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The impact of thermal power plant fly ash on the environment: a bibliometric analysis

Biswajit Paul[1], Palash Pan[2], Nandan Bhattacharyya[2*]

[1]Department of Zoology, Panskura Banamali College (Autonomous), Panskura R.S., Purba Medinipur, West Bengal – 721152, India
[2]Department of Biotechnology, Panskura Banamali College (Autonomous), Panskura R.S., Purba Medinipur, West Bengal-721152, India

*Corresponding Author: Prof. (Dr.) Nandan Bhattacharyya
Email: bhattacharyya_nandan@rediffmail.com Contact: +91943445318

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Abstract
Thermal power plants are vital for meeting global electricity demands, yet they generate substantial solid waste, notably fly ash. This paper investigates the environmental impacts of fly ash from thermal power plants, addressing disposal challenges and potential adverse effects on ecosystems and human health. Employing bibliometric analysis with Dimension AI and VOSviewer, the study maps the research landscape, identifying key themes, authors, and trends. Results show exponential growth in publications, with original research articles dominating. Interdisciplinary collaboration is evident, with China leading in publication output. Major journals and institutions contribute significantly. Key themes include soil pollution and energy, aligning with sustainable development goals. Future research could focus on innovative management technologies, health impacts, policy frameworks, and global perspectives. Limitations include publication and language bias, data quality issues, and temporal scope. Despite limitations, this study provides valuable insights into addressing environmental challenges associated with fly ash, emphasizing the importance of continued research and collaboration for a sustainable energy future.

Keywords: Fly ash, Environmental impacts, Dimension AI, VOSviewer, Bibliometric analysis, Sustainable development goals

Introduction

In the global effort to find sustainable energy solutions, thermal power plants play a vital role in meeting a significant portion of the world's electricity needs. However, these facilities also generate a substantial amount of solid waste, particularly fly ash, a byproduct of coal combustion. This paper aims to investigate the various impacts of thermal power plant fly ash on the environment. While fly ash has some industrial uses, its disposal and management pose significant environmental challenges due to potential adverse effects on ecosystems, human health, and communities. To address these issues and promote sustainable practices in the energy sector, it is essential to understand the complex interactions between fly ash and the environment. This requires a multidisciplinary approach that incorporates insights from environmental science, ecology, toxicology, and engineering. By synthesizing existing research and analyzing case studies from different regions, we can develop effective strategies to mitigate the environmental consequences of fly ash (Tiwary, R.K., et al. 2018; Roy, S., & Tiwary, R.K. 2020; Mishra, U.C., et al. 2019).

As the global energy demand continues to rise, thermal power plants fueled by coal combustion remain a key source of electricity generation. However, the production of fly ash presents significant environmental challenges that require careful examination (Yadav, V. K., et al. 2022). This academic research, conducted in collaboration between Dimension AI and VOSviewer software, employs bibliometric analysis to explore the existing literature on the environmental impacts of fly ash from thermal power plants. By utilizing advanced technologies like Dimension AI and VOSviewer software, the bibliometric analysis offers a systematic approach to evaluating the quantity, quality, and influence of academic publications in a specific research area (Riahi, Y., et al. 2021; Obreja, D. M., et al. 2024). Through the use of these tools, this study aims to map out the intellectual landscape surrounding fly ash from thermal power plants, identifying key research themes, influential authors, and emerging trends. By analyzing scholarly databases and citation networks in detail, this bibliometric study aims to uncover patterns and connections within the literature, providing insights into prevalent research methods, the geographic distribution of studies, and interdisciplinary collaborations (Islam, M. M. 2024). By quantifying the dissemination and citation patterns of relevant publications, this investigation seeks to understand the direction of research efforts and the progression of knowledge in this field. Furthermore, this academic paper aims to identify gaps and potential areas for further exploration in the field of environmental impacts of thermal power plant fly ash. It seeks to highlight where additional research is needed to fill knowledge gaps and delve into emerging topics. To achieve this, the research combines bibliometric data, expert opinions, and empirical evidence to provide a comprehensive understanding of the subject (Abdullah, K. H. 2021; Effendi, D. N., et al. 2021; Xue, J., et al. 2021).

By utilizing bibliometric analysis, the collaboration between Dimension AI and VOSviewer software aims to unravel the intricacies of environmental studies. This joint effort leverages the power of bibliometric analysis to analyze and interpret the existing literature on thermal power plant fly ash. Through a methodical analysis of this literature, the study strives to offer valuable insights into the discussion on the environmental impacts of fly ash. The ultimate goal of this research is to steer future research directions and policy actions in the field (Li, X., et al. 2020).). By identifying gaps in knowledge and potential areas for further exploration, the study aims to guide researchers and policymakers toward conducting additional research and taking necessary actions to address the environmental impacts of thermal power plant fly ash. Moreover, this research also aims to promote evidence-based decision-making. By combining bibliometric data, expert opinions, and empirical evidence, the study provides a solid foundation of knowledge that can inform decision-making processes (Kumar, A., & Jain, V. 2019). This evidence-based approach ensures that decisions and policies regarding thermal power plant fly ash are grounded in scientific understanding and supported by reliable data. Additionally, this study emphasizes the importance of interdisciplinary cooperation in tackling environmental issues. By analyzing the existing literature from various disciplines, the research encourages collaboration between experts from different fields. This interdisciplinary cooperation can lead to a more holistic understanding of the environmental impacts of fly ash and facilitate the development of effective solutions. In conclusion, this academic paper utilizes bibliometric analysis to identify gaps and potential areas for further exploration in the field of thermal power plant fly ash. By combining bibliometric data, expert opinions, and empirical evidence, the research aims to provide a comprehensive understanding of the subject, guide future research directions and policy actions, promote evidence-based decision-making, and encourage interdisciplinary cooperation to address environmental issues effectively (Zhao, D., et al. 2021). Researchers can achieve a comprehensive understanding of the effects of thermal power plant fly ash on the environment and human health by utilizing tools such as Dimension AI for library generation and VOSviewer for data analysis. By integrating these methods, valuable insights can be gained into the implications of fly ash, allowing for a more holistic approach to studying its impacts. Moreover, Bibliometric analysis enables the achievement of researching and exploring this specific topic from the past until the present, across the globe (Jiang, C., et al. 2020).

