



Decontamination Risk Management in Radioisotope Facilities: A Bibliometric Review

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Article Info:

Article history:

Received: July 03, 2026

Revised: September 24, 2026

Accepted: September 25, 2026

Available Online: October 07, 2026

Keywords:

Risk Management;
Decontamination;
Radioisotope;
Bibliometrics;
HIRARC;
AHP



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To cite this article: Supriyadi, Susilowati, I. H., Hartono, D. M., Pratama, H. A., & Yusuf, M. (2026). Bibliometric analysis of risk management of decontamination process of radioisotope and radiopharmaceutical production plants using HIRARC and AHP methods. *Equivalent: Jurnal Ilmiah Sosial Teknik*, 8(4), 1645–1655. <https://doi.org/10.59261/jequi.v8i4.398>

Abstract

Background: Risk management in the decontamination process of radioisotope and radiopharmaceutical production facilities has garnered significant research attention due to its vital contribution to environmental safety and occupational health. While the volume of literary evidence regarding radiation safety continues to expand, study focuses and methodological approaches remains diverse.

Objectives: This bibliometric analysis was conducted on decontamination risk management literature to broadly understand research patterns and directions.

Methods: A total of 340 articles were extracted from the Scopus database covering the decade from 2014 to 2024. Biblioshiny software was employed to perform performance analysis, content analysis, and thematic mapping.

Results: The review results reveal that research in this field is growing at an annual rate of 6.57%. Findings identify "risk assessment" as the most central and influential topic within the keyword network.

Conclusion: This study represents the first comprehensive bibliometric review in this domain, emphasizing the importance of integrating Hazard Identification, Risk Assessment, and Risk Control (HIRARC) with the Analytical Hierarchy Process (AHP) to strengthen risk assessment frameworks in nuclear installations.

INTRODUCTION

Risk management in nuclear installations and radiopharmaceutical production facilities is essential for environmental protection and occupational health because decontamination activities may involve uncertain radiation exposure, contaminated materials, and complex control decisions. Recent work on radiological risk assessment and radioactive waste management confirms the continuing importance of transparent hazard identification and risk mitigation in these settings (MacIntosh et al., 2022; Seidl et al., 2022; Vaillant et al., 2023). Recent reviews further show that radioactive waste management and radionuclide contamination require integrated controls across environmental compartments, decontamination processes, and exposure pathways (Adeola et al., 2023; Liu et al., 2022; Yap & Al-Mutairi, 2025).

Existing nuclear safety research addresses atmospheric dispersion, radiation dose,

emergency planning, and radioactive waste management; however, the intellectual development of decontamination risk management has not been systematically mapped at scale. Available studies typically address specific technologies or regulatory issues and do not reveal how concepts, authors, institutions, and emerging themes are connected across the broader research domain. A bibliometric review is therefore needed to establish this landscape before specific operational frameworks are advanced. Scientometric evidence maps the broader nuclear and radiation research domain ([Chen et al., 2024](#)), whereas earlier global research documented the long-term development of radioactive waste management studies ([Boostani et al., 2024](#); [Clayton et al., 2025](#); [Kademani et al., 2013](#); [Kafle et al., 2025](#)). These studies reinforce the need for a focused map of decontamination risk management at the facility level.

This study uses bibliometric analysis to identify publication trends, influential sources, collaboration structures, co-occurring concepts, and thematic evolution in 340 Scopus-indexed articles published from 2014 to 2024. Its novelty lies in the focused mapping of decontamination risk management in radioisotope facilities and radiopharmaceutical production rather than nuclear safety in general. HIRARC (Hazard Identification, Risk Assessment and Risk Control) and AHP (Analytic Hierarchy Process) are treated as prospective operational directions suggested by the mapped themes, rather than as methods empirically applied or validated in this bibliometric study. The findings provide a theoretical map of the field and practical priority signals for facility-level risk management research. Recent reviews also identify risk indicators for PET radiopharmaceutical production [Montero-Díaz et al. \(2025\)](#), phytoremediation options for Cs-137 decontamination [Nurliati et al. \(2024\)](#), and sustainable remediation of radioactive and heavy-metal contamination in aquatic systems ([Joshi et al., 2026](#)). Together, these contributions demonstrate that risk management must connect technical decontamination with environmental recovery and operational decision-making.

