TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 69, Issue Special III, July, 2026

BIBLIOMETRIC ANALYSIS OF RESEARCH TRENDS IN POLYMER MATRIX COMPOSITE USED FOR SAFETY HELMETS

**Cristian-Ștefan BUNDUC, Lucian-Ionel CIOCA,
Diana-Petronela BURDUHOS-NERGIȘ, Costică BEJINARIU**

Abstract: *People's protection is essential regardless of the field of activity. To ensure this, different types of Personal Protective Equipment (PPE) can be used. For example, safety helmets must be used where the risks of traumatic brain injury cannot be eliminated. However, as technological progress advances, the risks associated with work activities, as well as the characteristics of PPE, must be adapted. Therefore, this bibliometric study presents a summary of research in the field, focusing on identifying current gaps and limitations in polymer matrix composite safety helmets. The bibliometric analysis was conducted on three data sets extracted from the Scopus database ("polymer composite"; "protective helmet"; and "polymer composite" and "energy absorption") using the Bibliometrix software.*
Keywords: *Bibliometric Analysis, Safety Helmets, Polymeric Composite Materials, Personal Protective Equipment*

1. INTRODUCTION

Due to the almost limitless possibilities of obtaining a wide range of materials, composite materials are increasingly used in various fields [1], [2]. Composite materials combine the unique properties of two or more materials, with the final product exhibiting improved characteristics compared to the individual materials. Some serve as the matrix, and others reinforce the composite [3]. The reinforcing elements, often in the form of fibers, provide hardness and strength, while the matrix encapsulates them, holds them together, and transfers external forces to them [4]. Also, the reinforcing elements can be continuous or short fibers, particles of different sizes, or, in some cases, placed in layers, as shown in Figure 1. However, depending on their application, composite materials are divided into several categories. The matrix of the composite material can be metallic (MMC), polymeric (PMC), or ceramic (CMC). In biomedicine, the automotive industry, military applications, and beyond, metal matrix composites are widely used and offer good performance [5], [6]. CMCs have high thermal stability, excellent wear resistance, and exceptional resistance to thermal shocks. With applications in the aerospace, automotive, and electronics industries, CMCs offer numerous economic advantages and are expected to continue to grow in the market [7], [8].

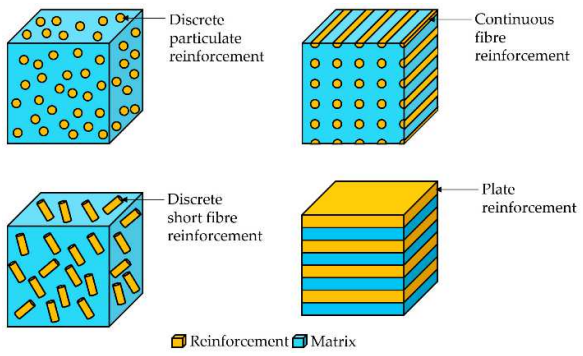


Fig. 1. Types of reinforcements [9]

PMCs have recently been used for 3D printing [10], and in some applications, they are used to exploit the shape memory effect they

exhibit [11]. Due to their ease of processing, very good mechanical properties, and degradability, they have applications in tissue engineering and regenerative medicine [12]. In addition, they are eco-friendly because they can be recycled or manufactured using industrial waste. They can successfully replace conventional materials used in construction, aerospace, or transport industries [13], [14]. Last but not least, PMCs are being developed to manufacture new hybrid composites used for personal protective equipment (PPE) with military applications [15].

The use of PMCs in occupational safety and health is very important. To ensure the occupational safety and health of workers across all fields of activity, it is strictly necessary that they are properly equipped [16], [17]. The use of appropriate personal protective equipment (PPE) tailored to workers' needs and particularities is imperative and ensures their safety [18]. In this regard, materials with very good performance and a long lifespan are needed, which can withstand the work environments in which they are used. The protective helmet provides safety against hazards encountered in many industries.

The various operating conditions in which these helmets are used create a continuous need for research to improve their performance [19], [20]. Due to the relatively short shelf life, premature aging due to UV radiation and sensitivity to extreme temperatures, helmets made of conventional materials are inferior to composite materials [21], [22]. Using composite materials to manufacture helmet shells may be the best way to reduce the number of accidents, which in some cases result in death, as they offer superior protection compared to conventional materials. In addition, composite materials offer economic and social benefits by efficiently using natural resources and integrating waste generated by other processes or industries [23], [24], [25].