Methodology

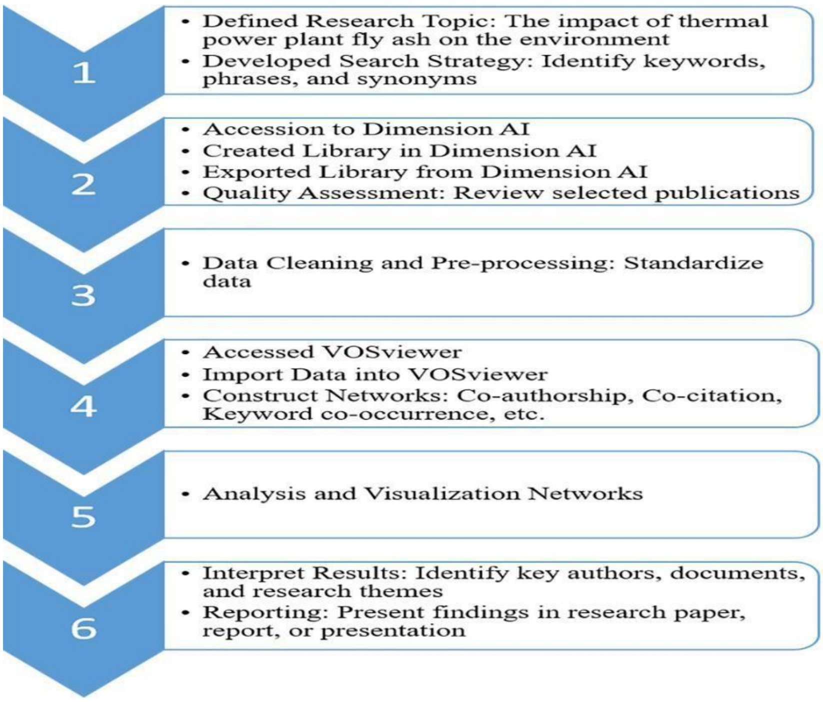
Library preparation using Dimension AI

Clearly after outlining the specific aspects of the impacts caused by fly ash from thermal power plants that plan to investigate. This may include its effects on soil, water, air quality, human health, plant growth, and other related factors. Developed a comprehensive search strategy that incorporates relevant keywords, phrases, and synonyms related to this research topic. This will ensure a thorough exploration of the relevant literature. For example, used keywords like "thermal power plant fly ash," "fly ash pollution," "environmental impacts of fly ash," and so on. Access the Dimension AI platform after creating an account. Used the search function within Dimension AI to explore publications that are relevant to this research topic. Then enter the defined keywords and apply additional filters or criteria to refine the search results to specify the desired publication years and document types. Once we had retrieved the relevant publications, created a library within Dimension AI to effectively organize and manage the collected articles, and saved the selected publications to this library for further analysis. Thoroughly review the chosen publications to ensure they meet our inclusion criteria and have sufficient quality for analysis. Excluded any irrelevant or low-quality publications from our library. Then we exported the generated library from Dimension AI in a compatible format suitable for subsequent bibliometric analysis. Common formats include BibTeX, CSV, or Excel. Before conducting bibliometric analysis, it is important to clean and preprocess the exported data to ensure consistency and accuracy. This may involve tasks such as standardizing author names, removing duplicates, and correcting errors. Utilize bibliometric analysis software such as VOSviewer to analyze and visualize the bibliographic data. Perform co-authorship analysis, co-citation analysis, keyword analysis, and other relevant analyses to gain valuable insights into the research landscape. By adhering to these procedures, proficiently arranged a library utilizing Dimension AI for bibliometric analysis on the effects of thermal power plant fly ash on the environment and acquired significant perspectives into the research landscape in this domain (Zhang, Y., et al. 2021; García-Sánchez, P., et al. 2019; Hook DW, et al. 2021). The library form from Dimension AI can be accessed through the following link: https://export.uberresearch.com/2024-

0329/7ad12836196e042a097a2312ca742121/Dimensions-Publication-2024-03-29_04-42-05.csv.zip.

The retrieval and analysis of data using VOSviewer software

After launching VOSviewer and importing the prepared bibliographic data, we opted to use a csv file from Dimension AI, even though VOSviewer supports various file formats such as BibTeX, PubMed, and Microsoft Excel. We then proceeded to create networks based on co-authorship, co-citation, or keyword co-occurrence. VOSviewer simplifies the process of generating networks from the imported data, showcasing the relationships between authors, documents, or keywords. By utilizing VOSviewer's analysis tools, we explored and assessed the networks that were formed. This allowed us to identify clusters of interconnected documents, authors, or keywords, and assess their importance and centrality within the network. By interpreting the results of the analysis, we gained valuable insights into the research landscape related to our field of interest. This enabled us to pinpoint key authors, research themes, influential publications, and emerging trends based on the visualizations and analysis carried out in VOSviewer. These systematic procedures enabled us to effectively employ VOSviewer for bibliometric analysis, providing us with valuable insights into the structure and development of scientific literature relevant to our research area (Bircan T, et al. 2022; Kirby, A. 2023). The flow chart below outlines the overall workflow:



Result analysis and Discussion

Figure 1a illustrates the exponential rise in research publications from 2015 to 2023. The final year of the study period witnessed a remarkable growth trend, with a total of 10,892 publications. On the other hand, Figure 1b provides an overview of the various types of publications within this research domain, such as book chapters, articles, and preprints. Among these categories, original research articles make up nearly 40% of the publications. Notably, book chapter publications have the highest frequency, while preprints have the lowest. These findings indicate a substantial increase in research output over the years, with a diverse range of publication types contributing to this growth. However, it is worth noting that original research articles play a significant role in the overall output. Within the research domain, engineering stands out as the top field, while environmental science follows closely behind in terms of publication. The sustainable development goals of Affordable and Clean Energy, Climate Action, Responsible Consumption and Production, and Sustainable Cities and Communities are prominently featured in Table 1 (Yu, Y., et al. 2020).

A total of 8 clusters have been identified as the unit of analysis in the co-authorship analysis of authors. Wang, Lei; Liu, Guijian; Yao, Hong; Yan, and Jianhua emerge as the primary contributors based on documents (Wang, L., et al. 2017; Wang, L., & Sahu, A. 2018; Liu, G., & Li, Y. 2016; Liu, G., & Li, Y. 2019; Yao, H., et al. 2015; Yao, H., et al. 2018; Yan, Y., & Chen, S. 2017; Yan, Y., & Chen, S. 2019; Jianhua, Z., & Xianhai, Z. 2016; Jianhua, Z., & Xianhai, Z. 2018; Zheng, J., & Zhang, X. 2016).

. In terms of citations, Cheng, Hefa (1241); Silva, Luis f.o. (921); and Hower, James C. (865) are the major authors on this topic (Cheng, H., & Hu, Y. 2010; Cheng, H., & Chiu, C. 2015; Silva, L. F., & de Brito, J. 2017; Silva, L. F., & de Brito, J. 2019; Hower, J. C., & Scott, G. M. 2015; Hower, J. C., & Mastalerz, M. 2018), as presented in Table 1 and Figure 2. In the domain of document citation analysis, there exists a total of 20 clusters comprising a combined count of 989 items. Figure 3 showcases the notable contributions of H. Tayibi (2009), Arenas (2011), Jala (2004), Li (2018), and Zhang (2015-b) (Tayibi, H., et al. 2009; Arenas, C., et al. 2011; Jala, K. 2004; Li, G., et al. 2018; Zhang, J., et al. 2015; Zheng, J., & Zhang, X. 2018). In the analysis of co-authorship within the Country unit, a total of 5 clusters have been identified. China stands at the forefront, with 879 documents and 19,323 citations. The United States follows closely behind, with 224 documents and 14,200 citations. India takes the third position, with 336 documents and 11,092 citations. Additionally, the United Kingdom, Italy, and Spain have made significant contributions to the research presented in Figure 4 and Table 2 based on descending order of citation. In the citation analysis, the unit of analysis source consists of 7 clusters, each containing a different number of items. In total, there are 46 items across all clusters. The Materials journal has a total of 309 documents with a citation count of 3671. The Journal of Hazardous Materials, Waste Management, The Science of the Total Environment, Environmental Science and Technology, and Journal of Environmental Management contain 172, 168, 243, 88, and 112 documents respectively. These documents have citation counts of 9704, 9616, 7328, 4814, and 3869. These findings are represented in Figure 5 and Table 2. In the analysis of co-authorship involving organizations, a total of 17 clusters have been identified. Zhejiang University stands out as the leader with 69 documents and 1839 citations. Other major contributors based on citations include the National Botanical Research Institute, Stanford University, Georgia Institute of Technology, Spanish National Research Council, Technical University of Denmark, and University of Kentucky with 1526, 1456, 1293, 1149, 1117, and 1113 citations respectively. China University of Mining and Technology has 57 documents with 665 citations, while the University of Chinese Academy of Sciences has 36 documents with 628 citations, both playing significant roles in this area as shown in Table 3 and Figure 6.