METHOD

Bibliometric analysis was selected because it quantitatively maps a large, reproducible body of literature through publication, citation, collaboration, co-word, and thematic indicators. Unlike a systematic review, it does not evaluate clinical or technical intervention effect sizes; rather, its strength lies in structural mapping, while its limitations include dependence on database coverage and metadata quality ([Donthu et al., 2021](#); [Ogutu et al., 2023](#); [Zupic & Čater, 2015](#)).

In its implementation, this process requires the selection of an appropriate database, the development of effective search strategies, and the application of relevant filters aligned with specific research objectives ([Donthu et al., 2021](#); [Ogutu et al., 2023](#); [Zupic & Čater, 2015](#)). When these principles are followed, bibliometric analysis provides a systematic and comprehensive approach to examining the academic landscape of a research domain. This methodology allows researchers to identify valuable insights, including current research trends, patterns of scientific collaboration among institutions and countries, and the influence of publications within the field under investigation. The use of this analysis is therefore appropriate because it provides a holistic overview of the research landscape surrounding a particular topic.

The Scopus database was selected for its broad multidisciplinary coverage and standardized bibliographic metadata. Searches were performed in the TITLE-ABS-KEY fields for the period 2014–2024 using the following Boolean search protocol: (decontamination OR “radioactive waste” OR radiopharmaceutical OR radioisotope) AND (“risk management” OR “risk assessment” OR HIRARC OR “hazard identification”). Records were limited to English-language journal articles; duplicates, non-article documents, and records outside the scope of decontamination and risk management were excluded. Screening based on titles, abstracts, document type, language, and relevance yielded 340 articles for analysis. The selection process is reported in terms of identification, screening, eligibility assessment, and inclusion to facilitate protocol transparency and reproducibility.

The analysis was conducted using Biblioshiny because its transparent, R-based workflow integrates descriptive performance analysis, collaboration mapping, co-word analysis, thematic mapping, and network visualization within a single reproducible environment. The parameters included annual scientific production, citation metrics, author and institutional productivity,

country collaboration, keyword co-occurrence, thematic-map centrality and density, and network centrality measures, including PageRank and betweenness centrality. Terms were cleaned by merging obvious variants, and co-occurrence networks were interpreted based on link strength, while thematic clusters were interpreted according to their centrality–density positions.

Biblioshiny was used to map the research field rather than to verify the effectiveness of HIRARC or AHP. HIRARC and AHP are included in the interpretation only as potential decision-support approaches that warrant targeted empirical testing where the bibliometric evidence identifies persistent themes related to risk assessment and waste management. Comparable healthcare literature further illustrates the value of structured risk analysis for complex waste and process hazards: toxic healthcare waste requires management across exposure and control pathways [Cirstea et al., \(2025\)](#) and [Eze & Vinken \(2024\)](#), while failure mode and effects analysis provides a systematic approach for identifying and prioritizing process failures ([Vecchia et al., 2025](#)).

RESULTS AND DISCUSSION

Dataset Key Information

The 340-article dataset shows moderate but sustained field growth (6.57% annually), substantial multi-author collaboration (6.07 authors per document), and an international collaboration rate of 35.59%. These metrics indicate a knowledge domain that is increasingly networked across radiation science, environmental management, and safety research. The mean document age of 5.01 years and the average of 11.64 citations per document further indicate that recent publications are contributing to an active, rather than mature and static, research frontier.

Table 1

Main Information

Description	Results
Key Data Information	
Timespan	2014:2024
Sources (Journals, Books, Etc.)	121
Documents	340
Annual Growth Rate (%)	6,57
Average Document Age	5,01
Average Citations Per Document	11,64
References	16096
Document Content	
Keywords Plus (En)	4716
Keywords Author (De)	1249
Author	
Authors	1799
Single Document Author	11
Author Collaboration	
Single Author Document	11
Average Authors per Document	6,07
International Collaboration Percentage	35,59
Document Types	
Article	340

Distribution of Publications and Articles

Annual output increased overall and peaked in 2022 before declining in 2023–2024. The decline should not be interpreted as a loss of relevance: recent publication years have shorter citation windows and may reflect indexing lags, while the positive aggregate growth rate signals continued attention. The fluctuation instead suggests a field responding to episodic safety, waste-management, regulatory, and technological priorities rather than a uniformly expanding literature.