Thus, following a study of the specialized literature, this paper aims to analyze the research directions and their evolution in the field of polymer matrix composite materials used for the manufacture of protective helmets.

2. METHODOLOGY

The research directions and the evolution of studies in this field were analyzed using bibliometric methods. This method has become increasingly used in vast research fields [26]. The analytical, qualitative, and quantitative approaches of the studies help identify the problems encountered in previous studies and provide new research directions; the methodology for implementing bibliometric analysis is presented in Figure 2 [27].

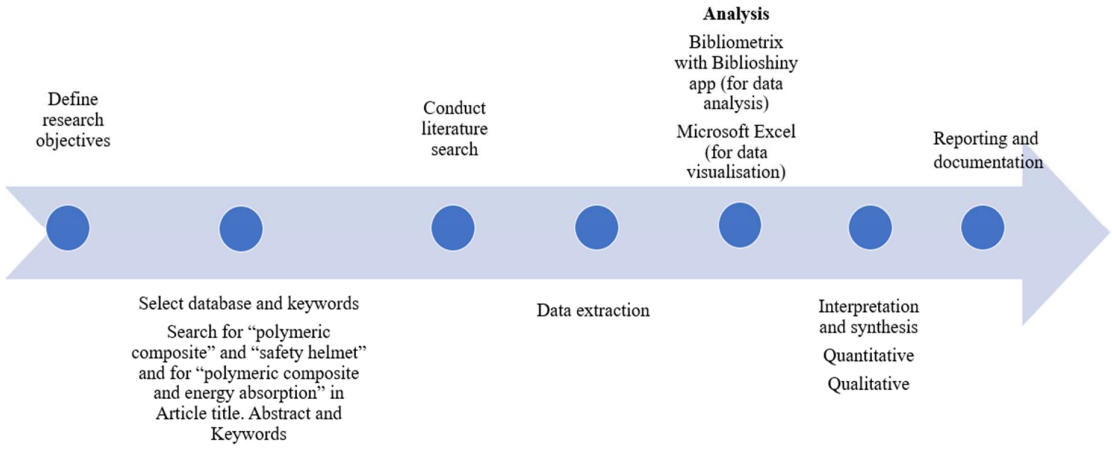


Fig. 2. Stages of study methodology

The data were extracted from the Scopus database following three different searches, as follows. The first search yielded 33272 research articles worldwide by searching for the word

group "polymeric composite" with the search query "Article Title, Abstract, Keywords". Of this number of works, only 20000 were analyzed, the maximum allowed for download. The data on the type of application were extracted using the term "safety helmet"; a total of 6188 papers were obtained using the search query "Article Title, Abstract, Keywords". The third search used the keyword groups "polymeric composite" AND "energy absorption"; it returned 564 scientific papers. The keyword "energy absorption" was used because it is one of the most essential characteristics that the polymer matrix composite material used to manufacture the helmets must possess.

To perform the bibliometric analysis, the Biblimetrix software was used with the Biblioshiny application [27], [28]. The quantitative analysis was based on the types of scientific research, the years of publication, and information about the authors and the countries where the research was conducted and published.

The qualitative analysis took into account the thematic areas of the research, but also the mapping of keywords, as well as different characteristics related to the structure or properties of the materials. All this data was processed, visualized, and verified using Microsoft Excel tools.

3. RESULTS AND DISCUSSION

3.1. Data obtained for „polymeric composite”

The time frame of the research included scientific papers between 1962 and papers planned for publication in 2025. The work with the highest number of citations was published in 1980 with over 18000 citations. A total of 44 papers are pending publication in 2025. In 2024, it is expected that most papers will be published, with over 2200 scientific papers already published. The trend in the number of papers is steadily increasing., and the number of scientific papers has increased. Moreover, the analysis shows that the vast majority of scientific works were article-type, as shown in Figure 3. The documents were of the type: articles (23467), conference papers (5430), review (2058), book chapter (1704), conference review (326), book (185), erratum (33), note (24), editorial (22), short survey (14), letter (12), data paper (8), retracted (7), report (4) and 2 undefined publications.