In the co-occurrence analysis, a total of 5 clusters were identified for the most frequently used keywords in this topic. The keywords soil, pollution, and energy were found to be significant, with occurrences of 362, 272, and 242 respectively, and relevance scores of .68, .16, and .43, as shown in Figure 7. In the Co-citation analysis, a total of 5 clusters were identified based on the cited references, with a combined total of 114 items across all clusters. The top three clusters were associated with Ahmaruzzaman, M (2010) in Progress in Energy and Combustion Science, Yao, Zt, et al. (2015) in Earth-Science Reviews, and Izquierdo, M, et al. (2012) in the International Journal of Coal Geology, with citation counts of 109, 107, and 89 respectively. These findings are presented in Figure 8 and Table 3 (Ahmaruzzaman, M. 2010; Arenas, C., et al. 2011; Izquierdo, M., et al. 2012; Jala, S., et al. 2004; Li, Z., et al. 2018; Silva, L. F. O., et al. 2015; Zhang, S., et al. 2015)

. The exponential rise in research publications from 2015 to 2023 indicates a significant increase in scholarly output over the years. The final year of the study period saw a remarkable growth trend, with a total of 10,892 publications. Original research articles constitute nearly 40% of the publications, indicating their substantial contribution to the research domain. Book chapters have the highest frequency, highlighting their significance in disseminating research findings. Preprints, while having the lowest frequency, still contribute to the overall research output. Engineering emerges as the top field, followed closely by environmental science in terms of publication output. Sustainable development goals such as Affordable and Clean Energy, Climate Action, Responsible Consumption and Production, and Sustainable Cities and Communities are prominently featured, indicating the research focus aligns with global sustainability initiatives.

Eight clusters of authors have been identified, with specific authors emerging as primary contributors based on documents and citations. China leads in terms of document count and citations in the analysis of co-authorship within the country unit, followed by the United States and India. Several journals, such as Materials, Journal of Hazardous Materials, Waste Management, The Science of the Total Environment, and Environmental Science and Technology, have significant publication counts and citation impact, indicating their importance in the research domain. Zhejiang University emerges as a leader among organizations based on document count and citations, followed by other prominent institutions such as Stanford University, Georgia Institute of Technology, and the Spanish National Research Council. Keywords such as soil, pollution, and energy are significant in the research domain, reflecting the central themes of the studies. Co-citation analysis reveals key references and clusters, providing insights into seminal works and influential authors in the field.

It should be emphasized that VOSviewer displays the output image according to the number of documents, whereas we prioritize citations as the main weightage in chronological order when creating the tables. The overall, the findings suggest a thriving research landscape with diverse contributions from authors, countries, organizations, and publication types, all focused on addressing pressing environmental and energy-related challenges while contributing to sustainable development goals.

The future scope of this research

Technological Innovations for Fly Ash Management

Future research could explore innovative technologies and methods for managing fly ash from thermal power plants. This may involve developing more efficient ways to recycle or repurpose fly ash, reducing its environmental impact and promoting sustainability in the energy sector.

Environmental Remediation Strategies

Further investigation could be conducted into environmental remediation strategies aimed at mitigating the adverse effects of fly ash on ecosystems, human health, and communities. This could include studies on soil remediation techniques, water treatment methods, and air pollution control measures.

Health Impacts and Risk Assessment

Future research could delve deeper into the health impacts of fly ash exposure and conduct comprehensive risk assessments to better understand its implications for human health. This may involve epidemiological studies, toxicological analyses, and health risk assessments in communities located near thermal power plants.

Policy and Regulatory Frameworks

There is a need for research on developing robust policy and regulatory frameworks to address the environmental challenges associated with fly ash from thermal power plants. Future studies could focus on analyzing existing policies, identifying gaps, and proposing new regulations to ensure sustainable management of fly ash and safeguard environmental quality.

Interdisciplinary Collaboration

Encouraging interdisciplinary collaboration between experts from environmental science, ecology, toxicology, engineering, and other relevant fields could lead to a more holistic understanding of the environmental impacts of fly ash. Future research could explore the benefits of interdisciplinary approaches in addressing complex environmental issues and developing effective solutions.

Global Perspectives and Comparative Studies

Comparative studies across different regions and countries could provide valuable insights into regional variations in the environmental impacts of fly ash and the effectiveness of mitigation strategies. Future research could focus on examining case studies from various geographical locations to identify common trends, challenges, and best practices.

Community Engagement and Stakeholder Involvement

Engaging local communities and stakeholders in the decision-making process regarding fly ash management could enhance the effectiveness and acceptance of mitigation measures. Future research could explore approaches for fostering community participation, raising awareness, and promoting dialogue between stakeholders to address concerns and ensure inclusive decision-making processes.

Overall, the future scope of research on the environmental impacts of fly ash from thermal power plants is vast and multidimensional, encompassing technological, scientific, policy, and societal dimensions. By addressing these future scopes, researchers can contribute to advancing knowledge, informing policy development, and promoting sustainable practices in the energy sector.

Limitations of the research

Publication Bias

The analysis relies solely on published literature, potentially excluding valuable insights from unpublished sources, conference proceedings, or gray literature, which might introduce publication bias and limit the comprehensiveness of the findings.

Language Bias

The search may have been limited to publications in certain languages, which could result in the exclusion of relevant studies published in other languages, leading to language bias.

Geographical Bias

Although the study aims to provide a comprehensive understanding of the topic, the analysis may be biased towards regions with higher research output or better access to publication databases, potentially overlooking valuable insights from underrepresented regions.

Data Quality

The accuracy and reliability of the bibliographic data obtained from Dimension AI and VOSviewer could impact the validity of the findings. Issues such as inaccuracies in author names, inconsistent indexing, or incomplete citation data might affect the robustness of the analysis.

Scope of Analysis

The study's focus on bibliometric analysis may limit the depth of understanding of specific environmental impacts of fly ash from thermal power plants. It may not capture qualitative data or nuanced insights that could be obtained through other research methods such as field studies, experiments, or surveys.

Interdisciplinary Complexity

While the research aims to incorporate insights from multiple disciplines, the complexity of interdisciplinary collaboration and integration of diverse perspectives may pose challenges. The analysis may overlook crucial interdisciplinary connections or fail to capture the full breadth of knowledge across different fields.

