse working environment and labor process factors. These include industrial noise and vibration, unfavorable microclimatic conditions, elevated airborne dust concentrations in the working zone—predominantly consisting of aerosols with fibro genic effects, as well as increased physical workload and work intensity.

Occupational exposure assessments indicate that noise levels at crushing, grinding, and ore transportation workstations range between 85 and 100 dB, exceeding the maximum permissible limits in nearly 85–90% of the studies reviewed, with some reports documenting exceedances in all observed cases. Airborne dust concentrations at these workplaces vary depending on the type of mineral raw material processed and the effectiveness of ventilation systems, ranging from 3.8 to 5.8 mg/m³ and containing more than 10% free silicon dioxide. Another consistently present occupational hazard is whole-body vibration. The reviewed literature demonstrates that vibration levels in both coarse and fine crushing facilities surpass the maximum permissible values by more than 50%.

Consequently, varying intensities of production-related factors result in different levels of risk for the development of occupational pathologies among workers. Occupational diseases most commonly arise in employees exposed to multiple harmful factors simultaneously. Risk assessment findings and the reviewed literature indicate that dust-related diseases, such as pneumoconiosis, are prevalent among crusher operators. Furthermore, prolonged exposure to whole-body vibration is associated with musculoskeletal disorders, including pain in the lower back, limbs, and joints, while sustained exposure to noise levels exceeding maximum permissible limits is a well-established cause of occupational hearing loss.

Although all four positions in mineral processing plant (flotation operator, filter press operator, mill operator, and flotation shift engineer) were classified as high-risk, the role of the mill

operator was identified as the most hazardous due to additional occupational exposures encountered during routine tasks, including work in confined space and the operation of cranes and elevators.

4. CONCLUSION

The synthesized findings demonstrate a high prevalence of occupational hazards in mineral processing plant, with a strong association between multifactorial exposures and the development of chronic health conditions. These results emphasize the need for integrated protective strategies and further targeted research.

Nevertheless, despite the research conducted to date, numerous unresolved issues and challenges remain regarding the occupational health and safety of workers in mineral processing plants. Evolving working conditions and the introduction of new technologies necessitate continuous monitoring and ongoing adaptation of occupational health and safety management systems.

Future research outcomes may contribute to the enhancement of existing safety practices, including the formulation of policy recommendations, the implementation of innovative technologies, and the development of improved risk assessment tools. Ultimately, ensuring safe and healthy working conditions requires the continuous updating of knowledge and the systematic refinement of occupational health and safety management frameworks.

Table 3. Professional risk assessment in mineral processing plant (MPP). L is Likelihood, C is Consequence and R is Risk

Danger or harmful	Shift engineer in MPP			Floater			Filter press operator			Mill opertaor		
	L	C	R	L	C	R	L	C	R	L	C	R
Insufficient safety due to rotating and moving parts	2	3	2	3	3	3	3	3	3	3	3	3
Internal transport and movement of working machines or vehicles	3	4	3	2	4	3	2	4	3	2	4	3
Exposure to mechanical blow	2	3	2	3	3	3	3	3	3	3	3	3
Hand tools				3	3	3	3	3	3	3	3	3
Crane and elevators	2	3	2							3	4	3
Possibility of slipping, falling (wet or slippery surfaces)	2	3	3	3	3	3	2	3	3	3	3	3
Working at height	2	4	3	3	4	3	2	4	3	3	4	3
Confined space										3	4	3
Electrical hazards	2	4	3	2	4	3	2	4	3	2	4	3
Dust (inhalation, skin absorption)	3	2	2	3	2	2	4	2	3	4	2	3
Hazardous chemical substances (inhalation)	2	4	3	3	4	3	2	4	3	3	4	3
Noise	3	2	2	3	2	2	3	2	2	3	2	2
Vibration	3	2	2	3	2	2	3	2	2	3	2	2
Unfavourable microclimatic conditions (low temperature, humidity, air flow speed)	2	3	3	3	3	3	3	3	3	3	3	3
Harmfuls arising from mental and psychophysiological efforts												
Strains when performing certain tasks that cause psychological strain - stress	4	2	3	3	2	2	3	2	2	3	2	2
Non-physiological body position: prolonged standing, bending.	4	2	3	4	2	3	4	2	3	4	2	3
Need for decision-making	4	1	2									
Using appropriate knowledge and skills	4	1	2	4	1	2	4	1	2	4	1	2
Responsibility in the conducting rules	4	1	2	4	1	2	4	1	2	4	1	2
Conflict situations	3	2	2	3	2	2	3	2	2	3	2	2
Harmfuls related to the organization of work												
Shift working	4	2	3	4	2	3	4	2	3	4	2	3
Night working	4	2	3	4	2	3	4	2	3	4	2	3

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