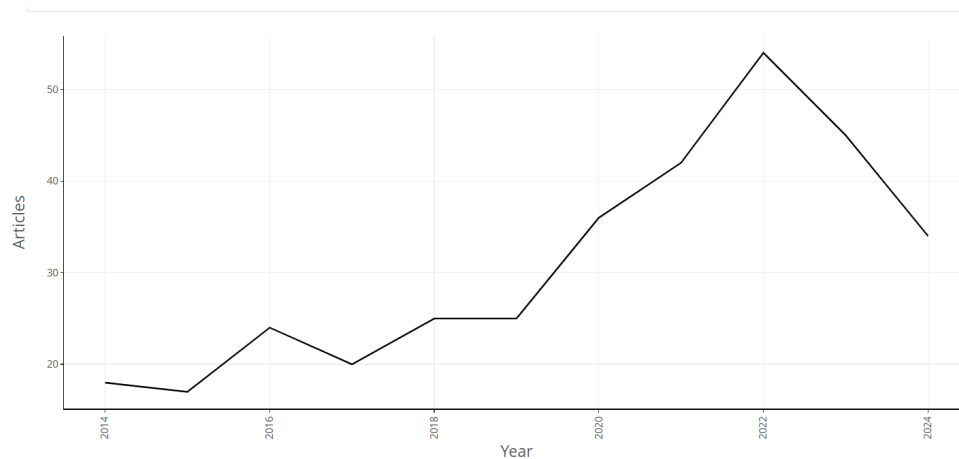


Figure 1. Annual Scientific Production

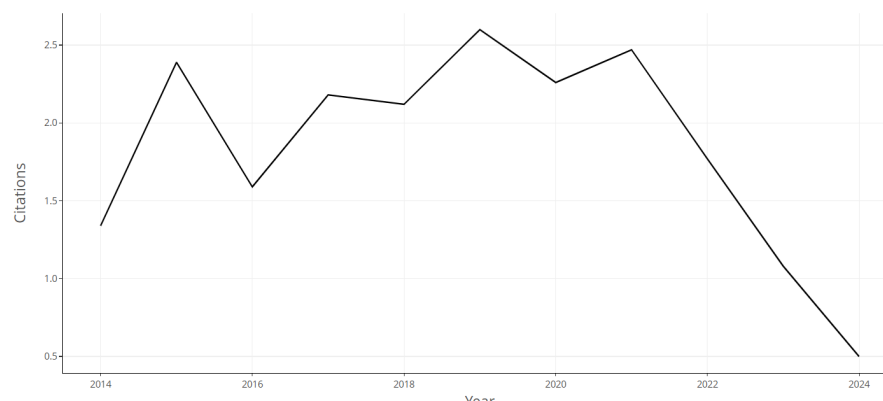


Figure 2. Average Citations per Year

Resources

The dominance of the *Journal of Environmental Radioactivity* and its position within the Bradford core indicate that decontamination risk management is anchored in environmental-radioactivity scholarship while increasingly connecting with public-health and broader environmental-science outlets. These journal trajectories signal growing interdisciplinarity, which is important because facility decontamination requires the integration of radiological, operational, environmental, and decision-management expertise.

The cumulative development of journal publications over time in Figure 3 shows that the *Journal of Environmental Radioactivity* (represented by the green line) maintained the most stable and highest rate of publication growth throughout the period from 2014 to 2024, reaching more than 40 cumulative documents. This dominance confirms its role as the main publication source in this dataset. In addition, the *International Journal of Environmental Research and Public Health* and *Science of the Total Environment* (both with a local h-index of 11) also showed significant cumulative growth, especially after 2019. Meanwhile, several other journals, such as *Risk Analysis* and *Environment International*, also showed significant local impact (h-index = 5) within the research community.