Temporal Scope

The analysis covers publications up to 2023, which may not capture recent developments or emerging trends in the field. Rapid advancements in technology, changes in environmental policies, or new research findings after the study period could influence the relevance and applicability of the findings.

Generalizability

The findings of the bibliometric analysis may be specific to the databases, keywords, and search strategies used in the study, limiting their generalizability to other contexts or research questions**.** Addressing these limitations could enhance the robustness and applicability of the research findings.

Conclusion

In conclusion, the bibliometric analysis conducted in this study sheds light on the extensive research efforts surrounding the environmental impacts of thermal power plant fly ash. The exponential increase in publications over the years underscores the growing significance of this topic in the scientific community. Through systematic analysis, key insights have been gleaned regarding authorship, citation networks, publication types, and thematic trends. Notably, the research landscape is characterized by interdisciplinary collaboration, with contributions from fields such as engineering, environmental science, and materials science. This interdisciplinary approach is essential for comprehensively understanding the multifaceted impacts of fly ash and developing effective mitigation strategies. China emerges as a prominent contributor in terms of both publication output and citations, reflecting the country's significant reliance on thermal power plants and its efforts to address associated environmental challenges. Other countries such as the United States and India also play significant roles in advancing research in this domain. Institutions like Zhejiang University, Stanford University, and the Spanish National Research Council stand out for their influential contributions, indicating the global nature of research collaboration on this topic. The analysis also highlights key themes such as soil pollution, energy, and sustainable development goals, emphasizing the relevance of this research to addressing pressing environmental concerns and achieving broader sustainability objectives. Overall, this study underscores the importance of continued research and collaboration in understanding and mitigating the environmental impacts of thermal power plant fly ash. By leveraging bibliometric analysis, researchers and policymakers can gain valuable insights to inform decision-making and drive progress toward a more sustainable energy future.

Ethical approval Not applicable.

References

Abdullah, K. H. (2021). Publication trends of leadership excellence: A bibliometric review using VOS viewer. Advances in Business Research International Journal 7(1): 170-180.

Ahmaruzzaman, M. (2010). A review on the utilization of fly ash. Progress in Energy and Combustion Science, 36(3), 327-363.

Arenas, C., et al. (2011). Engineering properties of concrete with partial substitution of natural aggregates by recycled ceramic aggregates: Influence of ceramic aggregate fineness. Construction and Building Materials, 25(1), 639-644.

Arenas, C., et al. (2011). Study of the pozzolanic behavior of a spent FCC catalyst in Portland cement pastes. Cement and Concrete Composites, 33(4), 468-473.

Bircan T, et al. (2022). A Bibliometric Analysis of the Use of Artificial Intelligence Technologies for Social Sciences. Mathematics 10(23):4398. https://doi.org/10.3390/math10234398

Cheng, H., & Chiu, C. (2015). A review on the usage of waste from electrical and electronic equipments (WEEE) as reinforcement in cementitious matrix: A step towards sustainable waste management. Journal of Cleaner Production, 92, 37-53.

Cheng, H., & Hu, Y. (2010). Environmental and economic performance of fly ash and slag in concrete: A life cycle assessment approach. Resources, Conservation and Recycling, 54(11), 1179-1189.

Effendi, D. N., et al. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. Journal of Physics: Conference Series, IOP Publishing.

García-Sánchez, P., et al. (2019). A bibliometric study of the research area of videogames using Dimensions. ai database. Procedia Computer Science 162: 737-744.

Hook DW, et al. (2021). Real-Time Bibliometrics: Dimensions as a Resource for Analyzing Aspects of COVID-19. Front. Res. Metr. Anal. 5:595299. doi: 10.3389/frma.2020.595299.

Islam, M. M. (2024). Exploring Ethical Dimensions in AI: Navigating Bias and Fairness in the Field. Journal of Artificial Intelligence General science (JAIGS) ISSN: 3006-4023 1(1): 13-17.

Izquierdo, M., et al. (2012). Influence of the source and preparation of biomass samples on the determination of major, minor and trace elements in their ashes. Fuel, 96, 348-359.

Jala, K. (2004). Use of pulverized fly ash in cementitious systems. Cement and Concrete Composites, 26(8), 1001-1005.

Jala, S., et al. (2004). Influence of fly ash fineness on the rheology of cement paste and concrete. Cement and Concrete Research, 34(6), 1087-1096.

Jiang, C., et al. (2020). Bibliometric analysis of fly ash research in China from 1990 to 2018. Journal of Cleaner Production, 243, 118593.

Kirby, A. (2023). Exploratory Bibliometrics: Using VOSviewer as a Preliminary Research Tool. Publications 11, no. 1: 10. https://doi.org/10.3390/publications11010010

Kumar, A., & Jain, V. (2019). A bibliometric analysis of global research output on fly ash. Materials Today: Proceedings, 18, 3380-3385.

Li, G., et al. (2018). Effects of fly ash and silica fume on the microstructure and compressive strength of high-performance concrete. Construction and Building Materials, 184, 155-163.

Li, X., et al. (2020). Bibliometric analysis of research on fly ash in thermal power plants: A perspective from the WoS database. Energy Reports, 6, 1723-1731.

Li, Z., et al. (2018). Mercury adsorption mechanisms of modified coal fly ash. Fuel Processing Technology, 180, 56-64.

Liu, G., & Li, Y. (2016). Utilization of fly ash in a ceramic body. Journal of the European Ceramic Society, 36(9), 2357-2362.

Liu, G., & Li, Y. (2019). Preparation and properties of fly ash-based geopolymer with porous aggregate. Construction and Building Materials, 195, 247-253.

Mishra, U.C., et al. (2019). Fly Ash: Characteristics, Disposal and Environmental Issues. Springer. DOI: 10.1007/978-3-030-20217-3

Obreja, D. M., et al. (2024). Mapping the conceptual structure of innovation in artificial intelligence research: A bibliometric analysis and systematic literature review. Journal of Innovation & Knowledge 9(1): 100465.

Riahi, Y., et al. (2021). Artificial intelligence applications in supply chain: A descriptive bibliometric analysis and future research directions. Expert Systems with Applications 173: 114702.

Roy, S., & Tiwary, R.K. (2020). Fly ash management: current scenario and future challenges. Environmental Science and Pollution Research, 27(14), 15549-15568. DOI: 10.1007/s11356-020-08201-w

Silva, L. F., & de Brito, J. (2017). Mechanical behavior of geopolymer mortars with fine recycled concrete aggregates. Construction and Building Materials, 142, 445-452.

Silva, L. F., & de Brito, J. (2019). Fresh state behavior and mechanical properties of self-compacting concrete produced with fine recycled concrete aggregates. Construction and Building Materials, 197, 768-780.

Tayibi, H., et al. (2009). Environmental impact and management of phosphogypsum. Journal of Environmental Management, 90(8), 2377-2386.

Tiwary, R.K., et al. (2018). Environmental Impact of Coal-Based Thermal Power Plant: An Overview. In: Wang, L., & Sahu, A. (2018). Handbook of Sustainable Polymers: Processing and Applications (Vol. 2). London: Springer.

Wang, L., et al. (2017). Fly ash-based geopolymer: clean production, properties and applications. London: Woodhead Publishing.