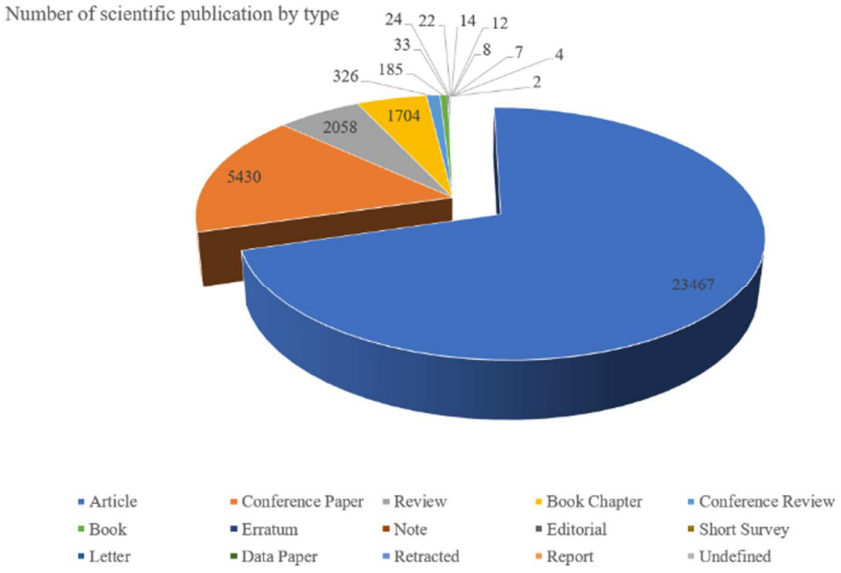


Fig. 3. Scientific publication number by type

Analyzing this number of papers and their diverse types, the field is of interest, and collaborations among researchers worldwide support this statement (Figure 4).

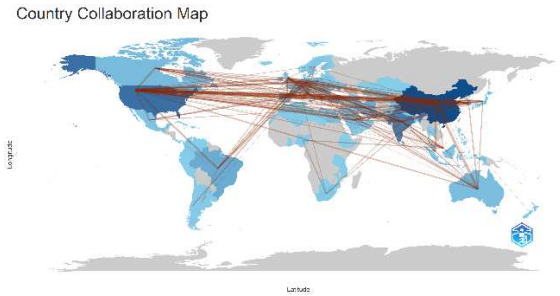


Fig. 4. Country collaboration map

As for the contributions of publications according to the top 10 sources (magazines, journals etc.), they are presented in Table 1. "RSC Advances" has 161 papers, "ACS Applied Materials and Interfaces" has 115 papers, "Composites part B: Engineering" with several 115 papers, and "Materials Science and Engineering C" with some 100 papers. These data show that the articles were published in top journals in composite materials, with the Hirsch index up to 64. The distribution of publications by authors' affiliations and countries of origin shows that research on composite materials has been carried out worldwide (Figure 5). On the other hand, the top 10 countries with the most research in the field of polymer matrix composite materials stand out. The production of scientific research in 2024, by origin of researchers, is as follows: China with 4911 papers, India with 3826 papers, the USA with 1668 papers, Iran with 1142 papers, and Brazil with 1130 papers.

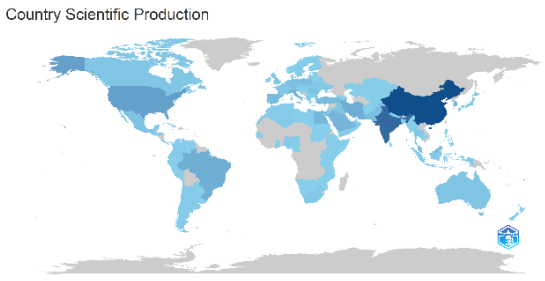


Fig. 5. Country scientific production over time

Over time, more than 100 countries have conducted research in this field, and 38 of them have published more than 100 scientific papers on polymer matrix composite materials.

In the analysis of global scientific publications, it can be seen that some countries marked in gray have not registered any research. In contrast, depending on the number of papers, publications are marked by a change in the shade of blue. Those with a very large number of scientific papers are deep blue, such as China, India, and the USA.

Table 1

Top 10 most relevant sources.