Table 2

Relevant Scientific Journals

Source	Number of Documents	Local Impact (h-index)
Journal of Environmental Radioactivity	45	14
International Journal of Environmental Research and Public Health	34	11
Science of the Total Environment	25	11

Source	Number of Documents	Local Impact (h-index)
Chemosphere	13	8
Journal of Radiological Protection	11	5
Health Physics	9	5
Journal of Radioanalytical and Nuclear Chemistry	7	(h-index data not shown)
Packaging, Transport, Storage & Security of Radioactive Material	7	(h-index data not shown)
Atmosphere	6	(h-index data not shown)
Radiation protection	6	(h-index data not shown)

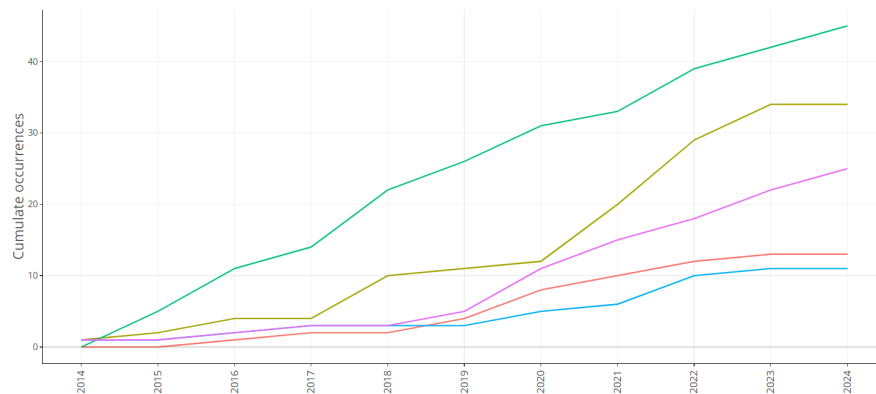


Figure 3. Production Source by Time Period

Productivity and Collaboration Between Writers

The high collaboration rate indicates that decontamination risk management is developed through team-based and potentially interdisciplinary research. Such collaboration can connect expertise in radiation protection, engineering, environmental science, and operational safety; however, publication counts alone do not establish author influence. Future analyses should complement productivity rankings with citation impact, network position, and author contribution roles.

The authors' productivity rankings during the period from 2014 to 2024 are presented in Figure 4, where the most productive author is Perko T, with the highest contribution of six documents. The next position is shared by five authors with the same contribution: Ammerman DJ, Kautsky U, Kovacs T, Yokonami S, and Weiner RF, each of whom is recorded as having five documents. These data show that research on this topic is still dominated by a core group of researchers who have maintained consistent publication contributions during the analysis period.

Institutional concentration at Hirosaki University, the University of Pannonia, Sandia National Laboratories, and *Università degli Studi di Messina* suggests that institutions with sustained radiological research capacity shape the field's agenda. Their prominence also provides a basis for international collaboration, but it should not be interpreted as evidence of global representativeness because database coverage and national publication practices vary.