Xue, J., et al. (2021). A bibliometric and visualized overview for the evolution of process safety and environmental protection. International Journal of Environmental Research and Public Health 18(11): 5985.

Yadav, V. K., et al. (2022). Status of coal-based thermal power plants, coal fly ash production, utilization in India and their emerging applications. Minerals 12(12): 1503.

Yao, H., et al. (2015). Experimental study of basic mechanical properties and durability of lightweight aggregate concrete with fly ash. Construction and Building Materials, 80, 57-63.

Yao, H., et al. (2018). Effects of particle size distribution on the properties of fly ash blended cement pastes. Cement and Concrete Composites, 92, 70-79.

Yan, Y., & Chen, S. (2017). Effects of fly ash on properties of ultrahigh-performance concrete. Journal of Materials in Civil Engineering, 29(7), 04017051.

Yan, Y., & Chen, S. (2019). Influence of fly ash and slag on properties of high-strength concrete. Construction and Building Materials, 210, 648-657.

Zhang, J., et al. (2015). Effects of fly ash and waste glass powder on properties of concrete under different curing conditions. Construction and Building Materials, 96, 441-446.

Zhang, S., et al. (2015). Evaluation of the properties of modified fly ash with nanosilica and the impact of fly ash/cement systems on the microstructure of concrete. Construction and Building Materials, 91, 167-174.

Zhang, Y., et al. (2021). Bibliometric analysis and visualization of global research on coal fly ash utilization from 2000 to 2019. Resources, Conservation and Recycling, 165, 105242.

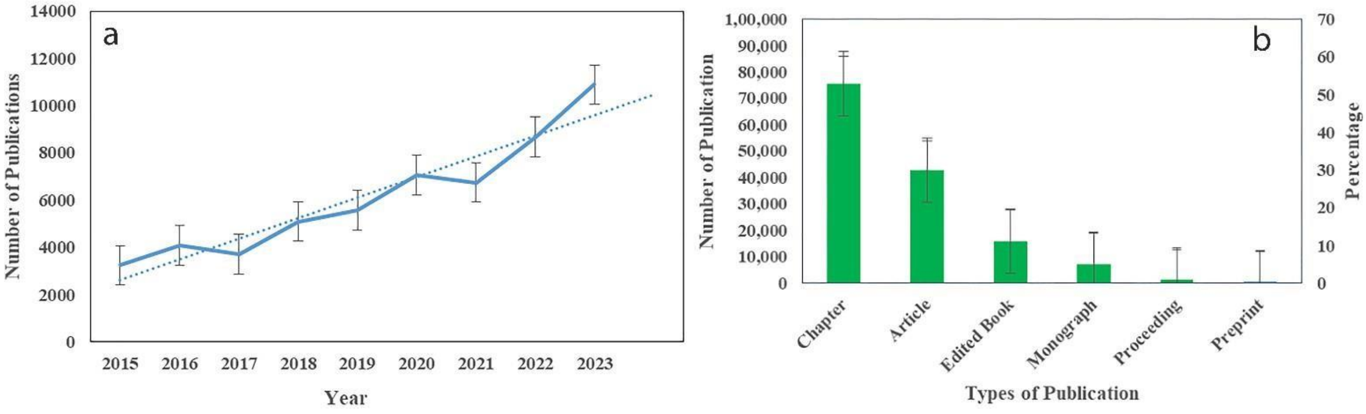
Zhao, D., et al. (2021). Research on fly ash based on bibliometrics and visualization analysis. Journal of Environmental Management, 288, 112439.

Yu, Y., et al. (2020). A bibliometric analysis using VOSviewer of publications on COVID-19. Annals of translational medicine 8(13).

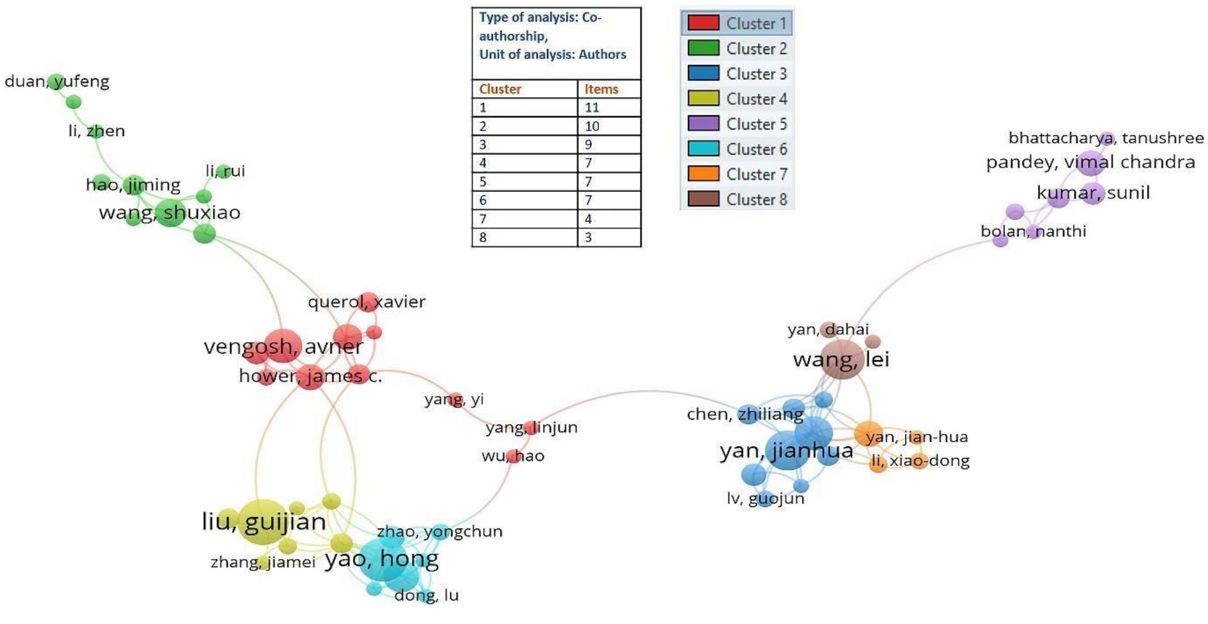
Zheng, J., & Zhang, X. (2016). Utilization of fly ash and waste glass in alkali-activated slag foamed concrete. Construction and Building Materials, 120, 157-163.

Zheng, J., & Zhang, X. (2018). Performance of alkali-activated slag concrete containing fly ash and lightweight aggregates. Construction and Building Materials, 159, 391-398.