Sources	Publisher	No. Pub.	IF	H-index
Chemical Engineering Journal	Elsevier	50	13.3	309
Composites part B: Engineering	Elsevier	115	12.7	203
Journal of Materials Chemistry A	Royal Society of Chemistry	61	10.7	295
Carbohydrate Polymers	Elsevier	43	10.7	274
ACS Applied Materials and Interfaces	American Chemical Society	115	8.5	311
Journal of Membrane Science	Elsevier	89	8.4	295
Composites Science and Technology	Elsevier	89	8.3	249
Materials Science and Engineering C	Elsevier	100	7.9	179
Composite Structures	Elsevier	73	6.3	199
RSC Advances	Royal Society of Chemistry	161	3.9	210

Among the 30 most frequent keywords in scientific publications, we observe that they highlight the properties, applications, and component elements of matrix composites (Figure 6). In addition, the use of nanoparticles in manufacturing nanocomposites is highlighted, as well as the importance of using additives in the manufacturing process of polymer matrix composites.

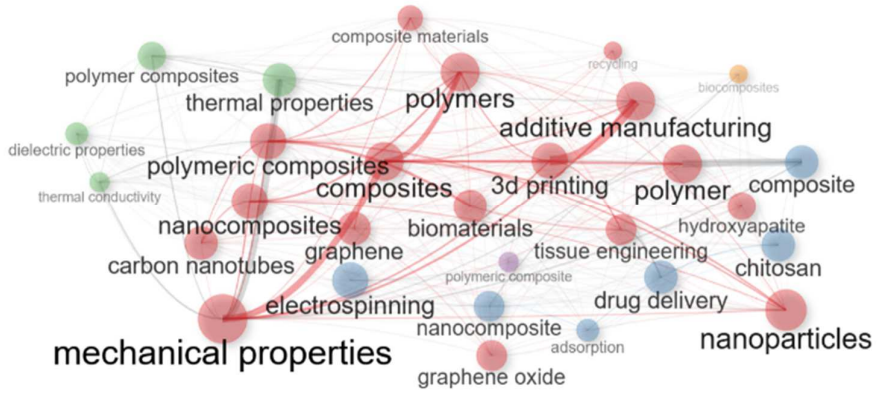


Fig. 6. Co-occurrence network.

3.2. Data obtained for "safety helmet"

The bibliometric analysis for the search for the term "safety helmet" in the Scopus database obtained 6188 scientific publications. The first registration of a scientific paper occurred in 1955, and interest in this area accelerated gradually starting in the 1990s.

The number of scientific studies on protecting workers' integrity in industry, as well as the use of protective helmets in other activities, has increased significantly and continues to grow. The search time frame was 1955-2024, and for 2025, 10 papers are scheduled for publication.

Of the total of 6188 scientific publications, the main types were 3477 Articles, 2088 Conference papers, 235 Reviews, and 102 Book chapters. These were published in different languages, most in English (5909), Chinese (99), German (62), and Spanish (29). Analyzing the data in Table 2, we can see that journals publishing scientific papers in the field of helmets are recognized for their involvement and significant contributions to innovation, prevention, human safety, and the improvement of quality of life. These statements are supported by their number of publications, the quality reflected in their Hirsch Index, and their impact factor.

Table 2

Top 10 most relevant sources.

Sources	Publisher	No. Pub.	IF	H-index
American Journal of Public Health	American Public Health Association	21	12.7	13
Accident Analysis and Prevention	Elsevier	167	5.7	50
Safety Science	Elsevier	26	4.7	15
Journal of Safety Research	Elsevier	51	3.9	21
Injury Prevention	BMJ Group	59	3.8	26
Annals of Biomedical Engineering	Springer New York	76	3.2	24
Applied Ergonomics	Elsevier	21	3.1	14
Traffic Injury Prevention	Traffic Injury Prevention	91	2.3	28
Injury	Elsevier	42	2.2	16
Proceedings of Spie - International Society for Optical Engineering	SPIE International Society for Optical Engineering	255	1.3	12

Considering the distribution of publications according to their authors, research on helmets has been carried out worldwide, and that collaborations among researchers have occurred. However, some countries, such as Russia, Vietnam, and others, the number of scientific publications was zero or lower for countries such as Malta, Slovenia, or Afghanistan.

Additionally, among the 30 most frequent keywords in scientific publications, we observe a focus on accident prevention (Figure 7). In addition, possible reasons for the non-use of protective helmets, areas of their use, and technological innovations in this field are highlighted.