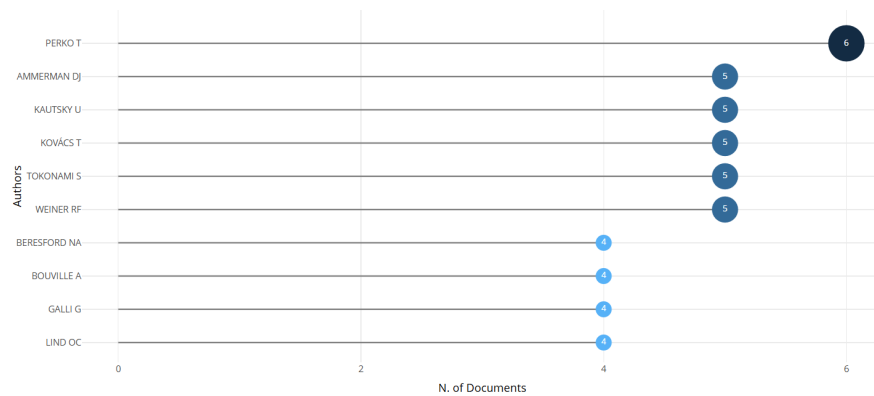


Figure 4. List of Most Relevant Authors

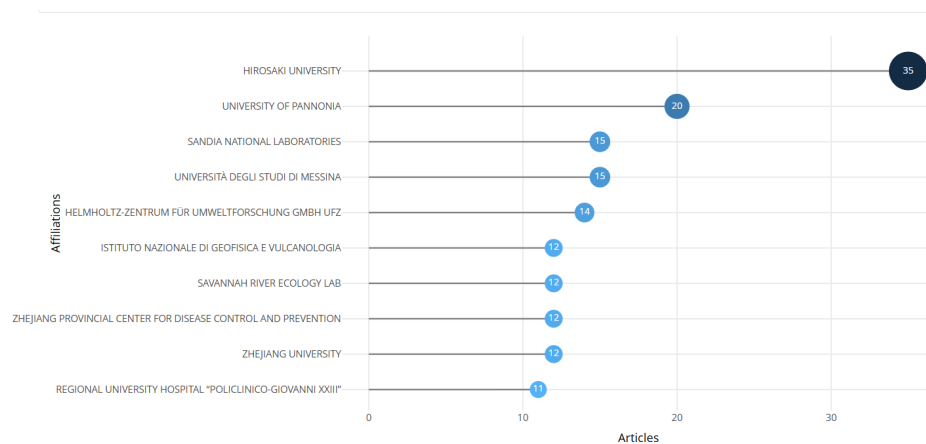


Figure 5. List of Most Relevant Affiliates

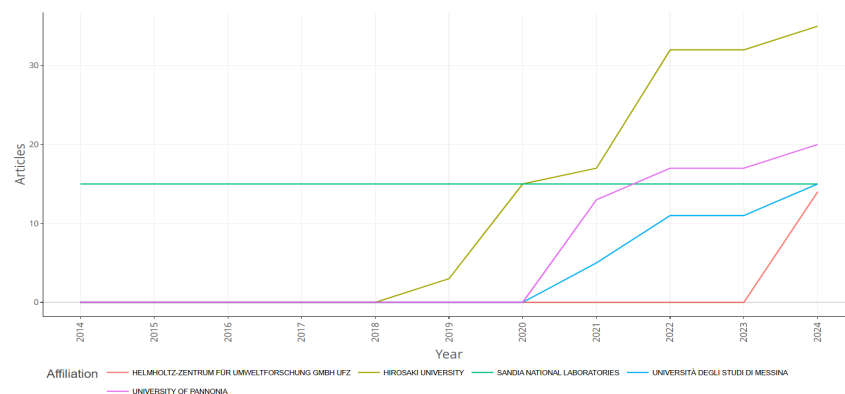


Figure 6. Affiliate Production Progress By Year

Productivity and Collaboration Between Countries

The 83-country network and 35.59% international collaboration rate indicate a geographically distributed field, with high publication activity in the United States and Europe. This distribution likely reflects established nuclear-research infrastructure and monitoring capacity; it also points to a practical need for knowledge transfer and collaborative capacity building in regions expanding radioisotope and radiopharmaceutical production.

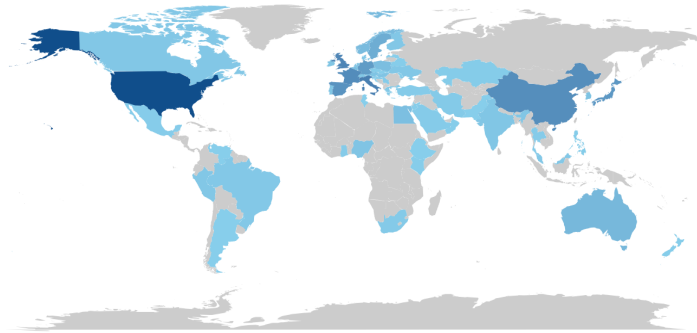


Figure 7. Scientific Production by Country

Mapping Current Research Trends

Research trend mapping was conducted to identify central themes, topic popularity, and key research clusters in the dataset. This analysis is supported by the evaluation of centrality metrics and a Thematic Map produced by Biblioshiny. After the data-cleaning process, a total of 1,249 author keywords and 4,716 Keywords Plus terms were identified.

As a first step in the mapping process, the Word Cloud in Figure 8 and the Tree Map in Figure 9 show that risk assessment keywords dominate, with the highest frequency of occurrence at 46 instances (approximately 14% of the 340 documents). This prominence indicates that risk assessment is a central topic and an important conceptual framework in this dataset. Other high-frequency keywords included radon (20 instances/6%), radionuclides (15 instances/5%), and radioactivity (12 instances/4%).