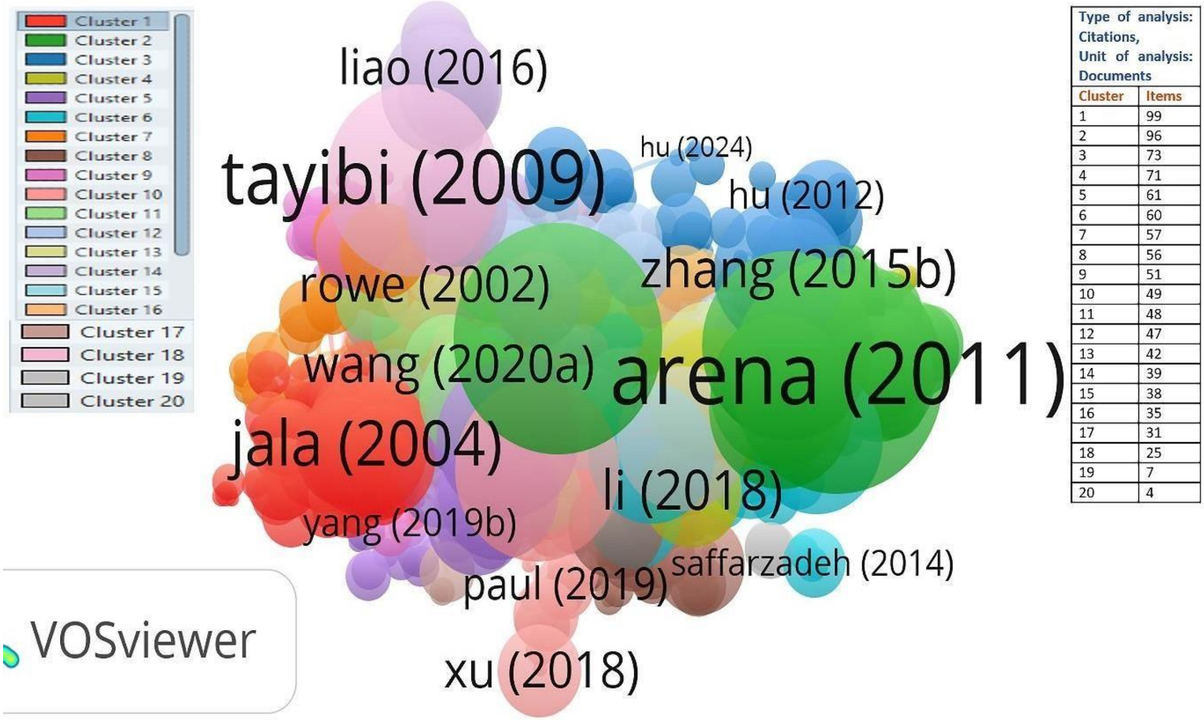
Figures and Captions:



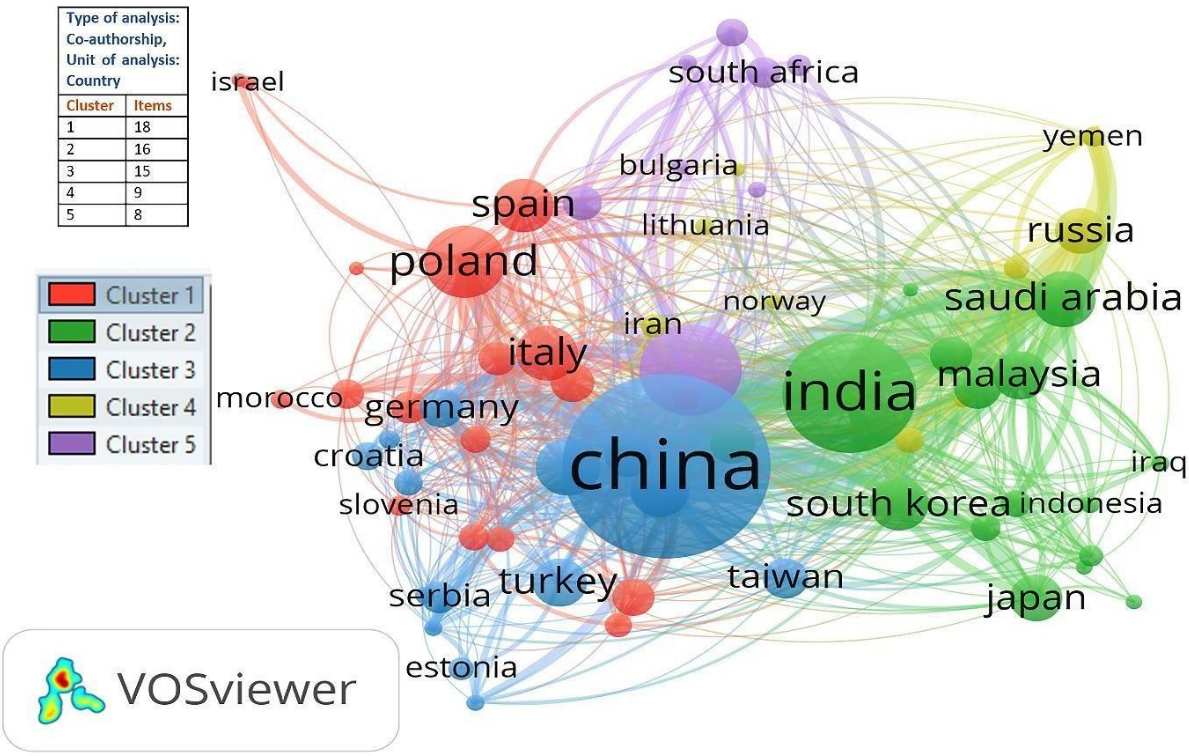
"Figure 1a": Numbers of publications in different years, "Figure 1b": Percentage of different types of publication



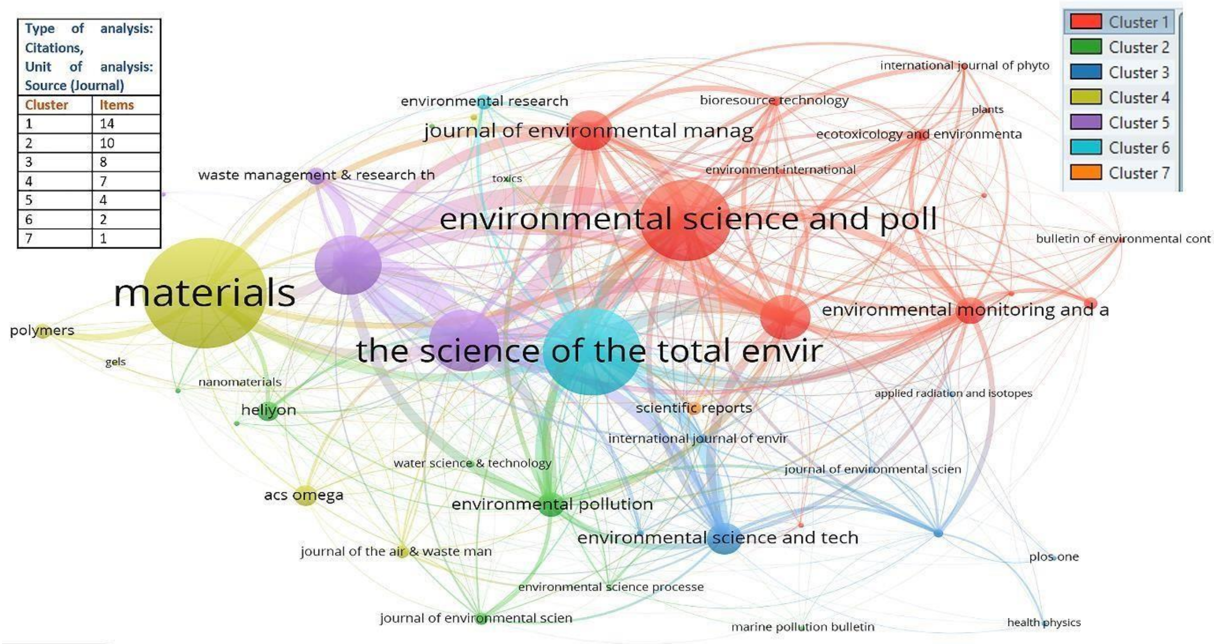
"Figure 2": Co-authorship analysis as a unit of Author analysis