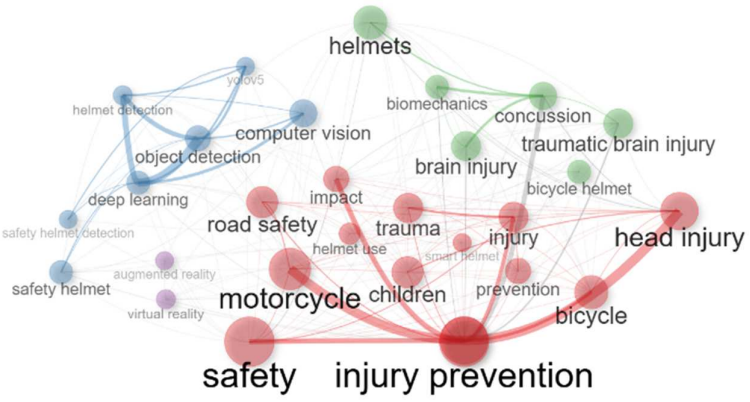


Fig. 7. Most frequent keywords used in scientific publications

3.3. Data obtained for "polymeric composite" AND "energy absorption"

From the bibliometric analysis of the Scopus database, 564 documents were obtained from 324 sources. The search interval was 1974-2024, with publications scheduled for 2025. And we can observe an upward trend in scientific publications each year that focus on the energy-absorption properties of polymer-matrix composite materials.

Table 3

Top 10 countries regarding the number of publication and their contribution.

Country	Number of publications	Contribution %
China	67	12.1
India	65	11.7
USA	35	6.3
Iran	26	4.7
Saudi Arabia	24	4.3
Brazil	21	3.8
Egypt	19	3.4
United Kingdom	15	2.7
Italy	14	2.5
Malaysia	13	2.3

Of the total 564 scientific publications, the main types were 414 Articles, 98 Conference papers, 24 Reviews, and 16 Book chapters. Analyzing the data in Table 3, we can see the top 10 countries with the number of papers and their contributions in journals on polymer matrix composites.

Table 4

Top 10 most relevant sources

Sources	Publisher	No. Pub.	IF	H-index
Polymers	MDPI	19	4.9	141
Composites part B: Engineering	Elsevier	12	12.7	203
Journal of Membrane Science	Elsevier	6	8.4	295
Composite Structures	Elsevier	10	6.3	199
Journal of Materials Science	Springer New York	6	3.5	214
Journal of Applied Polymer Science	Wiley	9	3	193
Journal of Materials Science: Materials in Electronics	Springer New York	7	2.8	97
Materials Letters	Elsevier	6	2.7	172
Proceedings of SPIE - International society for Optical Engineering	SPIE	8	1.3	193
Advanced Materials Research	Trans Tech Publications	8	0.13	52

Table 4 presents the top 10 sources ranked by the number of publications, impact factor, and Hirsch index. Given that many scientific papers have been published in prestigious journals, the study of polymer matrix composite materials is of interest and offers novelty. They also highlight in the foreground the properties of these materials, such as energy absorption, which is a fundamental property for helmet materials.

Considering the distribution of publications according to their authors, we can observe that research on polymer matrix materials focuses on shock absorption properties and beyond.