Figure 8. WordCloud Visualization Results



Figure 9. Tree Map Analysis Results

The co-occurrence network in Figure 10 visually reinforces these findings, showing that the concept of risk assessment, which is an integral part of the research methodology, is a central node in the dataset. The centrality of this concept is further indicated by the metrics in Table 3, which show the highest betweenness (69.000) and PageRank (0.140) values. This high

betweenness value indicates that risk assessment serves as a conceptual bridge connecting various other topic clusters, such as radon, radioactivity, and dose. The density visualization in Figure 12 further reinforces that risk assessment and radon (with a PageRank of 0.106) are among the most intensely studied areas.

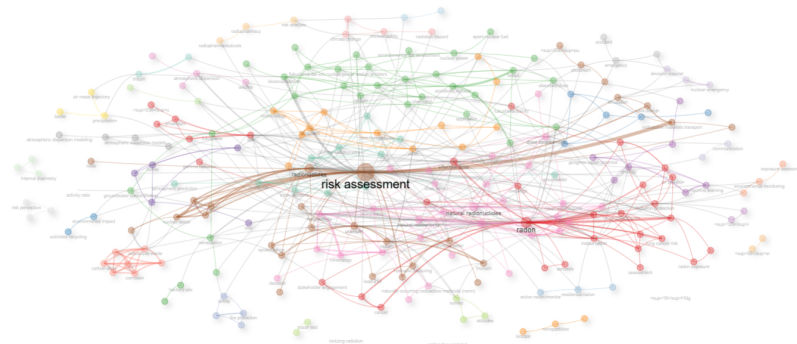


Figure 10. Thematic Map

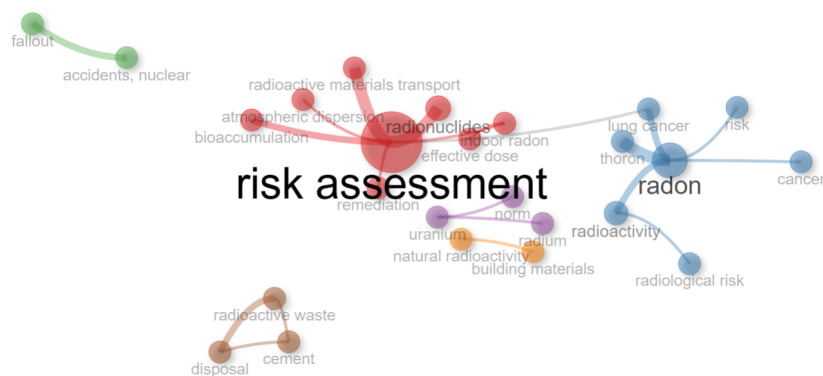


Figure 11. Network Co-occurrence Terms/Keywords



Figure 12. Density Level Co-occurrence Network

Table 3

Co-occurrence Network Data

Node	Cluster	Betweenness	Closeness	PageRank
Risk assessment	1	69.000	0.037	0.140
Radionuclides	1	0.000	0.025	0.031
indoor radon	1	13.000	0.026	0.037
effective dose	1	0.000	0.020	0.022
Remediation	1	0.000	0.025	0.019
atmospheric dispersion	1	0.000	0.025	0.019
Bioaccumulation	1	0.000	0.025	0.025
Radioactive Materials Transport	1	0.000	0.031	0.031
Radon	2	54.000	0.032	0.106

Node	Cluster	Betweenness	Closeness	PageRank
Radioactivity	2	13.000	0.024	0.043

Thematic-map positions reflect both centrality (relevance to the field) and density (internal development). Risk assessment, dose, and radionuclides function as motor themes because they are both central and well developed; radioactive-waste management is a niche theme because it is specialized and internally coherent; effective dose and radioactivity provide basic conceptual infrastructure; and probabilistic modeling appears as an emerging or declining theme because it has limited development and centrality. These patterns justify future empirical work on how HIRARC and AHP could operationalize, not replace, the field's central risk-assessment knowledge. The mapped themes are consistent with recent evidence linking decontamination technologies, environmental remediation, and integrated production-risk indicators across nuclear and radiopharmaceutical contexts (Liu et al., 2022; Montero-Díaz et al., 2025; Nurliati et al., 2024). This convergence supports the need for future facility-level studies that test how risk-control tools can prioritize hazards across technical, environmental, and organizational dimensions.