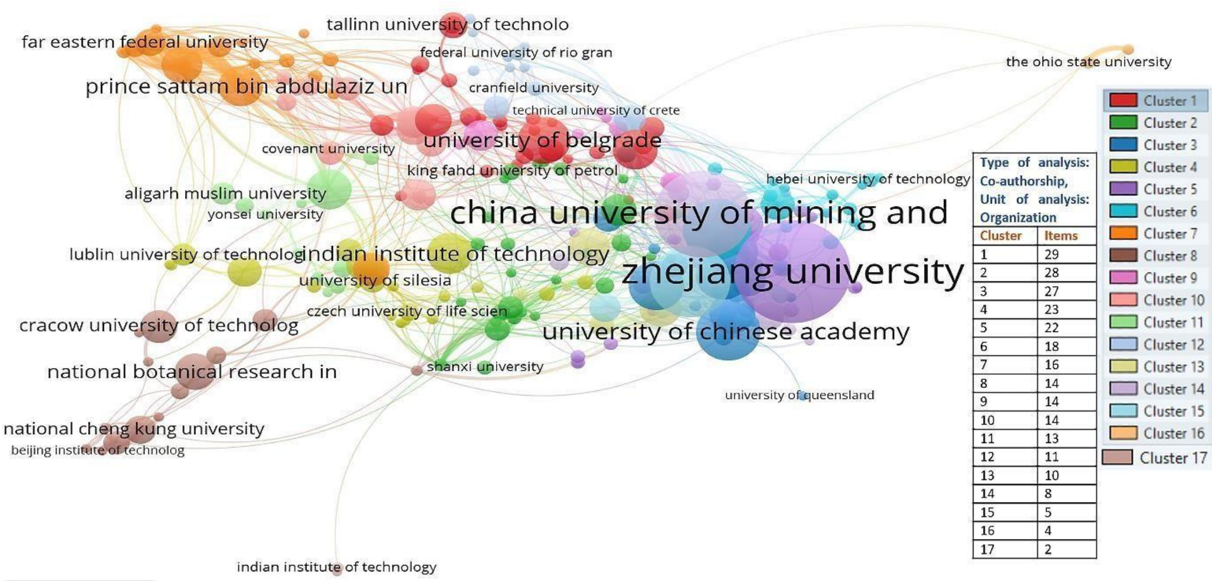
"Figure 3": Citations analysis as a unit of documents



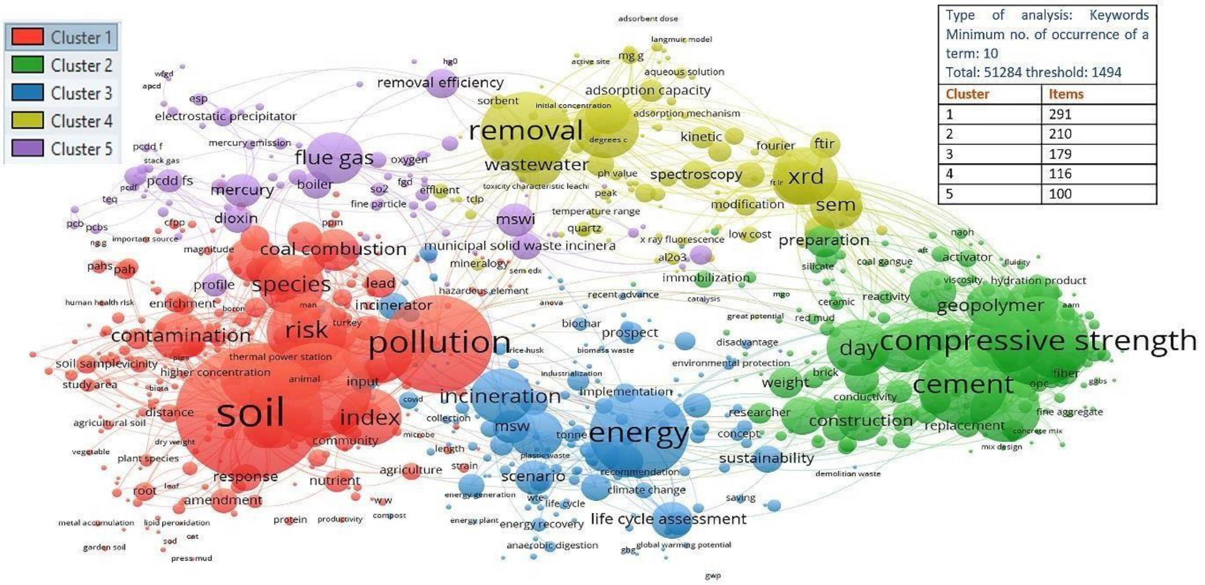
"Figure 4": Co-authorship analysis as a unit of Country



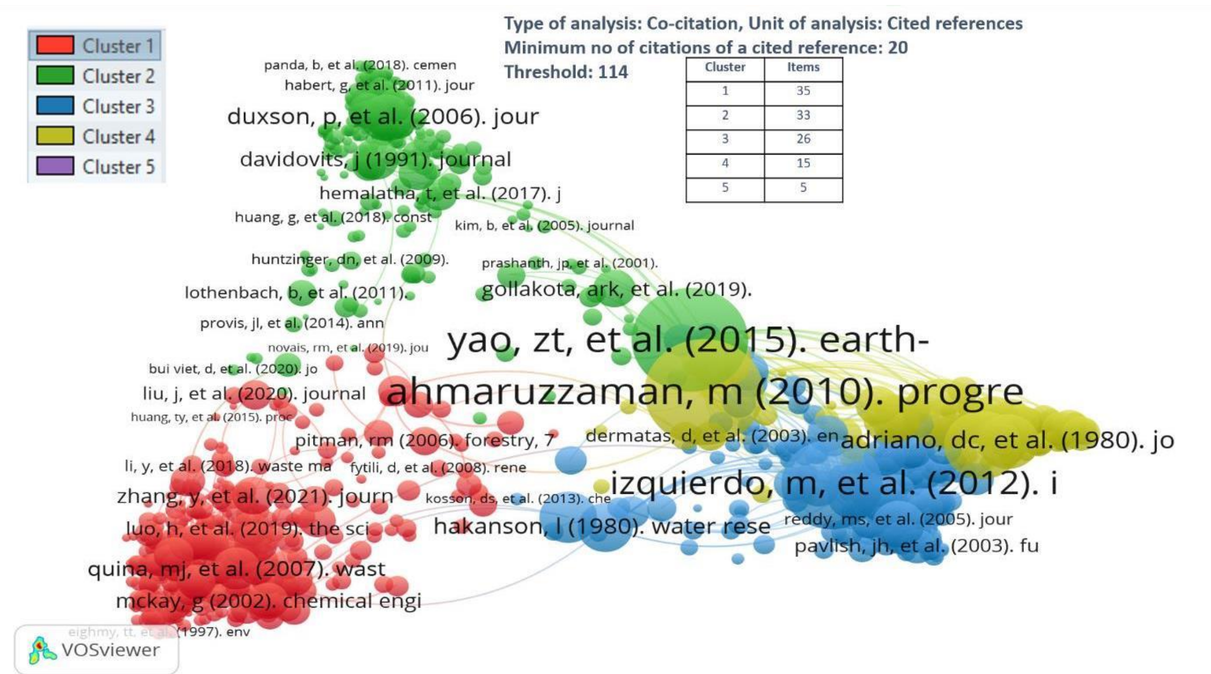
"Figure 5": Citation analysis as a unit of Sources