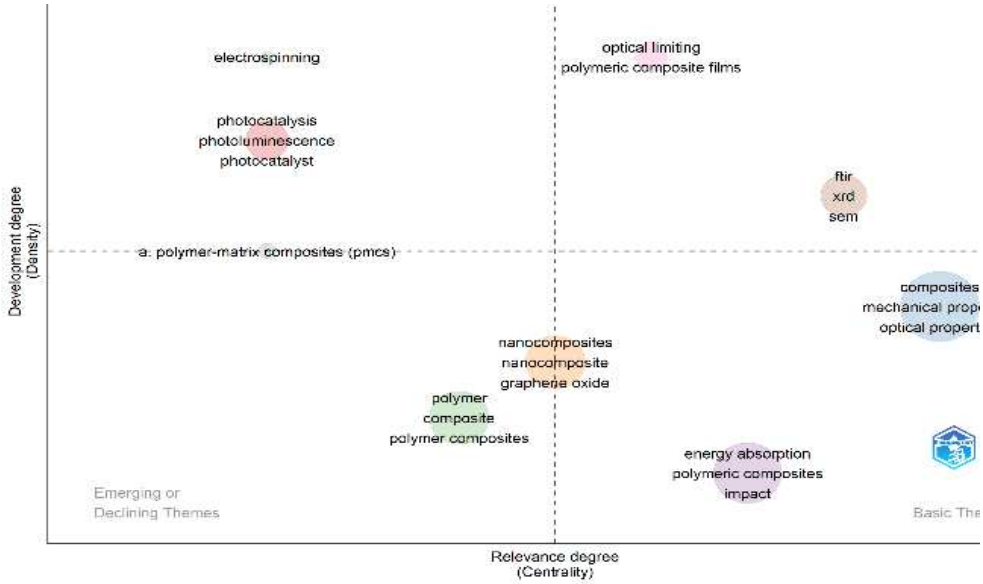


Fig. 8. Thematic map on centrality and density of the author's keywords

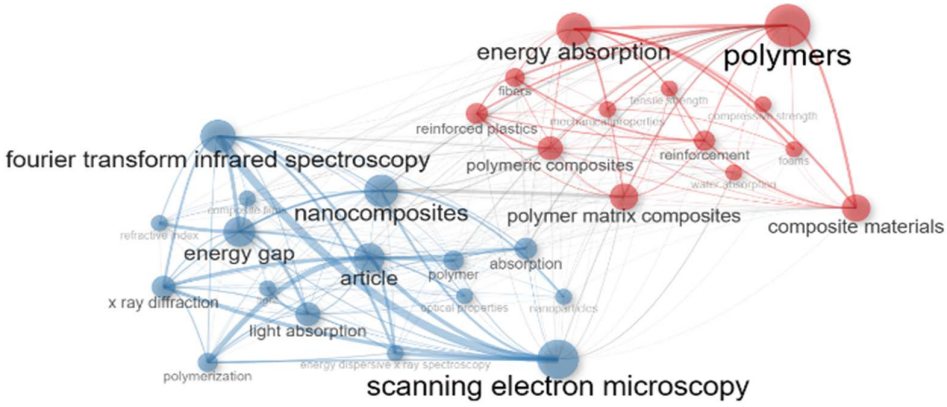


Fig. 9. Thematic map based on the author's keywords

Studying Figure 8, we can observe in the Density and Centrality quadrants that the volume of scientific papers has directed a small portion toward studying energy absorption.Last but not least, from Figure 9, it can be observed that the keywords in the scientific papers focus on the types of matrices that can be used, the types of reinforcing elements, the physical and mechanical properties, and, especially, the energy absorption properties of polymer matrix composites. Overall, the network takes a holistic approach: it's not just about what materials can be developed (polymer matrix + reinforcements), but also about how they can be optimized through advanced characterization to achieve superior performance, a critical indicator of the durability and operational safety of new composites.

4. CONCLUSIONS

Composite materials with a polymer matrix, reinforced with various elements, fibers, or particles, can be used to manufacture protective helmets for industrial and other applications. There are numerous studies in this field that have focused on various problems encountered by researchers, and this bibliometric analysis can provide new directions for future research.

The bibliometric analysis, conducted by querying the Scopus database, confirms the growing academic interest and the significant

impact of publications in this field, highlighting the diversity of PCM applications in industrial safety. Although the study confirms current trends in research and the high quality of the literature, certain methodological limitations are acknowledged: the restriction of the search to a single known database, the lack of indexing of some recent publications, and the possibility of including studies that, although they contain the selected keywords, do not directly address the subject of this paper.

It can be concluded that various researchers have considered the performance and characteristics that a protective helmet must meet. Shock energy absorption is one of the most important objectives researchers must meet when manufacturing protective helmets from polymer matrix composite materials.

5. REFERENCES

[1] Wazeer, A., Das, A., Abeykoon, C., Sinha, A., Karmakar, A., *Composites for electric vehicles and automotive sector: A review*, Green Energy and Intelligent Transportation, doi: 10.1016/j.geits.2022.100043, 2023.

[2] Tazwar, H. T., Antora, M. F., Rashid, A. Bin, & Hoque, M. E.. *Biopolymer-Based Materials for Advanced Military Applications.* Advanced Structured Materials, 244, 203–235. https://doi.org/10.1007/978-981-95-2469-3_8, 2026.

[3] Khan, F., *Advances of composite materials in automobile applications – A review*, Journal of Engineering Research, doi: 10.1016/j.jer.2024.02.017, 2024.