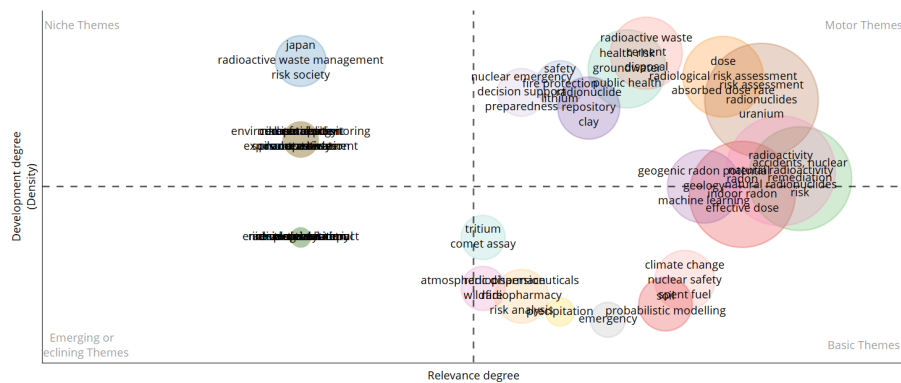


Figure 12. Thematic Map Visualization Results

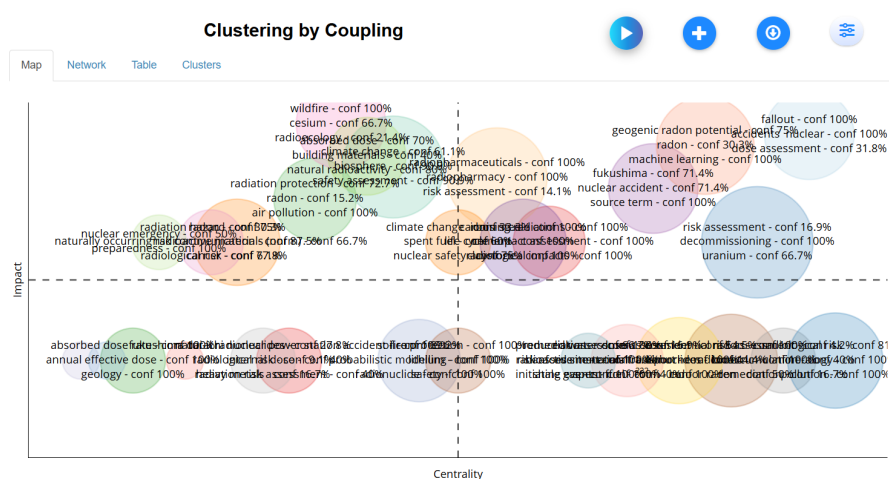


Figure 13. Clustering Results Based on Degree of Coupling

CONCLUSION

This bibliometric review maps the 2014–2024 knowledge landscape of decontamination risk management in radioisotope and radiopharmaceutical contexts. The field shows sustained growth, substantial international collaboration, and a conceptual core centered on risk assessment, dose, and radionuclides, while radioactive-waste management remains a specialized niche. The study contributes a focused bibliometric baseline for a domain previously dispersed across nuclear-safety and environmental-radioactivity literature. It does not test HIRARC or AHP; instead, it identifies their potential as future facility-level decision-support approaches that

should be evaluated empirically. Practically, the map can guide researchers and safety managers toward themes where more transparent hazard identification, control prioritization, and data-supported decision-making are needed. Future research should combine Scopus and Web of Science, conduct longitudinal thematic analyses, integrate bibliometrics with systematic or scoping reviews, and test HIRARC–AHP frameworks in real-world decontamination settings.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the institutions, researchers, and data providers whose published scientific records made this bibliometric review possible. The authors also thank colleagues and reviewers whose scholarly input supported the refinement of the manuscript.

AUTHOR CONTRIBUTION STATEMENT

All authors contributed substantially to the conceptualisation, bibliometric methodology, data curation, formal analysis, interpretation of results, manuscript drafting, and critical revision. All authors reviewed and approved the final manuscript and accept responsibility for the integrity of the work.

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