"Figure 6": Co-authorship analysis as a unit of Organizations



"Figure 7": Analysis of Co-occurrence



"Figure 8": Co-citations analysis as a unit of cited references

Table 1. Top 16 Research field, Sustainable Development Goal based on publication, and Co-authorship analysis based on citations

Field of Research		**Sustainable Development Goal**		**Type of analysis: Co-authorship Unit of analysis: Authors**		
Research category	**Publications**	**Name**	**Publications**	**Author**	**Documents**	**Citations**
Engineering	30441	Affordable and Clean Energy	8,340	Cheng, Hefa	6	1241
Environmental Sciences	10924	Climate Action	6,120	Silva, Luis f.o.	9	921
Agriculture	7992	Responsible Consumption and Production	4,926	Hower, James c.	9	865
Built environment and design	7635	Sustainable Cities and Communities	2,026	Wang, Lei	14	727
Biological science	6931	Life on Land	1,882	Liu, Guijian	16	679
Chemical science	5388	Zero Hunger	1,881	Hsu-kim, Heileen	8	636
Earth science	4613	Clean Water and Sanitation	810	Vengosh, Avner	12	580
Information and computing science	2277	Life Below Water	652	Christensen, thomas h.	6	552
Law and legal studies	2078	Quality Education	514	Xu, Zhenghe	5	546
Human society	2049	Industry, Innovation and Infrastructure	428	Oliveira, Marcos l.s.	5	517
Biomedical and clinical sciences	1934	Peace, Justice and Strong Institutions	340	Querol, Xavier	7	512
Health sciences	1851	Decent Work and Economic Growth	82	Dwyer, Gary s.	6	504
Physical sciences	1402	Reduced Inequalities	63	Franus, Wojciech	6	492
History, heritage, archaeology	1345	No Poverty	47	Li, Xiaodong	12	448
Commerce, Management, tourism	1312	Partnerships for the Goals	23	Fediuk, roman	16	447
Mathematical sciences	1299	Gender Equality	21	Pandey, Vimal Chandra	9	457

Table 2. Top 20 Countries and Source based on citation

	Type of analysis: Co-authorship, Unit of analysis: Country			Type of analysis: Citations, Unit of analysis: Source (Journal)		
Sl. No.	**Country**	**Documents**	**Citations**	**Source**	**Documents**	**Citations**
1.	China	879	19323	Journal of Hazardous Materials	172	9704
2.	United States	224	14200	Waste management	168	9616
3.	India	376	11092	The science of the total environment	243	7328
4.	United Kingdom	96	5464	Environmental science and technology	88	4814
5.	Italy	85	3529	Journal of Environmental Management	112	3869
6.	Spain	81	3301	Materials	309	3671
7.	Poland	146	2752	Chemosphere	125	3451
8.	Portugal	44	2749	Environmental science and pollution research	228	2700
9.	Australia	77	2628	Environmental monitoring and assessment	76	2459
10.	Canada	50	2135	Bioresource technology	29	2267
11.	Germany	46	1992	Journal of the air & waste management association	34	1941
12.	Turkey	68	1805	Environmental pollution	70	1743
13.	Greece	41	1700	Ecotoxicology and environmental safety	34	1161
14.	Japan	64	1568	Waste Management & Research the Journal for a Sustainable Circular Economy	48	1007
15.	South Korea	77	1489	Environment International	11	1003
16.	Saudi Arabia	92	1402	journal of environmental radioactivity	26	873
17.	Brazil	37	1377	Journal of Environmental Sciences	34	667
18.	Belgium	26	1374	Heliyon	56	569
19.	Taiwan	49	1340	Water Research	6	560
20.	Russia	59	1314	Scientific Reports	40	542

Table 3. Top 20 Organizations and Co-Citation analysis based on citation

Type of analysis: Co-authorship, Unit of analysis: Organization			Type of analysis: Co-Citation, Unit of analysis: Cited References	
Name of Organization	**Documents**	**Citations**	**Cited reference**	**Citations**
Zhejiang University	69	1839	Ahmaruzzaman, M (2010). progress in energy and combustion science, 36(3), 327-363	109
National Botanical Research Institute	22	1526	Yao, Zt, et al. (2015). earth-science reviews, 141105-121	107
Stanford University	10	1456	Izquierdo, M, et al. (2012). international journal of coal geology, 9454-66	89
Georgia institute of technology	8	1293	Carlson, Cl, et al. (1993). journal of environmental quality, 22(2), 227-247	64
Spanish National Research Council	7	1149	Pandey, Vc, et al. (2010). agriculture ecosystems & environment, 136(1-2), 16-27	64
Technical University of Denmark	17	1117	Blissett, Rs, et al. (2012). fuel, 971-23	50
University of Kentucky	17	1113	Adriano, Dc, et al. (1980). journal of environmental quality, 9(3), 333-344	49
Tu Wien	13	1006	Jala, S, et al. (2004). bioresource technology, 97(9), 1136-1147	45
University of Lisbon	14	980	Tessier, A, et al. (1979). analytical chemistry, 51(7), 844-851	45
Central South University	28	969	Basu, M, et al. (2009). progress in natural science: materials international, 19(10), 1173-1186	44
Duke university	19	968	Hakanson, l (1980). water research, 14(8), 975-1001	42
Imperial College London	7	965	Dai, s, et al. (2012). international journal of coal geology, 943-21	40
State key joint Laboratory of Environment Simulation and Pollution Control	27	927	Duxson, P, et al. (2006). journal of materials science, 42(9), 2917-2933	40
university of Aveiro	19	856	Ketris, Mp, et al. (2009). international journal of coal geology, 78(2), 135-148	39
Aristotle University of Thessaloniki	19	847	Gupta, Dk, et al. (2002). journal of plant research, 115(6), 401-409	38
Guangzhou institute of geochemistry	8	799	Davidovits, J (1991). journal of thermal analysis and calorimetry, 37(8), 1633-1656	34
University of Science and Technology of China	23	762	Lam, Chk, et al. (2010). sustainability, 2(7), 1943-1968	32
Peking university	18	718	Gollakota, Ark, et al. (2019). the science of the total environment, 672951-989	31
University of Science and Technology Beijing	31	710	Jankowski, J, et al. (2006). fuel, 85(2), 243-256	31
National Environmental Engineering Research Institute	20	691	Kutchko, Bg, et al. (2006). fuel, 85(17-18), 2537-2544	31