[4] Fan, Q., Duan, H., Xing, X., *A review of composite materials for enhancing support, flexibility and strength in exercise*, Alexandria Engineering Journal, doi: 10.1016/j.aej.2024.03.048, 2024.

[5] Baig, M. M. A., Hassan, S. F., Saheb, N., Patel, F., *Metal matrix composite in heat sink application: Reinforcement, processing, and properties*, Materials, doi: 10.3390/ma14216257, 2021.

[6] Gopi Krishna, M., Praveen Kumar, K., Naga Swapna, M., Babu Rao, J., Bhargava, N. R. M. R., *Metal-metal Composites-An Innovative Way for Multiple Strengthening*, Materials Today: Proceedings, doi: 10.1016/j.matpr.2017.07.148, 2017.

[7] Karadimas, G., Salonitis, K., *Ceramic Matrix Composites for Aero Engine Applications—A Review*, Applied Sciences, doi: 10.3390/app13053017, 2023.

[8] Sun, J., *A review on additive manufacturing of ceramic matrix composites*, Journal of Materials Science & Technology, doi: 10.1016/j.jmst.2022.06.039, 2023.

[9] Ostolaza, M., Arrizubieta, J. I., Lamikiz, A., Plaza, S., Ortega, N., *Latest Developments to Manufacture Metal Matrix Composites and Functionally Graded Materials through AM: A State-of-the-Art Review*, Materials, doi: 10.3390/ma16041746, 2023.

[10] Ma, T., *Advances in 3D printing for polymer composites: A review*, InfoMat, doi: 10.1002/inf2.12568, 2024.

[11] Yang, W., Liu, Y., Ouyang, Y., Xu, W., Zhao, W., & Ren, H. *Shape memory performance and mechanical properties of natural fiber-reinforced polymer composites enhanced via fabrication strategies*. Industrial Crops and Products, *239*, 122546. https://doi.org/https://doi.org/10.1016/j.indcrop.2025.122546, 2026.

[12] Solangi, N. H., Karri, R. R., Mubarak, N. M., Mazari, S. A., *Mechanism of polymer composite-based nanomaterial for biomedical applications*, Advances in Industrial and Engineering Polymer Research, doi: 10.1016/j.aiepr.2023.09.002, 2024.

[13] Li, H., Yang, J., Yang, D., Zhang, N., Nazar, S., Wang, L., *Fiber-reinforced polymer waste in the construction industry: a review*, Environmental Chemistry Letters, doi: 10.1007/s10311-024-01769-5, 2024.

[14] De, B., Bera, M., Bhattacharjee, D., Ray, B. C., Mukherjee, S., *A comprehensive review on fiber-reinforced polymer composites: Raw materials to applications, recycling, and waste management*, Progress in Materials Science, doi: 10.1016/j.pmatsci.2024.101326, 2024.

[15] Hu, Q., Shen, X., Qian, X., Huang, G., Yuan, M., *The personal protective equipment (PPE) based on individual combat: A systematic review and trend analysis*, Defence Technology, doi: 10.1016/j.dt.2022.12.007, 2023.

[16] Ammad, S., Alaloul, W. S., Saad, S., Qureshi, A. H., *Personal protective equipment (PPE) usage in construction projects: A scientometric approach*, Journal of Building Engineering, doi: 10.1016/j.jobe.2020.102086, 2021.

[17] European Parliament, *Regulation (EU) 2016/425 of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC*, Council of the EU, 2016.

[18] Pisu, A., Elia, N., Pompianu, L., Barchi, F., Acquaviva, A., Carta, S., *Enhancing workplace safety: A flexible approach for personal protective equipment monitoring*, Expert Systems with Applications, doi: 10.1016/j.eswa.2023.122285, 2024.

[19] Alnawmasi, N., Alogaili, A., Rangaswamy, R., Oviedo-Trespalacios, O., *A temporal statistical assessment of the effectiveness of bicyclist safety helmets in mitigating injury severities in vehicle/bicyclist crashes*, Analytical Methods in Accidents Research, doi: 10.1016/J.AMAR.2024.100338, 2024.

[20] Ptak, M., Dymek, M., Wdowicz, D., Szumiejko, A., Kwiatkowski, A., *Energy-absorbing limitations of hard hat safety helmets in mitigating trauma from falling objects*, Archives of Civil and Mechanical Engineering, doi: 10.1007/s43452-024-01012-6, 2024.

[21] Periasamy, D., *Assessing the recycling potential of thermosetting polymer waste in high-density polyethylene composites for safety helmet applications*, e-Polymers, doi: 10.1515/epoly-2023-0080, 2024.

[22] Singh, O., Behera, B. K., *Review: a developmental perspective on protective helmets*, Journal of Materials Science, doi: 10.1007/s10853-023-08441-3, 2023.

[23] Dias, R. R., Meliande, N. M., Kotik, H. G., Camerini, C. G., Pereira, I. M., *Thermoplastic-Based Ballistic Helmets: Processing, Ballistic Resistance and Damage Characterization*, Journal of Composites Science, doi: 10.3390/jcs8100385, 2024.

[24] Omara, A. A. M., Mohammedali, A. A. M., Dhivagar, R., *Helmets cooling with phase change materials: A systematic review*, Journal of Energy Storage, doi: 10.1016/j.est.2023.108555, 2023.

[25] Kafle, S. V., Upadhyay, G., Akouwah, S. B., Lakshman, Y. M., Singh, J. I. P., *Development and mechanical characterization of construction helmet using natural fibre reinforced polymer composites*, AIP Conference Proceedings, doi: 10.1063/5.0192264, 2024.

[26] Santos, C. M., *A bibliometric review on applications of lignocellulosic fibers in polymeric and hybrid composites: Trends and perspectives*, Heliyon, doi: 10.1016/j.heliyon.2024.e38264, 2024.

[27] Passas, I., *Bibliometric Analysis: The Main Steps*, Encyclopedia, doi: 10.3390/encyclopedia4020065, 2024.

[28] Dervis, H., *Bibliometric analysis using bibliometrix an R package*, Journal of Scientometric Research, doi: 10.5530/JSCIRES.8.3.32, 2019.

Analiza bibliometrică a tendințelor de cercetare în domeniul compozitelor cu matrice polimerică utilizate pentru căștile de protecție

Rezumat: Protecția persoanelor este esențială, indiferent de domeniul de activitate. Pentru a asigura acest lucru, pot fi utilizate diferite tipuri de echipamente individuale de protecție (EIP). De exemplu, căștile de protecție trebuie utilizate în cazul în care riscurile de leziuni cerebrale traumatice nu pot fi eliminate. Cu toate acestea, odată cu progresul tehnologic, riscurile asociate activităților de muncă, precum și caracteristicile EIP, trebuie adaptate. Prin urmare, acest studiu bibliometric prezintă un rezumat al cercetărilor din domeniu, concentrându-se pe identificarea lacunelor și limitărilor actuale ale căștilor de protecție din compozite cu matrice polimerică. Analiza bibliometrică a fost realizată pe trei seturi de date extrase din baza de date Scopus („compozit polimeric”; „cască de protecție”; și „compozit polimeric” și „absorbție de energie”) utilizând software-ul Bibliometrix.

Cristian-Ștefan BUNDUC, PhD Student, Faculty of Materials Science and Engineering, Gheorghe Asachi Technical University of Iași, cristian-stefan.bunduc@student.tuiasi.ro, +40 232 278 683, 67 Dimitrie Mangeron Blvd., Iași, Romania.

Lucian-Ionel CIOCA, Professor, Industrial Engineering and Management Department, Faculty of Engineering, Lucian Blaga University of Sibiu, lucian.cioca@ulbsibiu.ro, +40 269 217 779, 10 Victoriei Blvd., Sibiu, Romania, and Academy of Romanian Scientists, 3 Ilfov, Bucharest, Romania.

Diana-Petronela BURDUHOS-NERGIȘ, Professor, Faculty of Materials Science and Engineering, Gheorghe Asachi Technical University of Iași, diana-petronela.burduhos-nergis@academic.tuiasi.ro, +40 232 278 683, 67 Dimitrie Mangeron Blvd., Iași, Romania.

Costică BEJINARIU, Professor, Faculty of Materials Science and Engineering, Gheorghe Asachi Technical University of Iași, costica.bejinariu@academic.tuiasi.ro, +40 232 278 683, 67 Dimitrie Mangeron Blvd., Iași, Romania. Academy of Romanian Scientists, 3 Ilfov, Bucharest, Romania.